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Editorial

Dear readers,

In November 2009, IPI, together with key partners, organized a large symposium in Orissa, India focusing on the role of potassium in food production and security, covering various aspects of nutrient management in selected crops and the environment. Besides having the opportunity to network and share experiences and exchange knowledge with many scientists, we are pleased to report a welcome legacy that has resulted from this meeting. The journal *Plant and Soil* is dedicating a special edition of selected papers presented at the symposium. The nine selected papers are preceded by an editorial from guest editor, Prof. Ismail Cakmak, who was the scientific mind behind the symposium. The papers are available in *Plant and Soil Online*.

Another outcome of this meeting in Orissa last year was the creation of an ad-hoc team to review the need to change potassium recommendations for vertisols in India. You will find out more about this new development on page 21/22.

With favorable policies and a good environment, farmers have an opportunity to enhance their crop productivity and their incomes. A report in *The Economist* (26 August 2010) highlights the success story of Brazilian agriculture, supported by well-established policies and a strong scientific arm (EMBRAPA) and, of course, with plentiful land and water. But that story can be replayed in many other regions, if farmers are provided with the right conditions. We at IPI believe that much of the additional food required to meet increasing global demand can be produced simply by doing things right, and by doing so improve yields two-to-four fold. It is possible in Africa, for example.

In this issue of *e-ifc* you will find various research reports including the use of fertigation in sugarcane production in India, which can significantly reduce the amounts of nutrients and water required. This application has considerable potential for many regions around the world. A comprehensive report on the effect of potassium (K) on yield and quality of tobacco leaves is featured with findings provided from China, Cuba and France. And a large-scale experiment on the efficiency of K fertilizer is also reported from China. In addition, as always, we bring you updates of events, new scientific publications and more.

I wish you all an enjoyable read.

Hillel Magen

Director

Detailed fertilizer recommendation for irrigated rice described on a billboard distributed in Wuhu county, Anhui Province, China. The recommendations are detailed for three levels of N and P and four levels of K fertility in soil, adapted to different rice seasons (early rice, later rice or single rice) under the expected yield. This procedure, backed by rigorous soil sampling and analysis, allows a higher degree of efficient nutrient use. Photo by IPI.

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Effect of Various Levels of Potash Application Through Drip Irrigation on Yield and Quality of Sugarcane

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Abstract

Water and nutrients are the most crucial inputs for sugarcane cultivation and their application through micro irrigation systems is highly important as a means of increasing land, water and fertilizer use efficiency. An experiment studying the effects of various levels of potash application through drip irrigation on yield and quality of sugarcane using the variety Co 86032 over three crop seasons (2003-2004, 2004-2005 and 2006-2007) is reported. Application of nitrogen and potash fertilizers through drip irrigation not only saved 30 percent of nitrogen (N) and potassium (K) fertilizer, but also increased yield by 19.1 percent and more than doubled water use efficiency, as compared to the control using the recommended application of chemical fertilizers and conventional irrigation. The total quantity of irrigation water applied under conventional irrigation was 26,560 m^3 ha^{-1} compared to only 14,560 m^3 ha^{-1} under drip irrigation, resulting in 45.2 percent reduction in water use. The cane yield obtained in the control was 142.82 mt ha^{-1}, while with 70 percent N and K fertilizers through drip irrigation and 100 percent P through soil application the cane yield was 170.08 mt ha^{-1}. Agronomic efficiency of K fertilizer with 30 percent saving of N and K fertilizers was 1.43 mt cane kg^{-1} K_2O as compared to 0.84 mt cane kg^{-1} K_2O in the control. The optimal treatment yielded savings of 30 percent N and 15 percent of K (as compared to the control), and increased the net income by more than Rs. 18,000 (approx. USD 400) per hectare.

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Keywords: Drip irrigation, paired planting, long furrow irrigation, water use efficiency, fertilizer use efficiency, water saving.

Introduction

Sugarcane is a major cash crop in India responsible for the overall socio-economic development of the farming community. It is cultivated on 5.15 million hectares providing an annual sugarcane production of 340 million mt (2008-2009). Average productivity is thus relatively low, at 66 mt ha^{-1}. Production of the crop is mainly located in the states of Uttar Pradesh, Maharashtra, Tamil Nadu, Karnataka and Gujarat. Currently India consumes about 18.5 million mt of sugar but to meet the demands of an increasing population, there will be a need to produce 28 million mt of sugar by 2015.

Project location in India.

It is believed that improper water management and imbalanced nutrition are the main constraints to increased productivity. Improving the application of these two inputs certainly raises sugarcane yields. Consequently, there is an urgent requirement to increase sugarcane production through modern and precise methods of cultivation, including fertigation.

Sugarcane is a long duration crop which produces huge amounts of biomass, requiring large quantities of water,

Experimental plot at the Vasantdada Sugar Institute fields. Photo by IPI.

Research Findings

which typically are supplied through 25-30 irrigation cycles per crop season. It has been estimated that the total water requirement of sugarcane crop varies from 20,000 to 30,000 m^3 ha^{-1} $year^{-1}$ and it is estimated that 12,000 to 13,000 m^3 of water is required for a sugarcane crop of 12 months duration if used efficiently. The crop requires 400 m^3 of water to produce one metric tonne of total dry matter and 200 m^3 of water to produce one metric tonne of cane. Irrigation management in sugarcane is therefore of prime importance to raise crop yield and sugar production.

The K requirement of sugarcane is 1.32-1.44 kg K_2O mt^{-1} of cane (IFA, 1992). K applications are usually made together with N because of the more efficient utilization of N by the crop in the presence of K. However, late application of K up to six months into the growth of the crop has also been found to improve sugar recovery.

Potassium application raises milleable stalk yield, percentage sugar in the cane and degrees Brix (°Bx), a measure of the percentage of sugar in the juice. K deficiency impairs sucrose transport from the leaf into the stalk. There is a positive interaction between N and K, the lowering of the sugar content caused by high rates of N being ameliorated by an adequate supply of K. Excessive dosages of K (i.e. over and above optimal rates) may exert a negative influence on apparent sucrose percentage in cane (pol percent cane) and may promote an increase in the ash content of the juice, since K is the major constituent in the ash. The main effect of excess K is to depress the recovery of sucrose during milling by maintaining a certain amount of sucrose in solution (Ng Kee Kwong, 2002). The unfavorable effects of K, however, should be anticipated only when excessive rates are used; on low potassium soils, improvement in cane quality is to be expected.

Erratic and uncertain monsoons which lead to poor recharging of the groundwater table and over depletion of groundwater due to overuse of irrigation, have led to water becoming the most limited and costliest input in agri-culture. There is an acute shortage of irrigation water, especially during the summer season, resulting in a decline in cane yield. Fertilizer use efficiency is also low under conventional irrigation.

Table 1. Treatments for the fertigation experiment.

Treatments	Irrigation method	$N-P_2O_5-K_2O$	No. fertilizer application	Application method
		kg ha^{-1}		
T1	Long furrow	340-170-170	4	A
T2	Drip	340-170-170	4	A
T3	Drip	240-170-196	13	B
T4	Drip	240-170-170	13	B
T5	Drip	240-170-145	13	B
T6	Drip	240-170-120	13	B
T7	Drip	240-170-95	13	B

Notes:
A = All fertilizers applied directly to soil.
B = N and K applied in fertigation; P as single super phosphate (SSP) in two soil applications.

Adoption of drip irrigation in sugarcane offers an opportunity for placing fertilizer in a soluble form at the root zone of the crop along with the irrigation water, thus increasing water and fertilizer use efficiency. Fertigation ensures that essential nutrients are supplied precisely at the area of most intensive root activity according to the specific requirements of sugarcane crop and type of soil, thereby resulting in higher cane yields and sugar recovery.

This paper describes the results of a three-year experiment conducted at the experimental farm of the Vasantdada Sugar Institute (VSI) in Pune, Maharashtra State. The results from three farmers' fields located in different districts, using two selected treatments, are reported in an appendix. The application of N and K fertigation were tested with five levels of K to better understand the potential of the fertigation system to achieve a higher water and K use efficiency. The objectives of the research project were as follows:

1. To study the effect of different levels of K through drip irrigation on yield and quality of the sugarcane crop.

2. To study fertilizer and water use efficiency with different levels of fertilizer application.

3. To analyze the cost benefit ratio with different levels of fertilizer application.

Materials and methods

The work was carried out at the VSI's experimental farm beginning in 2003 using the plant cane (Variety – Co 86032) and was continued for the first ratoon crop and second plant cane. The experiment was set up in a random block design (RBD) with four replications. Total plot size was 58 x 58 m, with individual plots of 8.5 x 13.5 m.

Soil analysis was carried out before planting the crop. The soil of the experimental plot was non-calcareous with a pH around 8. The electric conductivity (EC) in different plots varied from 0.35 to 0.45 dS m^{-1}. Organic carbon was in the range of 0.59 to 0.95 percent. Available phosphorus was estimated by using the Olsen method and was in the range of 4.38 to 6.97 ppm, while 1 N Ammonium Acetate Extractable Potash was more than 400 ppm in all the treatment plots (Table 1).

T1: Recommended dose (for Maharashtra State) of chemical fertilizers ($N-P_2O_5-K_2O$ of 340-170-170 kg ha^{-1}) in four splits under conventional irrigation (soil application), N in four splits i.e. at planting and then every 45 days after planting, P_2O_5 and K_2O in two splits at planting and after 120 days of planting on earthing up.

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T2: Recommended dose (for Maharashtra State) of chemical fertilizers ($N-P_2O_5-K_2O$ of 340-170-170 kg ha^{-1}) in four splits under drip irrigation (all fertilizers applied in soil application).

T3: 70 percent of recommended dose of urea + 115 percent recommended dose of KCl in 13 equal splits through drip irrigation + recommended dose of single super phosphate (SSP) in two splits by soil application.

T4: 70 percent of recommended dose of urea + 100 percent recommended dose of KCl in 13 equal splits through drip irrigation + recommended dose of SSP in two splits by soil application.

T5: 70 percent of recommended dose of urea + 85 percent recommended dose of KCl in 13 equal splits through drip irrigation + recommended dose of SSP in two splits by soil application.

T6: 70 percent of recommended dose of urea + 70 percent recommended dose of KCl in 13 equal splits through drip irrigation + recommended dose of SSP in two splits by soil application.

T7: 70 percent of recommended dose of urea + 55 percent recommended dose of KCl in 13 equal splits through drip irrigation + recommended dose of SSP in two splits by soil application.

The irrigation schedule of the furrow irrigation treatment was based on Irrigation Water/Cumulative Pan Evaporation (IW/CPE) = 0.75, and in drip irrigation treatments the irrigation quantity was applied based on a climatological approach i.e. monthly average evaporation, pan coefficient and crop coefficient as per crop growth stages. Under furrow irrigation the average irrigation interval was 18, 14 and 9 days in the rainy (June to September), winter (October to January) and summer (February to May) seasons respectively. Under drip irrigation, the estimated irrigation quantity was applied daily to maintain the moisture content close to the field capacity of the soil. The total quantity of irrigation water applied under conventional long furrow irrigation was 26,556 m^3 per hectare, and under drip irrigation system was 14,563 m^3 per hectare (54.84 percent of the conventional method).

Table 2. Growth observations at harvest (pooled data of two plant and one ratoon crop).

Treatments	$N-P_2O_5-K_2O$	Milleable height	Girth	No. of internodes
	kg ha^{-1}	-------------*cm*-------------		*No.*
T1	340-170-170	271.35	8.55	22.83
T2	340-170-170	300.57*	8.44	25.02*
T3	240-170-196	300.84*	8.93*	25.00*
T4	240-170-170	299.62*	8.64	24.58*
T5	240-170-145	305.74*	8.86*	24.19*
T6	240-170-120	300.56*	8.97*	24.83*
T7	240-170-95	277.69	8.33	23.91
SE ±		2.99	0.08	0.38
CD at 5%		8.82	0.23	1.13

*Statistically significant data as compared to other treatments.

Results and discussion

Based on three years data (two plant crops and one ratoon crop), the results of the experiment are discussed below:

Growth observations at harvest

Growth observations including milleable cane height; number of internodes and cane girth were recorded at the time of harvest and pooled data are presented in Table 2. The milleable cane height at harvest varied from 271 to 305 cm between treatments. Significant differences between both milleable cane height and number of internodes with the respective controls were found in all the treatments except in T7 (240 and 95 kg N and K_2O ha^{-1}, respectively). Cane girth in this treatment (8.33 cm) was the lowest, possibly due to the lowest K level applied among all treatments.

Yield and CCS at harvest

Cane yield significantly changed in response to the irrigation method and fertigation. A significant increase in yield and commercial cane sugar (CCS) was achieved by using drip system (T2) instead of flood (T1), despite a large decrease in water used (Fig. 1; Table 3). T1 and T2 differ only in the irrigation system used and amount of water. These results demonstrate the high wastage of water in the flood system (T1).

Treatments T3-T7 all use N & K in the fertigation system, as compared to basal application to soil in T1 and T2. From the pooled results given in Table 3, it

Table 3. Cane and CCS yield, water quantity applied, and water use efficiency of sugarcane with different irrigation and nutrition treatments (pooled data of two plant and one ratoon crop).

Treatments	$N-P_2O_5-K_2O$	Cane yield	Milleable canes at harvest	CCS at harvest	CCS yield	Quantity of water applied	Water use efficiency
	kg ha^{-1}	*mt ha^{-1}*	*No. ha^{-1}*	*%*	*mt ha^{-1}*	*m^3 ha^{-1}*	*kg cane m^3*
T1	340-170-170	142.82	111,293	13.71	19.60	26,556	5.4
T2	340-170-170	163.88*	122,141*	14.11	23.12*	14,563	11.3
T3	240-170-196	170.32*	136,815*	14.01	23.88*	14,563	11.7
T4	240-170-170	169.43*	130,026*	14.30	24.22*	14,563	11.6
T5	240-170-145	175.50*	133,869*	14.06	24.67*	14,563	12.1
T6	240-170-120	170.08*	129,813*	14.11	24.00*	14,563	11.7
T7	240-170-95	148.25	117,666	13.95	20.67	14,563	10.2
SE ±		2.12	2,333	0.15	0.36	-	-
CD at 5%		6.24	6,864	N. S.	1.08	-	-

*Data is statistically significant.

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can be seen that the cane yields obtained in treatments with fertigation through drip irrigation are superior to the control, T1 (all fertilizers as basal, with flood irrigation) and T2 (split of nutrients applied to soil and use of drip system). Moreover, the use of N and K in fertigation allowed a 30 percent reduction in the N and 15 percent of the K (T5) applied.

Highest yield of cane (175.5 mt ha^{-1}) was obtained with T5 (drip and fertigation, with 70 and 85 percent of the N & K as compared to farmers' practice, T1). A further reduction in K application (T7, 55 percent of farmers' practice) caused yield reduction and was not significantly higher than the control (T1).

CCS at harvest was higher in all drip-irrigated treatments, but not significantly (Table 3). However, with the additional cane yield, CCS yield was significantly higher in all the drip irrigated treatments, except T7 (with the lowest K level), and responded well to the amount of K applied (Fig. 1). These results show that in terms of gained income, which is strongly related to the CCS yield, farmers can achieve the highest income with treatment T5, which is significantly higher than the control.

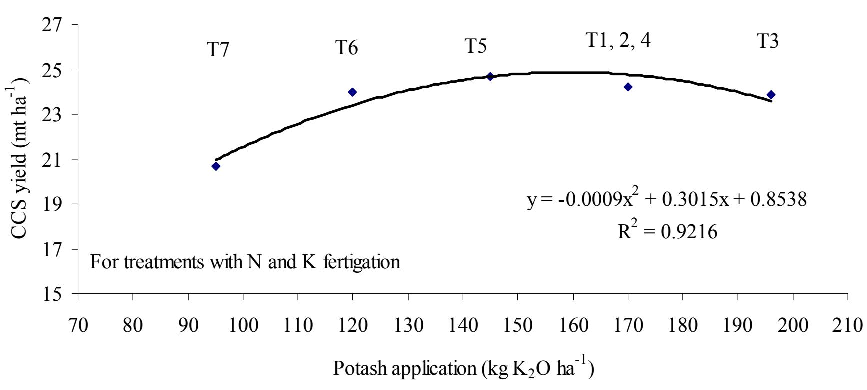

Fig. 1. CCS yield after potash application.

Water use efficiency

Water use efficiency more than doubled with the use of the drip system, from 5.4 to 12.1 kg cane m^{-3} (Table 4). This astonishing finding demonstrates the significant benefit in using water saving technologies. The economic benefit can be seen as either enabling farmers to double the cane area for the same amount of available water, or use and pay less for the same land. This value is still not calculated, but we are certain that policymakers should attribute the required added economic benefit to drip systems.

Economics

The average pooled costs of cultivation of sugarcane, including the drip irrigation system for three crop seasons in treatments T1 - T7 (based on return of cost of system in five years), were Rs. 86,549, 100,666, 100,657, 100,315, 101,085, 99,969 and 96,105 respectively (Table 4). Considering the yield levels in these treatments and

Table 4. Water use efficiency and profitability of sugarcane production under water and nutrient savings via the use of drip fertigation (pooled data of two plant and one ratoon crop).

Treatments	$N-P_2O_5-K_2O$	Water applied	Cane yield	Water use efficiency	Cost of cultivation(†)	Gross income	Net income(§)	B:C ratio(‡)
	kg ha^{-1}	*m^3 ha^{-1}*	*mt ha^{-1}*	*kg cane m^{-3}*	*Rs. ha^{-1}*		*Rs. ha^{-1}*	
T1	340-170-170	26,556	142.82	5.4	86,549	142,820	56,271	1.65
T2	340-170-170	14,563	163.88*	11.3	100,666	163,880	63,214*	1.63
T3	240-170-196	14,563	170.32*	11.7	100,657	170,320	69,663*	1.69
T4	240-170-170	14,563	169.43*	11.6	100,315	169,430	69,115*	1.69
T5	240-170-145	14,563	175.50*	12.1	101,085	175,500	74,415*	1.73
T6	240-170-120	14,563	170.08*	11.7	99,969	170,080	70,111*	1.70
T7	240-170-95	14,563	148.25	10.2	96,105	148,250	52,145	1.54
SE ±		-	2.12	-	-		1,782.8	0.021
CD at 5%		-	6.24	-	-		5,244.1	0.064

Notes:

- Selling price 1 mt cane = Rs. 1,000; Farm gate costs of N, P_2O_5 and K_2O (as urea, SSP and muriate of potash (MOP) were 10.87, 18.75, and 7.67 Rs. per kg nutrient.
- Including cost of drip system: cost of drip irrigation system is based on the life of five cropping seasons, i.e. Rs. 60,000 ha^{-1} in five years equates to Rs. 12,000 + interest at 12 % = Rs. 16,320 yr^{-1}. This cost has been added to treatments T2 to T7.

(†) The cost of cultivation is the total expenditure made from land preparation to harvesting of the crop including the cost of drip irrigation system (Rs. 16,320 yr^{-1} ha^{-1}).

(§) Net income = Gross Income - Cost of cultivation.

(‡) Benefit Cost Ratio (B:C) is the ratio between gross income and cost of cultivation.

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sugarcane price at Rs. 1,000 per metric tonne, the income in treatments T1 to T7 worked out to be Rs. 142,820, 163,880, 170,320, 169,430, 175,500, 170,080 and 148,250 respectively, leaving a net income of 56,271 to 74,415 Rs. ha^{-1}, depending on the treatment (Table 4). Net income was significantly higher in all the treatments with drip irrigation, except T7. Net profit significantly increased over the control by Rs. 18,144 (approx. USD 403) ha^{-1} (Table 4).

According to our results, switching from flood to drip irrigation generates an additional Rs. 7,000 yr^{-1} just with the increased yield. Clearly, once water use is charged, this additional profit will increase.

The cost benefit ratio in treatments T1 to T7 was 1:1.65, 1:1.63, 1:1.69, 1:1.69, 1:1.73, 1:1.70 and 1:1.54 respectively (Table 4). The cost benefit ratio under drip irrigation systems i.e. in treatments T2 to T7 were worked out on the basis of the actual cost of the system in the market. However there is provision for a subsidy up to 50 percent for the drip irrigation system. In addition to increased yield under the drip irrigation system, there was water saving of 45.16 percent in drip treatments T2 to T7, as compared to the control i.e. conventional long furrow irrigation with recommended dose of chemical fertilizers.

Conclusions

Sugarcane is a major cash crop in India, yield and crop quality being critically dependant on supply of water and nutrients. Experiments carried out over three seasons are reported here in which drip irrigation was compared with conventional irrigation with recommended doses of chemical fertilizers. The results demonstrated that by using drip irrigation it was possible to achieve more than two-fold higher water use efficiency, and at the same time reduce fertilizer requirement and raise crop yield and quality. Cane yields of sugarcane increased by 19.09 percent with CCS values raised by 22.47 percent. This was achieved in addition to a 42.5 percent water saving using 30 percent less N and K fertilizer. The consequent cost benefits of drip irrigation to the farmer are economically assessed and are of major importance.

Acknowledgement

The authors are thankful to International Potash Institute for the financial assistance for carrying out this experiment at VSI Pune and its demonstrations in the fields of three farmers. Special thanks goes to Dr. Patricia Imas for her continuous close association, guidance and support throughout the conduct of this experiment.

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The paper "Effect of Various Levels of Potash Application Through Drip Irrigation on Yield and Quality of Sugarcane" appears also at:

Regional Activities/India

Appendix: Demonstration plots

Three demonstration plots were laid out at three farmers' fields in Ahmednagar, Sangli and Latur districts, Maharashtra State. Two treatments were demonstrated:

T1: Conventional irrigation with a recommended dose of fertilizers (340-170-170, N, P_2O_5 and K_2O, respectively).

T2: 70% N, 70% K_2O through drip irrigation in 13 equal splits and 100% P_2O_5 through soil application (240, 170 and 120 N, P_2O_5 and K_2O, respectively).

The (pooled) results of these farm demonstrations are presented in the table below, and are comparable to the results obtained at the VSI farm.

Treatment	Germination	Tiller ratio at earthing up	Milleable cane height	Number of internodes	Cane girth	Plant population	Cane yield	CCS	CCS yield	Quantity of water applied	Water use efficiency
	%		*cm*	*No.*	*cm*	*No. ha^{-1}*	*mt ha^{-1}*	*%*	*mt ha^{-1}*	*m^3 ha^{-1}*	*kg m^{-3}*
T1	73.16	5.96	247.67	22	9.85	90,357	88.24	12.25	10.82	26,370	3.3
T2	74.12	6.49	262.67	23.33	10.09	94,627	111.53	12.41	13.84	14,844	7.5

Research Findings

Effect of Potassium on the Production and Quality of Tobacco Leaves

Marchand, M.[(1)]

Tobacco plantation and barn in Cuba. Photo by M. Marchand.

Abstract

Potassium (K) and nitrogen (N) are two major nutrients in crop production. A deficiency of either one or both of these nutrients causes yield loss. In the specific case of tobacco production, both nutrients play a key role in controlling important quality parameters such as leaf colour, texture, hygroscopic properties, combustibility, sugar and alkaloid contents. Monitoring N applications thoroughly for form, quantity, and timing of application is a prerequisite in modern agriculture. As in other field crops, balanced N-K fertilization enhances tobacco growth and improves the uptake of both nutrients, which in turn reduces nitrate losses during and after the cropping season. The importance of K on mineral nutrition in tobacco production in terms of yield and quality is presented. The role of K in determining the chemical composition of tobacco leaf is now well established. K content of dry matter must reach 2 to 2.5 percent and chloride (Cl) content must remain below 1 to 1.5 percent in order to ensure good maturation, perfect combustibility and a good taste. The paper reports several pot and field experiments carried out in France, China and Cuba, in which various factors affecting yield and quality of the tobacco crop were studied including dose, source, and timing of potash applications. The effect of the combination of various potash forms (potassium sulphate, potassium chloride, potassium nitrate, potassium bicarbonate) with two N sources (nitrate –N from potassium nitrate, and ureic-nitrogen from urea) was investigated. The following measurements were recorded: yield parameters; mineral nutrients; sugar; the alkaloid contents of tobacco leaves at three stalk-levels; and water-soluble alkalinity which is an indicator of combustibility. In an experiment on tobacco for cigar production, the effect of sources of K for fertigation was investigated showing the benefit of potassium sulphate on quality of tobacco when applied over a longer period. Finally, an experiment with foliar applications of potassium sulphate in China is presented, illustrating the positive effect of foliar applied K on K content in the tobacco leaf.

Keywords: Tobacco, mineral nutrition, potassium, leaf composition, fertigation, foliar application.

Introduction

Growth and general physiology of crop plants can be significantly altered by varying cultural practices. In tobacco, the effects of spacing, topping, suckering, and harvesting all directly influence total yield as well as the proportion of the different classes of leaf, and their chemistry.

Standard tobacco production requires 130-150 kg N ha^{-1}, 30-40 kg P_2O_5 ha^{-1} and 230-240 kg K_2O ha^{-1} which is closely dependent on mineral nutrient supply. Fertilization also plays a key role in influencing the most important quality parameters such as leaf colour, texture, hygroscopic properties, combustibility, sugar and alkaloid contents. Leaf-burn, or combustibility, is one of the key criteria taken into account by the tobacco industry for assessing quality. Many studies have shown that organic acids, associated with K, enhance combustibility, whereas excessive N, especially in the ammonium form, is detrimental in this respect. The detrimental role of Cl in inducing leaf-burn and poor smoke taste is well documented in contrast to the role of other nutrients, such as sulphur (S), where their influence is less known. Sugar and alkaloid content are also important parameters of quality, which are partly controlled by mineral nutrition, and especially by the quantity and form of N fertilizer applied.

This paper presents the results of pot and field experiments carried out over recent years in France, Cuba and China to improve knowledge of the influence of

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fertilizer application on the yield and quality of the tobacco crop. The K fertilizer sources used in these experiments were potassium nitrate (KNO_3, NOP), potassium sulphate (K_2SO_4, SOP), potassium chloride (KCl, MOP) and potassium bicarbonate (K_2CO_3, Kbic).

Table 1. Soil analysis for the pot experiments (P_2O_5 Joret Hebert).

	Clay	Silt	Sand	pH	O.M.	CEC	P_2O_5	K_2O	K/CEC	MgO	CaO	Cl
	-----%-----				%	*meq 100 g^{-1}*	*----ppm----*		*%*	*-----ppm-----*		
Content	15.6	76.8	5.5	6.2	2.12	10.2	153	73	1.52	100	2.87	11

Table 2. Quantities of fertilizers applied on the pot experiments.

Fertilizer	Flue-cured		Air-cured	
	g pot^{-1}	*kg ha^{-1}*	*g pot^{-1}*	*kg ha^{-1}*
KNO_3	17.61	80N+270K20		
KNO_3+urea			25.98+5.06	200N+400K20
K_2SO_4+urea	14.82+4.98	80N+270K20	21.98+12.41	200N+400K20
KCl+urea	12.64+4.98	80N+270K20	18.74+12.41	200N+400K20
K_2CO_3+urea	11.34+4.98	80N+270K20	16.81+12.41	200N+400K20

France - pot experiments (1995)

Two experiments were carried out in which the pots were irrigated daily, with leached water being recycled for the next irrigation. The first experiment was conducted on dark air-cured tobacco (ITB 1000) from December 1994 till May 1995 in a closed greenhouse under controlled conditions, and the second on flue-cured tobacco (ITB 32) grown from June till September 1995 in an open greenhouse with adjustable roof protection.

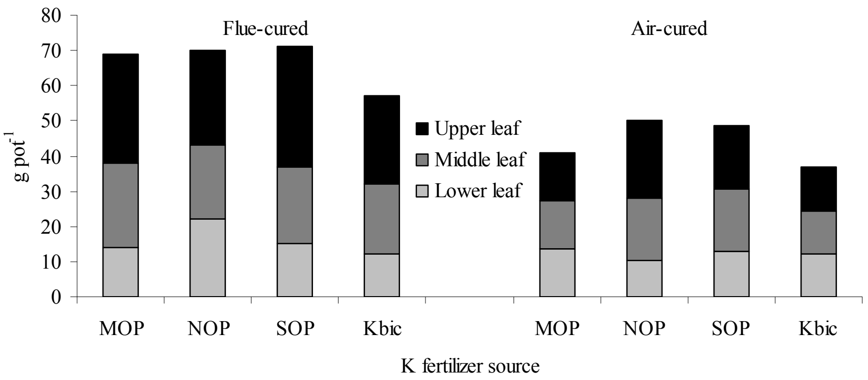

Fig. 1. Dry matter production of flue-cured and air-cured tobacco leaves with different sources of K fertilizers.

Soil analysis

The same soil was used for both experiments: a loamy soil, slightly acidic, poor in phosphorus, and very poor in exchangeable K (Table 1). All fertilizers were mixed with the soil before filling the pots.

Treatments

The quantity of K applied to Virginia flue-cured tobacco was fixed at 270 kg K_2O ha^{-1}, corresponding to the concentration of NOP (13-0-44) on the basis of 80 kg of N, in accordance with K and N requirements under French conditions (Table 2). NOP, SOP, KCl and Kbic were applied with urea on the same basis for N and K quantities. Dark air-cured tobacco grown under French conditions requires 200 kg ha^{-1} and 400 kg K_2O ha^{-1} on the basis of 38,000 plants ha^{-1}. In this case, the additional N required in the NOP treatment was made up with urea in order to have the same rate of N application in all treatments (Table 2). Each treatment was replicated six times and randomised within each block. The equivalent of 75 kg P_2O_5 ha^{-1} and 20 kg MgO ha^{-1} was applied uniformly as triple super phosphate and as magnesium carbonate.

Results

Dry matter production

SOP, MOP, and NOP appeared to be equivalent in terms of total yield production whereas Kbic gave the lowest yields in both experiments (Fig. 1). The relevant quantity of dry matter (DM) produced was much higher for flue-cured tobacco, probably because the air-cured experiment was made under completely artificial conditions for light and temperature.

Mineral composition

Nitrogen

As expected, the total N content was higher for air-cured tobacco, receiving the equivalent of 200 kg N ha^{-1} in comparison to the flue-cured tobacco which received only 80 kg N ha^{-1}. For both, more than 95 percent of the total N was in organic form (see Fig. 2). The nitrate content was highest with the NOP treatment in the flue-cured experiment, but this was not the case for the air-cured (results not shown).

Potassium

The threshold of two percent necessary for adequate quality of tobacco was easily achieved in both experiments

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(Fig. 3). It is worth remembering, however, that this value is not so easily reached under field conditions. All potash forms gave similar results in terms of K concentration in tobacco leaves. The K content decreased from lower to upper leaves, which is in agreement with previous observations. Although the air-cured tobacco received a much higher application of potash (400 kg K_2O ha^{-1}) than the flue-cured tobacco (270 kg K_2O ha^{-1}) as occurs in practice in contrast to N, the leaves of the air-cured did not contain more K except in the upper leaves.

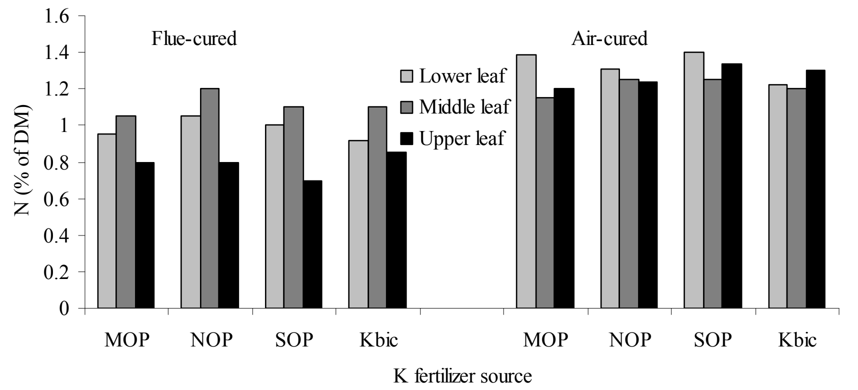

Fig. 2. N concentration (percent in DM) in flue-cured and air-cured tobacco leaves with different sources of K fertilizers.

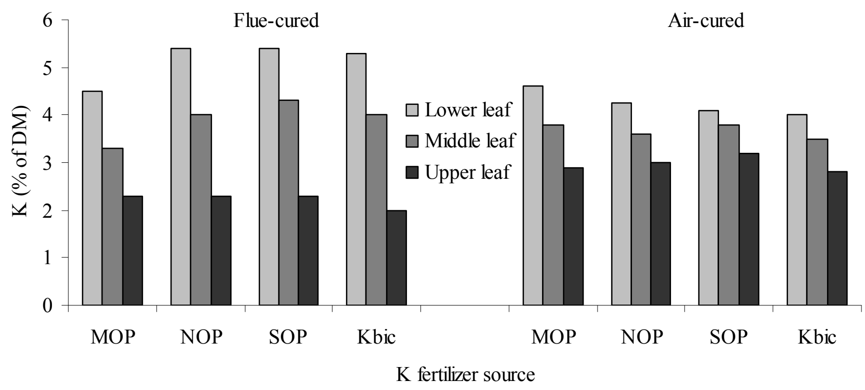

Fig. 3. K concentration (percent in DM) in flue-cured and air-cured tobacco leaves with different forms of K fertilizers.

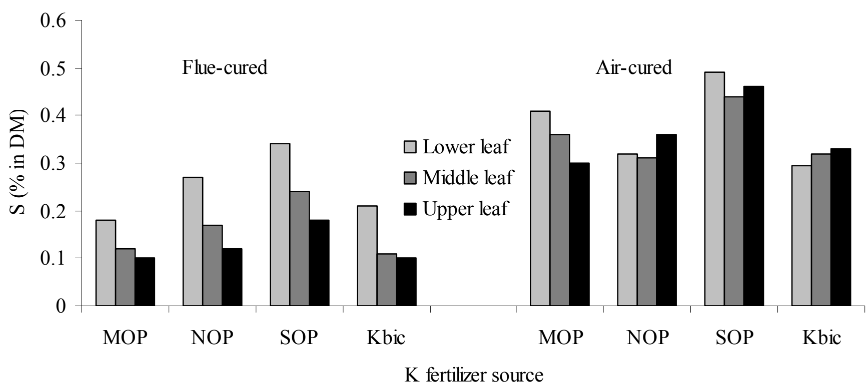

Fig. 4. Sulphur concentration (percent in DM) in flue-cured and air-cured tobacco leaves with different forms of K fertilizers.

Sulphur

The S concentration remained below the 0.65 percent threshold. Even with the equivalent of 800 kg ha^{-1} of SOP (144 kg S ha^{-1}), the maximum concentration reached was 0.49 percent. This finding confirms previous results that S uptake seem to be self-regulating in tobacco. Despite high application of sulphate, the resulting S concentrations in the leaves did not exceed 0.5 percent. This value is very low in comparison to Cl fertilization in which leaf Cl concentrations can reach up to about four to nine times that level (Fig. 5).

Chloride

In both experiments the Cl content was very high in the MOP treatment. It is generally accepted in the tobacco industry that a very good grade of tobacco requires less than one percent Cl and when it exceeds two percent Cl, the tobacco has no commercial value.

Water-soluble alkalinity

There is a highly significant relationship between leaf-burn and water-soluble ash alkalinity (WSA). An even closer relationship is obtained if WSA is replaced by the ratio of WSA to total N, expressed as percent of the DM. Potentially, the higher this ratio, the better the combustibility. In both experiments, the lowest ratios, and consequently the lowest potential regarding combustibility, were obtained in the MOP treatment which relates to the high Cl content. WSA values were similar for NOP, SOP, and Kbic treatments in both experiments. Highest WSA:N ratios were found for Kbic in the flue-cured experiment because the total N content was lowest in this treatment. The ratios for NOP and SOP were similar. Consequently, S content

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has probably only a marginal effect on combustibility compared to K and Cl.

France - field experiments (2001)

Materials and methods

An experiment was carried out in 2001 at Pôle d'Aspach, a research station in the eastern part of France. This station is located in the second largest tobacco cropping area in the country and the aim of the experiment was once again to examine the effect of N and K application in relation to timing. The three treatments maintained the same nutritional levels as 156 kg ha^{-1} N, 100 kg ha^{-1} P_2O_5, and 400 kg ha^{-1} K_2O. The fertilizers applied were ammonium nitrate (AN), NOP, SOP and a soluble form of K sulphate:

T1: conventional fertilization at planting (AN + SOP, 466 + 800 kg ha^{-1}), using drippers for irrigation only (control).

T2: conventional fertilization at planting (AN + SOP, 299 + 400 kg ha^{-1}) and fertigation every week with AN + soluble SOP (56 + 40 kg ha^{-1}) for three weeks followed by fertigation with soluble SOP (40 kg ha^{-1}) for seven weeks.

T3: conventional fertilization at planting (AN + SOP, 299 + 400 kg ha^{-1}) and fertigation every week with NOP (43.5 kg ha^{-1}) for ten weeks.

Results

In the two field experiments, both leaf production and quality parameters (based on tobacco industry criteria) were analyzed. Table 3 reports leaf production and shows the advantage of an early N application followed by a later application of K in response to plant requirement. Table 4 indicates that quality is also in line with yield production. Treatment 2 gave the lowest N and Cl contents, and adequate K based on cigarette factory requirements. In addition, S values did not exceed the threshold of 0.65 percent (considered as the maximum for a good combustibility).

For both varieties, the grade index shows there is a benefit from the application of N in the first three weeks after planting (Table 5). On Virginia, the effect was much more pronounced and the fraction of class A leaf was close to 60 percent.

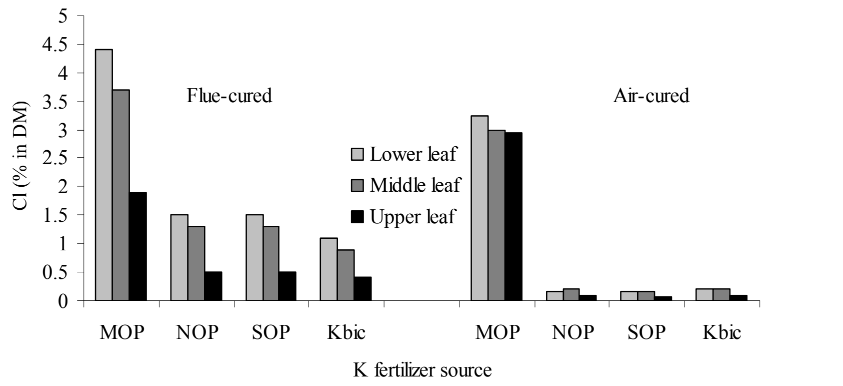

Fig. 5. Chloride concentration (percent in DM) in flue-cured and air-cured tobacco leaves with different forms of K fertilizers.

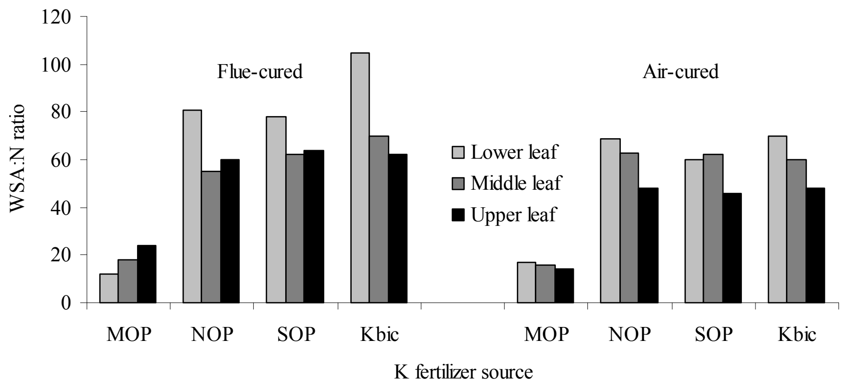

Fig. 6. WSA:N in DM ratio in flue-cured and air-cured tobacco leaves with different forms of K fertilizers.

Table 3. Influence of the treatments on tobacco yield.

Treatment	Black tobacco		Virginia tobacco	
	------------*g ha⁻¹*------------			
T1	14,396	b	9,587	c
T2	15,650	a	11,637	a
T3	14,743	b	10,309	b
SE	890 kg		444 kg	
CV %	6.00		4.40	

Table 4. Mineral composition of the leaves (%).

Treatment	Black tobacco				Virginia tobacco			
	N	K	Cl	S	N	K	Cl	S
	-----%							
T1	2.09	3.21 a	0.38 b	0.56 b	1.08 a	2.26 a	0.12 a	0.43 a
T2	2.06	3.09 b	0.35 c	0.60 a	1.04 b	2.23 b	0.10 b	0.44 a
T3	2.08	2.88 c	0.47 a	0.51 c	1.08 a	2.17 c	0.13 a	0.34 b
SE	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.04
CV %	1.2	0.6	2.6	0.3	0.8	0.6	4.4	0.8

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Table 5. Grade index for black and Virginia tobacco (%); grades: from A, high quality to E, low quality (classification used by European tobacco industry).

Treatment	Black tobacco					Virginia tobacco				
	A	B	C	D	E	A	B	C	D	E
T1	17	36	0	0	47	22	2	6	0	71
T2	21	20	11	0	47	59	4	12	0	26
T3	21	14	13	0	52	36	11	15	0	38

Table 6. Treatments for the Cuban experiment.

Treatment	Type	K fertilizer	Method	N; K fertigation
T1	Farmer's practice	SOP	Manure + fertigation	0 to 18 DAT
T2	Recommended program, based on absorption curves	SOP	Basal dressing + fertigation	N fertigation from 0 to 21 DAT; K fertigation from 0 to 28 DAT
T3	Standard program	SOP	Fertigation only	N and K fertigation from 0 to 21 DAT
T4	Program based on NOP	NOP	Basal dressing + fertigation	N and K fertigation from 0 to 28 DAT
T5	T5 = T2 without basal dressing	SOP	Fertigation only	N fertigation from 0 to 21 DAT; K fertigation from 0 to 28 DAT

DAT – days after transplanting.

Table 7. Soil analysis before and after the experiment.

Treatment	pH	Organic matter	Concentration in soil	
			K_2O	P_2O_5
		%	*------mg 100 g^{-1}------*	
Before	6.02	2.59	15.79	46.50
After (T1)	6.10	2.44	14.41	39.26
After (T2)	5.90	2.54	15.45	37.87
After (T3)	6.05	2.49	15.63	43.62
After (T4)	6.00	2.42	15.57	44.75
After (T5)	6.12	2.50	15.23	45.38

Cuba - field experiments (1997/2001)

In order to define the most suitable timing and number of applications of fertilizer on shade-grown, dark tobacco (variety "Criollo 98") for cigar production, fertigation research was carried out at the Tobacco Experimental Station in San Juan y Martinez, Pinar del Río province where five treatments were studied.

Materials and methods

The soil at this station was classified as an Ultisol, with ferrallitic quartzitic yellow and lixiviated characteristics according to the latest classification of Soil Taxonomy. The experiment was conducted following a protocol using long plots with five treatments and four replications.

The fertilizers applied were ammonium nitrate (AN), NOP and a soluble form of potassium sulphate. The five different treatments of the experiment are described in Table 6. For all treatments, levels of N, P_2O_5, and K_2O were 125, 51 and 188 kg ha^{-1} respectively, but applied at different times and methods. The variety used was "Criollo 98" developed at the Tobacco Experimental Station. For this variety the size of the largest leaf ranges between 33 and 36 cm in maximum width and between 53 and 58 cm in length. The variety has a potential mean yield of 2,250 kg ha^{-1}, and is resistant to the main diseases. Five plants were selected and identified at random in the calculation area in each plot between 20 and 25 days after the plantation establishment. Measurements of the length, width and dry mass of the middle leaf were made according to Torrecilla *et al*. (1980). Combustibility was measured by the procedure proposed by Guardiola (1992). In the cultivation of the crop, all normal agricultural procedures were carried out as required in wrapper tobacco production. The crop was planted during the second ten days of November and harvested at the beginning of February.

Results and discussion

The mean temperature, relative humidity and precipitation during the three-year experiment did not show any significant difference to the mean value over 25 years for any of the months in which the field experiments were carried out.

In the soil tests for each experimental plot, conducted before and after concluding each season, only small variations in the values of pH, OM, and P and K concentrations were observed (Table 7).

It should be noted that the nutrient ratios K/Ca, Ca/Mg, and pH were based on the recommendations in Cuba according to Morejón (1988).

Table 8 indicates that in all treatments, the increase in length, width, dry mass, and combustibility of the leaf were superior to the control (farmers' practice). Combustibility was considered "excellent" in all treatments but the control. The combination of formulations used in T2 (basal dose + NK fertigation, using SOP and limiting N application to 21 DAT) achieved the highest dry matter yield, while that of T4 (basal dose + NK fertigation, using NOP and NK fertigation till 28 DAT) achieved the highest combustibility value.

Table 9 presents the yield and its fractions. Highest yield of wrapper leaves for export, a very significant factor for the economics of tobacco growing, was achieved with T2. This

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treatment was superior in all fractions, demonstrating the value of SOP used with shortened time for N fertigation to reduce its negative effects (up to 21 DAT), and long for K fertigation (up to 28 DAT).

In general, under these Cuban conditions, fertigation between 7 and 28 days after transplanting with four application timings, markedly increased the quality and total yield of cigar wrappers for export.

As a consequence of the results obtained in the experiment, the recommendation to tobacco growers is to use fertigation techniques and to limit N application to the first stage of the vegetative cycle, whilst taking advantage of the fact that K can be successfully applied later.

Table 8. Influence of the treatments in the biological indices.

Treatment	Length		Width		Dry matter		Combustibility [(*)]
	------------cm----------				*g*		*seconds*
T1	46.75	c	27.5	b	3.90	c	18.50
T2	59.75	a	33.2	a	4.85	a	24.25
T3	48.50	bc	26.2	b	4.11	b	22.50
T4	48.00	bc	27.0	b	3.18	d	28.50
T5	51.50	b	28.0	b	3.87	c	26.25
SE	1.13		0.77		0.27		-
CV %	4.59		5.64		2.95		-

[(*)] According to Guardiola (1992), combustibility is considered low (0-5 sec.); acceptable (6-10 sec.); good (11-20 sec.) and excellent (>20 sec.).

Table 9. Influence of the treatments on yield and quality of production.

Treatment	Wrapper for export		Wrapper for national consumption		Binder and filler		Total yield	
	-------------------kg ha^{-1}-------------------							
T1	674.05	b	395.87	bc	621.32	d	1,691.24	d
T2	898.69	a	507.87	a	833.67	b	2,237.23	a
T3	661.62	b	343.17	c	764.87	c	1,769.66	c
T4	443.95	c	449.15	ab	913.25	a	1,806.35	bc
T5	499.20	c	443.77	b	873.94	ab	1,816.91	b
SE	20.18		20.06		15.80		14.55	
CV %	7.00		10.28		3.96		1.65	

China - field experiments (1997)

Materials and methods

As already observed on many crops, foliar application of soluble SOP has a positive effect on production and increases the K content of the leaf. Additionally, because of the lack of foliar-applied N, leaf N content decreases which is favourable for tobacco maturation.

Experiments were conducted in China and France. In the experiment presented below, carried out in Guangdong province, the same basal dressing was applied to each plot (120 kg N ha^{-1}, 60 kg P_2O_5 ha^{-1} and 200 kg K_2O ha^{-1}). Three foliar sprays were applied 45, 55 and 65 days after transplanting. Treatments were designed to determine the optimal K concentration in the foliar spray (Table 10).

Table 10. Effect of foliar application on tobacco leaf. Data from Hong He Tobacco Research Station.

Treatment	K content in leaf	Total yield	Upper leaves	Middle leaves
	%	*----------kg ha^{-1}--------*		
Control	1.66	2,709	1,524	838
Soluble SOP 2%	2.04	2,795	1,595	840
Soluble SOP 4%	2.17	3,062	1,628	970
Soluble SOP 6%	2.25	2,894	1,610	929

Results

The results confirmed that increased K concentration in the foliar spray solution up to six percent affects and increases K concentration in the leaves, which in turn increase yields. Maximum yield (3,062 kg ha^{-1}) was achieved with four percent of soluble SOP in the foliar spray. Foliar spray with six percent soluble SOP further increased K concentration in the leaves (2.25 percent), but with no further yield response. Foliar spray with four percent of soluble SOP achieved the highest tobacco quality (data not shown).

A high response was observed as the K content increased from 1.66 percent up to 2.25 percent as a consequence of increasing K content in the foliar spray. In comparison with the control, a slight effect on yield in upper and middle leaves was also observed. In relation to the foliar application, the small amount of sulphate of potash sprayed cannot in itself explain the K increase in the tobacco leaves. A tentative explanation to account for this beneficial effect may be as follows: spraying K salts on the leaves of plants of low K status but

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adequately supplied with other nutrients would be expected to promote sucrose (and K) transport in the phloem from shoot to roots. Energy would thus be provided to further root growth thereby enhancing K acquisition from the soil in a K pump-like action. Both foliar applied and any enhanced K uptake would also favour growth by improving water status, photosynthetic activity, protein synthesis etc.

Conclusions

From this series of experiments in different regions, and the experimental conditions under which they were carried out, the following conclusions may be drawn:

- K fertilization is a prerequisite to quality production of tobacco in order to improve curing and combustibility.
- Application of K fertilizers separately from N application can be beneficial because it allows the adjustment of N and K, both in supply and timing of supply, which in many cases can improve quality aspects of tobacco.
- MOP significantly reduces the quality of tobacco, which includes altering N metabolism and drastically decreasing combustibility.
- As a general rule, split applications of potassium are more efficient when water is not a limiting factor as shown in the experiments in France. In drip irrigation cropping systems, SOP and Kbic can be applied when K uptake is maximised and N is not required. NOP should be used only if application of N is limited at the early stage of tobacco growth, as demonstrated in the experiment from Cuba.

  Foliar application of K is a very effective way of supplying K under severe K deficiency or when K is restricted by soil characteristics. It enhances K uptake by the roots and consequently improves K leaf content which is an important quality criteria for the cigarette factories.

Drip irrigated tobacco experiment in France. Photo by M. Marchand.

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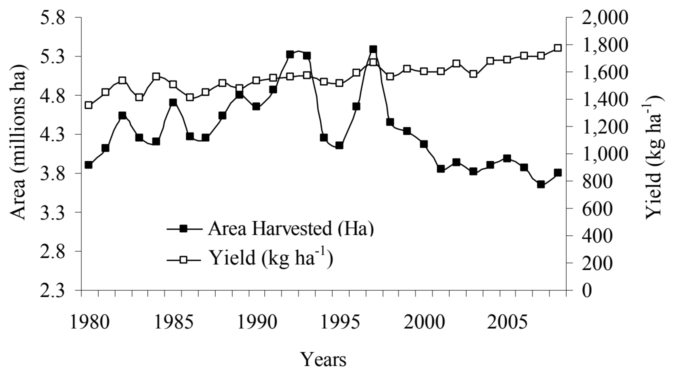
The paper "Effect of Potassium on the Production and Quality of Tobacco Leaves" is also available at:

[Regional Activities/WANA]

Area and productivity of tobacco, 1980-2008

Total world production of tobacco in 2008 was 6.7 million mt, of which 2.8 million mt were produced in China, followed by Brazil (0.8), India (0.5) and the USA (0.36 million mt). While global area decreased from 5.3 million ha in the 90s to 3.8 million ha in 2008, productivity improved steadily and reaches now 1,770 kg ha^{-1} (unmanufactured). Data from FAOSTAT, accessed September 2010.



Research Findings

Potassium Efficiency and Potassium Balance of the Rice-Rice Cropping System Under Two Different Agro-Ecosystems

Yulin Liao[2,3], *Shengxian Zheng*[1,3], *Jun Nie*[1,3], *Yanhong Lu*[1,2,3] *and Jian Xie*[1,3].

One of the experimental plots. Photo by Yulin Liao.

Abstract

The paper considers the effect of potassium (K) together with nitrogen (N) and phosphorus (P) fertilizer supply on grain yield, and K use efficiency and K balance of the rice-rice cropping system in a hilly agro-ecosystem region and lake agro-ecosystem region in south China. Comparing various levels of K supply, highest grain yields were obtained at 150 kg K_2O ha^{-1}, for both early and late rice in the reddish-yellow clayey soil of the hilly agro-ecosystem. For the Dongting lake agro-ecosystem, the purple calcareous clayey soil was much less responsive; K fertilizer efficiency being lower because of the higher soil available K and slowly available K contents. Grain yield increase resulting from N fertilizer was much greater than that from K fertilizer in both agro-ecosystems. The recovery by rice crop of fertilizer K was determined by measuring total of straw and grain K contents compared to the total K applied to the soil. For all three treatments of applied K, recovery rates were higher in the reddish-yellow paddy soil than in the purple calcareous clayey soil. The average value of K recovery efficiency for the three K fertilizer treatments in the reddish-yellow paddy soil was 35.0 percent for early rice and 51.8 percent for late rice; while the comparative figures for the purple calcareous clayey soil were 27.1 percent for early rice and 42.6 percent for late rice. N fertilizer recovery efficiency increased with K fertilizer application. This trend was more obvious in late rice. All three K application rates of 112.5, 150 and 187.5 kg K_2O ha^{-1} resulted in a deficit in K balance. N surpluses with early rice occurred with applications of 165 kg N ha^{-1} on the reddish-yellow paddy soil and with 150 kg N ha^{-1} on the purple calcareous clayey soil. With late rice, application of 180 kg N ha^{-1} resulted in N surpluses on the soils of both agro-ecosystems. The surplus amounts of N decreased with increasing K fertilizer application.

Keywords: Rice-rice cropping system; potassium fertilizer; potassium efficiency; potassium balance.

Introduction

The rice-rice production system is an important one in south China, contributing most of the food for the country. There are, however, signs of productivity decline and deterioration in soil fertility of the system because of a lack of K. Over recent years, increase in rice production has been achieved by the use of improved germplasm, associated with increased application of N and P fertilizers, but without a corresponding increase in the use of K fertilizers. This lack of K has been exacerbated by the practice of resource poor farmers who remove nutrients from their fields, especially K, in the form of straw for fuel and cattle feed (Wihardjaka *et al*., 1999; Yadav, 1998). Burning straw, to allow ease of tillage, also reduces soil fertility by consequent loss of organic matter (OM). For similar reasons the same problem of K depletion and deterioration in soil fertility has been observed under cropping systems in India (Römheld and Kirkby, 2010). Under the current fertilizer application regime of the rice-rice cropping system in south China, K is usually is inadequate in terms of the N, P to K nutritional balance, and may even be highly K deficient. The need to increase soil K fertility as well as take into account the K balance in soils in order to stabilize high yields was highlighted by Wang *et al*. (2005).

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Research Findings

Understanding K supply capacity of soils in different rice-rice planting areas, as well as the requirement to increase K-supplying potential capacity of paddy soils by adequate potassium application, is one of the important measures to increase rice crop yields and sustain K fertility of paddy soils. K fertilizer management in paddy soil is the key to high yield rice crops and the maintenance of soil K balance. According to Zheng *et al.* (1989), K fertilizer application is a traditional agricultural measure to sustain rice crop yield in the rice-rice cropping system.

In order to apply K at a rate to meet the needs of the rice crop during growth, and to obtain a rationale for K fertilizer use with optimal economic benefit, it is necessary to study K efficiency, K recovery efficiency and K balance of the rice-rice cropping system. The aim of the present study was thus to provide a scientific rationale for K fertilizer application for paddy soil in two contrasting agro-ecosystems in two different regions in Hunan province. The effect of K fertilizer on grain yield, potassium efficiency and potassium balance of the rice-rice cropping system were investigated over the 2005-2006 crop season.

Table 1. Some chemical properties of soils at the sites used in experiments.

Location	Soil name	Physiographic pattern	pH*	OM	Total N	Avail. N	Avail. P	Slowly avail. K	Avail. K
				---$g\ kg^{-1}$---		-------------$mg\ kg^{-1}$------------			
Changsha county	Reddish yellow clayey soil	Hilly agro-ecosystem	5.7	38.7	12.2	196.5	19.9	115.0	106.6
Yuanjiang city	Purple calcareous clayey soil	Dongting lake agro-ecosystem	7.3	46.0	24.4	216.0	17.9	349.0	131.0

* At soil to water ratio of 1:2.5(w/w).

Materials and methods

Site description

The experiments were carried out at two sites in Hunan province, one in Changsha County and the other in Yuanjiang city. The physiographic patterns of Changsha County and Yuanjiang city are a hilly ecosystem and the Dongting lake ecosystem, respectively. In the hilly ecosystem in Changsha County, the soil is a reddish-yellow paddy soil derived from Quaternary red clay, whereas the soil derived from lake sediment in Yuanjiang city is a purple calcareous clayey soil. The chemical properties of the soils at the two experimental sites are shown as Table 1.

Experiment design

The experiment treatments as shown and described in Table 2 included NP, PK2, NPK1, NPK2 and NPK3 for both early and late rice planting seasons. A detailed description of the experimental design is presented in Fig. 1. As shown in the figure the NPK2 plots in the early rice season was divided into NP, PK2 and NPK2 plots in the late rice season. The N application rates for early rice were 165 kg N ha^{-1} in the hilly agro-ecosystem region and 150 kg N ha^{-1} in the Dongting lake region, except where N was omitted in the PK2 treatments, respectively. The N application rate for late rice was 180 kg N ha^{-1} for both experimental sites. Two thirds of the N fertilizer was applied as basal fertilizer before transplanting both the early and late rice and the other third was applied as topdressing at an early tillering stage. The application rates of P fertilizer were 90 kg P_2O_5 ha^{-1} in early rice and 45 kg P_2O_5 ha^{-1} in late rice applied as basal fertilizer. K fertilizer was also applied as basal fertilizer. Each treatment had three replications arranged in a randomized block design with a plot size of 20 m^2. The rice varieties used, or their combinations, in the experiments were "Baliangyou100" in early rice and "Weiyou64" in late rice in Changsha, and "Baliangyou100" in early rice and "Iyou198" in late rice in Yuanjiang, respectively. In each year, early rice transplanting took place in late April and late rice was transplanted about late July, with 16.7 cm × 20 cm spacing for early conventional rice and 20 cm × 20 cm spacing for late hybrid rice. Early rice was harvested around the middle of July in the early planting season and late rice was harvested around late October in the late planting season.

Table 2. Nutrient application treatments of the experiment.

Treatments	Early rice			Late rice		
	N[(*)]	P_2O_5	K_2O	N	P_2O_5	K_2O
	----------------------$kg\ ha^{-1}$----------------------					
NP	165/150	90	0	180	45	0
PK2	0	90	150	0	45	150
NPK1	165/150	90	112.5	180	45	112.5
NPK2	165/150	90	150	180	45	150
NPK3	165/150	90	187.5	180	45	187.5

Note: [(*)]165 and 150 kg N ha^{-1} in Changsha County and Yuanjiang city, respectively.

Analysis method and data analysis

The concentration of OM, total N, available N, available P, available K

Early rice in first season

NPK2			NPK1	NPK3	NP	PK2
NPK1	NP	PK2	NPK3	NPK2		
NPK3	NPK2			PK2	NPK1	NP

Late rice in second season

NPK2	NP	PK2	NPK1	NPK3		
NPK1			NPK3	NPK2	PK2	NP
NPK3	NPK2	NP	PK2		NPK1	

Fig. 1. Experimental design used in the field studies.

Research Findings

Table 3. The response of grain yield to K application in different types of agro-ecosystems region.

Treatment	Grain yield		Agronomic efficiency	
	Early rice	Late rice	Early rice	Late rice
	----------kg ha^{-1}-----------		----kg grain kg^{-1} K_2O----	
	Changsha County; Hilly agro-ecosystem			
NP	7,283.3 c	7,983.3 c	-	-
NPK1	7,483.3 b	8,150.0 b	1.78	1.48
NPK2	7,700.0 a	8,333.3 a	2.78	2.33
NPK3	7,683.3 a	8,433.3 a	2.13	2.40
	Yuanjiang city; Dongting lake agro-ecosystem			
NP	7,666.7 a	8,316.7 a	-	-
NPK1	7,800.0 a	8,366.7 a	1.18	0.44
NPK2	7,866.0 a	8,516.6 a	1.33	1.33
NPK3	7,783.3 a	8,517.3 a	0.62	1.07

Note: Statistical significance is indicated at a 95 percent level ($P \leq 0.05$).

and pH value in soil and total K and total N in the rice plants were analyzed by the use of conventional methods (Lu, 2000). Statistical analyses were performed with SPSS 10. Input of nitrogen included the N applied together with that returned by crop residues. Output included the N uptake by the rice crop together with gaseous losses. These losses were estimated by using data from other authors (Liu *et al*., 2002; Zheng *et al*., 2004). Input of K included the K applied as fertilizer and that returned by crop residues. The output included the K uptake by the rice crop.

Results

K fertilizer application effect on grain yield in the two agro-ecosystem regions

In the hilly agro-ecosystem, grain yield difference between the three treatments with K fertilizer application and the treatment without K fertilizer application was significant at $P<0.05$ (Table 3). The difference between yields of the NPK3 and NPK2 treatments, however, was not significant at $P<0.05$. The results indicate that the comparatively higher grain yield was obtained when 150 kg K_2O ha^{-1} was applied (NPK2 treatment) under the K fertility status and production condition of this agro-ecosystem. In the Dongting lake agro-ecosystem, the grain yields were increased in the three treatments with K applied in early rice and late rice, but the difference between them and the no K fertilizer application treatment was not significant, at $P>0.05$. This finding indicates that native soil K was adequate to sustain the higher yield in Dongting lake agro-ecosystem. The agronomic efficiency of K (i.e. kg grain per kg K_2O applied) of early rice in the hilly agro-ecosystem varied from 1.78 to 2.78 and that of late rice varied from 1.48 to 2.40. In the Dongting lake region, the comparative values for early rice ranged from 0.62 to 1.33 and late rice 0.44 to 1.33. The agronomic efficiency of K in the hilly agro-ecosystem was thus higher than in the Dongting lake region, with an average value of agronomic efficiency of K being 2.15 kg grain kg^{-1} K_2O in the hilly agro-ecosystem as compared with 1.00 kg grain kg^{-1} K_2O in the Dongting lake agro-ecosystem.

The recovery efficiency of K and N by rice plants in early rice and late rice in different agro-ecosystem regions

The average value of K recovery efficiency (i.e. the K in grain and straw as compared with the K applied) for the three K fertilizer treatments is given in Table 4. For the hilly agro-ecosystem region with the reddish-yellow paddy soil, it was 35.0 percent (33.5-36.7 percent) for early rice, and 51.8 percent (47.3-55.8 percent) for late rice. For the lake agro-ecosystem region with purple calcareous clayey soil, the comparative figures were 27.1 percent (26.1-27.8 percent), and 42.6 percent (36.9-48.7 percent), respectively. Calculating the average value of K recovery efficiency by rice plants for the two seasons, the average of three K fertilizer treatments on the reddish-yellow paddy soil (43.4 percent) was 8.5 percent higher than that on the purple calcareous clayey soil (34.9 percent). The average N recovery efficiency values of the three K fertilizer application plots in the hilly agro-ecosystem region for early rice and late rice were 32.7 percent (30.3-34.1 percent) and 34.6 percent (32.2-35.3 percent), respectively. In the Dongting lake agro-ecosystem region, the comparative figures were 34.6 percent (33.5-35.3 percent) and 35.0 (34.2-36.3 percent), respectively. Fertilizer N recovery efficiency increased with increasing K fertilizer application, this trend being more obvious in late rice.

Balance of K and N in different agro-ecosystem regions

The input of potassium included the K

Table 4. Recovery efficiency of K fertilizer and N fertilizer by rice plants (grain+straw) in rice–rice cropping system of different types of agro-ecosystem region.

Treatment	Changsha County; hilly agro-ecosystem region			Yuanjiang city; Dongting lake agro-ecosystem region		
	Early rice	Late rice	Average	Early rice	Late rice	Average
	----------------%					
	Potassium recovery efficiency					
NPK1	36.7	52.4	44.6	27.3	48.7	38.0
NPK2	34.7	55.8	45.3	26.1	42.3	34.2
NPK3	33.5	47.3	40.4	27.8	36.9	32.4
	Nitrogen recovery efficiency					
NPK1	30.3	32.2	31.3	33.5	34.5	34.0
NPK2	33.2	35.3	34.3	34.9	36.3	35.6
NPK3	34.1	36.3	35.2	35.3	34.2	34.8
NP	25.8	23.0	24.4	25.6	20.9	23.3

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applied and that returned by crop residues. The output of K included the K uptake by the rice crop. From the results of total K balance (Table 5), the total input of K increased with increasing rate of K fertilizer application. The amount of K output increased with the increasing input rate. Comparing the soil K output rate of the two agro-ecosystem regions, the soil K output in Dongting lake agro-ecosystem was obviously higher than that in the hilly agro-ecosystem region. This may be due to the abundance of soil K in Dongting lake agro-ecosystem region. When the K fertilizer application rate increased from 112.5 kg ha^{-1} per season to 187.5 kg ha^{-1} per season, the amount of K uptake by the rice crop showed no obvious increase, but the amount of soil K deficit decreased with increasing K fertilizer application rate. The total grain yield of two season's rice crop did not increase with increasing rate of K fertilizer application. The total amount of K uptake from two seasonal rice crops in Dongting lake agro-ecosystem region was far higher than that in the hilly agro-ecosystem region. The results illustrate a most important reason for the absence of yield increase with increasing K fertilizer application in this region.

Table 5. Estimates of K balance in different fertilization treatment at different types of agro-ecosystem region (kg K_2O ha^{-1}).

Treatment	Early rice			Late rice			Total		
	Input	Output	Balance	Input	Output	Balance	Input	Output	Balance
					kg ha^{-1}				
					Changsha County; Hilly agro-ecosystem region				
NP	0	129.6	-129.6	3.5	186.8	-183.3	3.5	316.4	-312.9
NPK1	112.5	170.9	-58.4	116.2	245.8	-129.6	228.7	416.7	-188.0
NPK2	150	181.7	-31.7	153.8	270.5	-116.7	303.8	452.2	-148.4
NPK3	187.5	192.4	-4.9	191.1	275.4	-84.3	378.6	467.8	-89.2
					Yuanjiang city; Dongting lake agro-ecosystem region				
NP	0	164.7	-164.7	3.7	245.7	-242.0	3.7	410.4	-406.7
NPK1	112.5	195.4	-82.9	116.4	300.5	-184.1	228.9	495.9	-267.0
NPK2	150	203.8	-53.8	153.8	310.0	-156.2	303.8	513.8	-210.0
NPK3	187.5	216.9	-29.4	191.3	314.9	-123.6	378.8	531.8	-153.0

The results of soil N are shown in Table 6. The input of N includes the N applied and that derived from crop residues. Output of N includes N uptake by the rice crop together with gaseous losses. Gaseous losses were calculated using related data of other authors (Liu *et al*., 2002; Zheng *et al*., 2004). Nutrient composition of irrigated water is similar to that of leached water. A calculation of input of irrigated water and output of leached water was therefore not included in the balance (Ji *et al*., 2006). An N surplus occurred in the balances of both agro-ecosystem regions but was greater in the hilly agro-ecosystem region. Highest surpluses were found in the NP treatments with N surpluses in the hilly agro-ecosystem and Dongting lake agro-ecosystem region being 81.8 and 43.8 kg N ha^{-1}, respectively. Increasing rate of K fertilizer application resulted simultaneously in a decrease in N surplus. The same trend could be seen in the findings for both agro-ecosystem regions.

Changes in available K values in soils induced by different fertilization treatments in the soils of the two different types of agro-ecosystem region

Change of available K in soils is correlated with level of available K and slowly available K in soil used prior to the onset of the experiment (Muneshwar *et al*., 2002). As fertilizer treatment is known to affect the available K status of soils, measurements of available K were made after, as well as before, the experiment. In both agro-ecosystems, NP treatment caused the highest decrease of available K (Table 7). However, in the Dongting lake agro-ecosystem this decrease was smaller, presumably because of the higher amounts of available and slowly

Table 6. Estimates of N balance in different fertilization treatments at different types of agro-ecosystem region (kg N ha^{-1}).

Treatment	Early rice			Late rice			Total		
	Input	Output	Balance	Input	Output	Balance	Input	Output	Balance
					kg ha^{-1}				
					Changsha County; hilly agro-ecosystem region				
NP	165	115.1	49.9	186.4	154.5	31.9	351.4	269.6	81.8
NPK1	165	118.5	46.5	189.1	166.6	22.5	354.1	285.1	69.0
NPK2	165	123.3	41.7	189.2	172.2	17.0	354.2	295.5	58.7
NPK3	165	124.7	40.3	189.3	173.9	15.4	354.3	298.6	55.7
					Yuanjiang city; Dongting lake agro-ecosystem region				
NP	150	128.9	21.1	187.0	164.3	22.7	337.0	293.2	43.8
NPK1	150	137.9	12.1	189.7	178.5	11.2	339.7	316.4	23.3
NPK2	150	139.9	10.1	189.6	181.7	7.9	339.6	321.6	18.0
NPK3	150	140.5	9.5	189.7	178.0	11.7	339.7	318.5	21.2

Note: Gaseous loss of N from the NP treatment was calculated as 20.9 percent of the fertilizer N applied in early rice and late rice of the hilly agro-ecosystem region while that of NPK1, NPK2 and NPK3 treatment was calculated as 18.5 percent of the fertilizer N applied in early rice and late rice of the hilly agro-ecosystem region. Gaseous loss of N from the NP treatment was calculated 25.3 percent of the fertilizer N applied in early rice and late rice of Dongting lake agro-ecosystem region, while that of NPK1, NPK2 and NPK3 treatment was calculated as 23.5 percent of the fertilizer N applied in early rice and late rice of Dongting lake agro-ecosystem region.

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available soil K. Application of K fertilizer lessened the decrease in available K levels, in both agro-ecosystems, but not to the initial level of K before the onset of the experiment. While this may point to a net depletion of K, it can also be attributed to rather slow release of K to its available form.

Discussion

The efficiency of K fertilizer application in a rice-rice cropping system is higher in the hilly agro-ecosystem region compared to that in Dongting lake agro-ecosystem region, the main reason for this difference being the K-supplying capacity level of soil. The content of slowly available K and available K in reddish-yellow paddy soil derived from Quaternary red clay in hilly agro-ecosystem region is obviously lower than that of purple calcareous clayey soil derived from lake sediment in the Dongting lake agro-ecosystem region. The high K supplying capacity of this soil is able to meet the K requirement to produce a high grain yield of rice in the Dongting lake agro-ecosystem region. This finding is in accord with the lower agronomic efficiency K values measured in this agro-ecosystem.

Under continuous K fertilizer application from 112.5 to 187.5 kg K_2O ha^{-1}, the associated trend in increasing yield was smaller for late rice than for early rice in both agro-ecosystem regions. The results showed a residual effect of K fertilizer to the soil (Bao and Xu, 1993). The yield increase effect and agronomic efficiency, resulting from N fertilizer application, was much bigger than that from K fertilizer in both types of agro-ecosystem regions. Reasonable N fertilizer application is thus a key to obtaining high yield in rice production, and the most important measure to ensure the benefit of K fertilizer application to paddy soil which are deficient in K.

The recovery efficiency of N fertilizer increased with increasing rate of K fertilizer application, the trend being more significant in late rice. This result indicates that K fertilizer application induces the rice crop to take up more nitrogen from N applied fertilizer, the effect being consistent in both types of agro-ecosystem regions.

Table 7. Status of available K in soils of different fertilization treatment in rice-rice cropping system of different types of agro-ecosystem region (K mg kg^{-1}).

Treatment	Changsha County; Hilly agro-ecosystem region		Yuanjiang city; Dongting lake agro-ecosystem region	
	Early rice	Late rice	Early rice	Late rice
	-------------------------*mg kg^{-1}*-------------------------			
Initial K status(†)	106.6; 115.0		131.0; 349	
NP	59.7c	53.4d	95.5d	95.5b
PK2	86.1a	83.3a	128.3a	128.3a
NPK1	63.5b	57.6c	108.4bc	98.2b
NPK2	66.3b	66.5b	97.7d	99.7b
NPK3	64.8b	67.3b	114.2b	100.3b

(†) Available K; slowly available K.

Note: Statistical significance is indicated at a 95 percent level (P≤0.05).

The K balance was negative under 112.5, 150 and 187.5 kg K_2O ha^{-1} fertilizer application rate in each planting season. N surpluses occurred under early rice at rates of 165 kg N ha^{-1} in reddish-yellow paddy soil, and 150 kg N ha^{-1} in purple calcareous clayey soil. With late rice with application of 180 kg N ha^{-1}, surpluses of N were also present in both agro-ecosystems. The amount of surplus N decreased with increasing K fertilizer application regardless of the agro-ecosystem.

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The paper "Potassium Efficiency and Potassium Balance of the Rice-Rice Cropping System Under Two Different Agro-Ecosystems" appears also at:

[Regional Activities/China]

IPI Events

March 2010

International symposium on "Importance of Soil Management and Potash Fertilization for Sustainable Agricultural Development of Central America and the Caribbean" 10-13 March 2010, San Salvador, El Salvador.

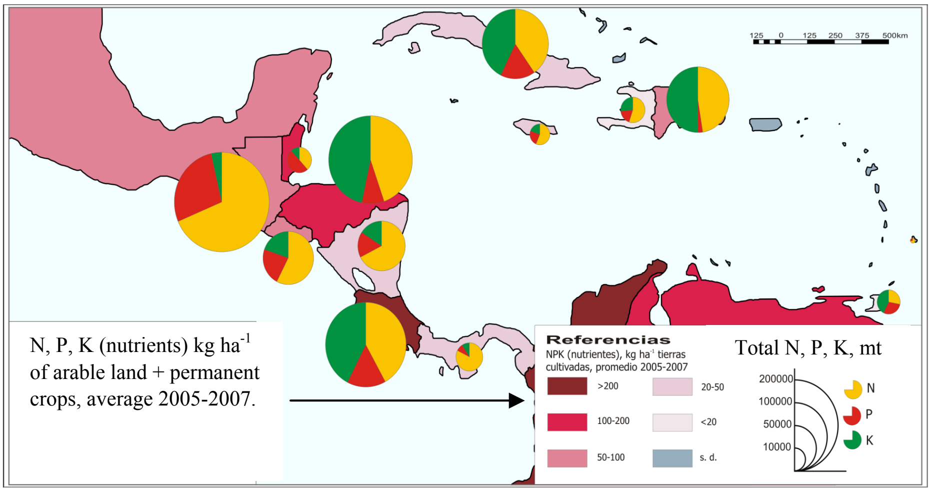
Naumov, A.[(1)]

Symposium participants during sessions. Photo by A. Naumov.

The Central America and Caribbean region is known for its exports of agricultural commodities, including banana, citrus, coffee, cotton, flowers, and sugarcane, which provide important revenue. However, in rural areas subsistence farmers, who are dependant on agriculture for their livelihoods, make up the majority of the population. Moreover, for many, fertilization practices are far from modern; the concept of "balanced fertilization" is not well-known and the use of potassium is particularly neglected.

The sustainability of agricultural systems greatly depends on balanced fertilization to improve soil fertility for secure and sustainable food production. Potassium fertilizers play a crucial role in improving the quality and yields of crops and thus contribute to the welfare of farming communities. Many areas of the region with tropical soils are susceptible to significant nutrient deficiencies and, consequently, deteriorating fertility. Greater adoption of advanced technologies and fertilization practices must be a priority if food production in the region is to be significantly improved.

To share experiences and discuss ways forward for the region, an International Symposium on the "Importance of Soil Management and Potash Fertilization for Sustainable Agricultural Development of Central America and the Caribbean" was held during 10-13 March, 2010 in San Salvador, El Salvador. The event was organized by IPI in collaboration with the Soil Science Association of El Salvador (A.S.C.S.), and supported by the Salvadorean government with co-



Central America and the Caribbean: Consumption and use of fertilizers (total N, P, K per ha). Map designed by A. Naumov. Data sources: IFA and FAO.

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IPI Events

sponsorship provided by the International Potash Company.

The symposium was attended by soil and plant nutrition scientists and agronomists from Costa Rica, Cuba, Dominican Republic, El Salvador, Guatemala, Honduras, Nicaragua, and Puerto Rico. Speakers were invited from Argentina, Brazil, Colombia, France, Israel, Russia and USA to contribute their knowledge and experience in key areas. Other stakeholders were represented by the participation of international organizations, including Food and Agriculture Organization (FAO) and the Inter-American Development Bank (IADB), various fertilizers industries and agribusiness companies. The event organizers were also particularly pleased to welcome participation of young student scientists from local universities.

Presentations on fertilization of banana, coffee, cotton, sugarcane, tobacco, various fruits and vegetables, maize, rice and soybean were given by symposium participants (which can be accessed at http://www.ipipotash.org/speech/index.php?ev=103). Various aspects of evaluation and maintenance of soil fertility, recycling of nutrients in no-till systems, compound fertilizer use, fertigation, use of processed sewage waters (treated waste-water) for fertilization as a source of nutrients, and foliar application of fertilizers were also covered in the presentations. In addition, the influence of the current world crisis on development of agriculture and disparities in mineral fertilizer use between Central-American countries and Caribbean islands was highlighted.

The presentations provided evidence that countries within the region provide several examples of good fertilization practices (including potassium as one of the basic elements), enabling high yields and quality of crops along with sustainability of agricultural systems. Sugarcane cropping in Costa Rica and management of coffee plantations in El Salvador provide some of the best case studies. On Costa Rican *ingenios* (agro-industrial complexes specialized in sugarcane cropping and processing), highest yields of sugarcane and levels of sugar production per ha were obtained with 200 kg ha^{-1}, or more, of K_2O applied (data from Chaves Solera). In the Salvadorian *fincas* (small and medium size farms) high quality coffee beans (dry) yielded up to three mt per ha, with nearly 500 kg ha^{-1} of K_2O applied as top dressing (Drench) (data from Sandoval).

However, it is well-known that many farmers neglect scientifically-based knowledge on soil management, plant nutrition and fertilizer use or, because of low income levels, do not have access to modern techniques and means of production. These factors explain the extremely low average levels of fertilizer use in Haiti and Nicaragua amongst other countries, together with unequal N-P-K proportions, as shown on the map.

At the conclusion of discussions, participants recommended that dissemination on the efficient use of mineral fertilizers to farmers becomes a key priority, and the symposium should be considered as a starting point for developing extension activities in this area. It was also noted that by bringing together different countries representatives, the event not only highlighted problems that agricultural producers encounter in plant nutrition and soil management, but also united a group of professionals, who could form a task force to address concerns on key topics.

At the end of two and a half days of plenary sessions, symposium participants had a day to visit farms in rural areas of El Salvador, where they had a chance to interact with farmers. Participants, who arrived to San Salvador prior to the event, also enjoyed a visit to Aguascalientes coffee farm and processing factory, which was organized courtesy of its owners, the Borja family.

Data sources:

- Chaves Solera, M., LAICA, Costa Rica.
- Sandoval, J., PROCAFE, El Salvador.

To access the symposium presentations, click on the IPI website at Papers and Presentations. ■

Symposium participants examining coffee processing at Benefifio del café Aguascalientes, east of El Salvador. Photo by A. Naumov.

The report on the International Symposium "Importance of Soil Management and Potash Fertilization for Sustainable Agricultural Development of Central America and the Caribbean" 10-13 March 2010, San Salvador, appears also at:

Regional Activities/Latin America

August 2010

IPNI-IPI-NBSS & LUP Workshop on "Review and Refinement of Fertilizer K Recommendations in Vertisols", 24-25 August 2010, Nagpur, India.

In recent years, it has become apparent that potassium (K) fertilizer recommendations are rather generalized when it comes to inclusion of vertisols. Vertisols, with high clay content, need a much higher K status to meet plant

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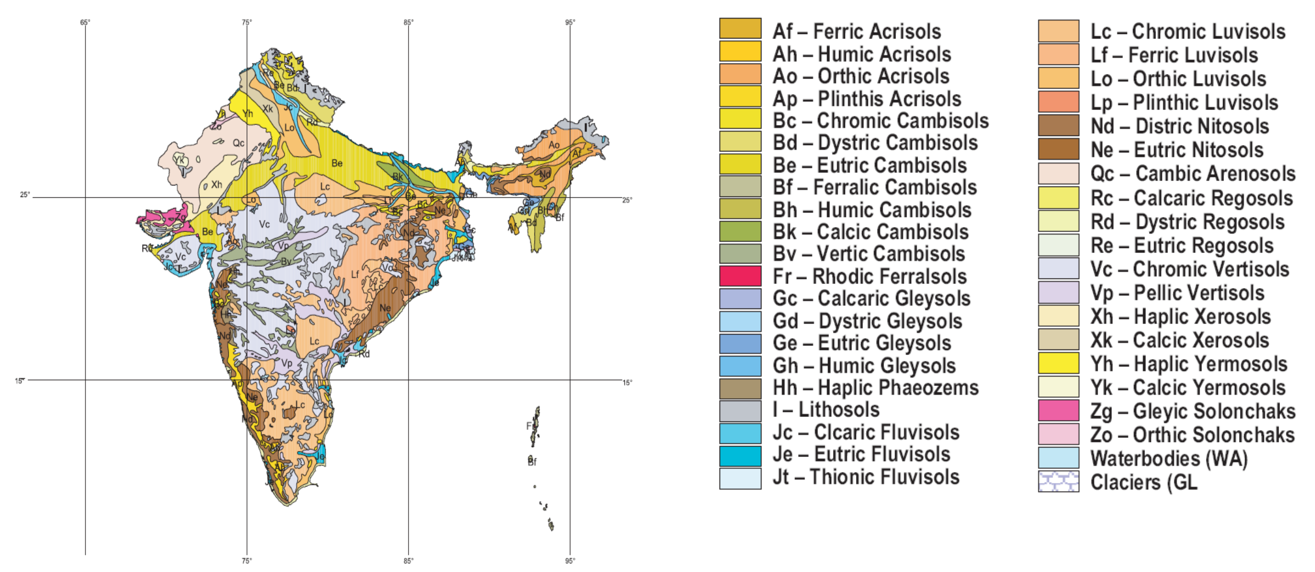
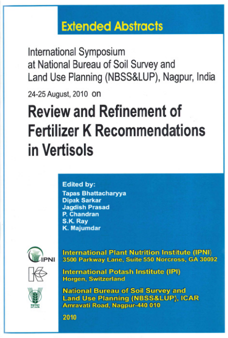


Soil map of India (original scale: 1.5 million). Source: FAO, 2005. Fertilizer use by crop in India. ftp://ftp.fao.org/agl/agll/docs/fertuseindia.pdf.



Extended abstracts of the papers presented at the IPNI-IPI-NBSS & LUP Workshop on Review and Refinement of Fertilizer K Recommendations in Vertisols.

requirements, as compared to light textures soils.

The majority of vertisols in India are found in Maharashtra, Madhya Pradesh, Andhra Pradesh, Karnataka, Tamil Nadu, Gujarat, Rajasthan and Chhattisgarh (see soil map of India). Crops grown are predominantly rainfed and include sorghum, soybean, cotton, maize, groundnut, chickpea, sugarcane, and citrus, among others.

Within this context, the International Plant Nutrition Institute (IPNI), International Potash Institute (IPI), and the National Bureau of Soil Survey and Land Use Planning (NBSS & LUP) of the Indian Council of Agriculture Research (ICAR) organized a one and a half-day workshop to assess the requirement for changing K fertilizer recommendations in vertisols.

Around forty scientists from universities in the vertisol regions, ICAR and state officials were invited to discuss this issue with the aim to re-align fertilizer recommendations to maximize farmers' income and maintain soil fertility. Twelve papers were presented including coverage of the special mineralogy of vertisols, K requirements of crops grown, typical responses to K applied, and suitability of the recommendations with regard to the actual responses reported over many years.

After lively and frank discussions, it was unanimously agreed that the present threshold for K fertilizer recommendations in vertisols (55 ppm as the limit that only below K is given) needs to be significantly increased, even doubled to 250 kg ha^{-1} (approx. 120 ppm). Further steps are needed to be taken at universities working on vertisols to refine and conclude this recommendation. Dr. Dipak Sarkar, Director of NBSS & LUP summarized the workshop.

[Dr. Harmandeep Singh](), Deputy Director IPNI, organized the workshop and also edits its proceedings, which will be available later this year. ■

Workshop participants at the NBSS & LUP facility. Photo by IPI.

The report on IPNI-IPI-NBSS&LUP Workshop on "Review and Refinement of Fertilizer K Recommendations in Vertisols", 24-25 August 2010, Nagpur, India, appears also at:

[Regional Activities/India]()

November 2010

International symposium on "Soil Management and Potash Fertilizer Uses in West Asia and North Africa Region", Antalya, Turkey, 22-25 November 2010.

See the [2nd circular]() on the IPI website.

The International Potash Institute (IPI),

IPI Events

in collaboration with Ege University organizes an international symposium in Antalya entitled "Soil Management and Potash Fertilizer Uses in West Asia and North Africa Region". The WANA region is known for its exports of agricultural products, including fruits and vegetables, which provide important incomes. However, a large part of the production is used to feed the population, which is increasing in a huge way. Balanced fertilization and particularly the use of potash is generally not well known.

During the symposium, issues including soil fertility, quality of mineral fertilizers, efficient use of fertilizers, fertigation and foliar application will be discussed. This event will be of interest to soil and plant nutrition scientists, agronomists, and extension officers from universities and research organizations, government offices, agribusinesses and farmers who share an interest in improving food production and quality in the region. The organizers anticipate participation from across the region. Invited speakers will include scientists from the WANA region and from Europe. The symposium will be announced at all universities in Turkey. Poster presentations are open to all, and students in the region are particularly encouraged to participate and present research related to the themes of the symposium.

For more details see IPI website or contact IPI Coordinator Mr. M. Marchand. ■

December 2010

N2010: 5th International Nitrogen Conference 3-7 December 2010, New Delhi, India. IPI is organizing an IPI-INI-ING special session on "N and K Interactions in Plants". Speakers will be from China, India and Israel. This special session will take place on either the 4th or 5th of December 2010. See details on IPI web. See also conference website. ■

Spring 2012

IPI is preparing for an international symposium in South West China, with the tentative title "Potassium in Soil and Plant Systems".

More details will soon be available (see on IPI website). ■

Other Events

November 2010

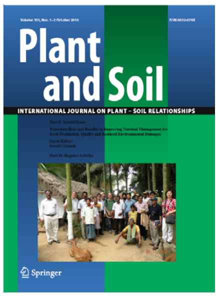
3rd International Rice Congress, Vietnam National Convention Center, Hanoi, Vietnam, 8-12 November 2010. With the theme "Rice for Future Generations", IRC 2010 will provide a forum for representatives from the public and private sectors including researchers, scientists, professionals, traders, and policy makers. Delegates will discuss the latest rice research, future technologies, trade issues, and policies that will define the future role of rice in supporting the poor rice-dependent communities. For more details go to http://www.ricecongress.com/. ■

February 2011

International symposium on Sensing in Agriculture, in Memory of Dahlia Greidinger, 21-24 February 2011, Faculty of Civil and Environmental Engineering, Technion, Israel Institute of Technology, Haifa, Israel. The aim of this symposium is to review research and development in the fields of remote and direct sensing systems and their future operational support in assuring sustainable agricultural production.

For more details see symposium website. ■

Publications



Plant and Soil, 335(1-2). October 2010.

Part I: Potassium Role and Benefits in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damages. Guest Edited by Ismail Cakmak.

This special issue covers nine papers that were presented at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, Orissa, India.

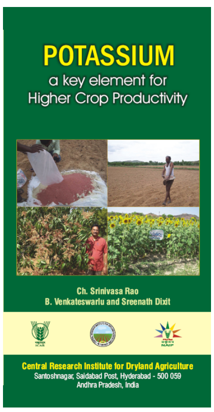
- Editorial: Potassium for Better Crop Production and Quality. Cakmak, I. p. 1-2.
- Quantifying Uptake Rate of Potassium from Soil in a Long-Term Grass Rotation Experiment. Öborn, I., A.C. Edwards, and S. Hillier. p. 3-19.
- Potassium Nutrition of Crops under Varied Regimes of Nitrogen Supply. Zhang, F., J. Niu, W. Zhang, X. Chen, C. Li, L. Yuan, and J. Xie. p. 21-34.
- Field-Specific Potassium and Phosphorus Balances and Fertilizer Requirements for Irrigated Rice-Based Cropping Systems. Buresh, R.J., M.F. Pampolino, and C. Witt. p. 35-64.
- Rice-Maize Systems of South Asia: Current Status, Future Prospects and Research Priorities for Nutrient Management. Timsina, J., M.L. Jat, and K. Majumdar. p. 65-82.
- Forest Fertilization: Trends in Knowledge and Practice Compared to Agriculture. Smethurst, P.J. p. 83-100.
- The Opening of Pandora's Box: Climate Change Impacts on Soil Fertility and Crop Nutrition in Developing Countries. St. Clair, S.B., and J.P. Lynch. p.101-115.

Publications

- [Impact of Potassium Nutrition on Postharvest Fruit Quality: Melon (*Cucumis melo* L) Case Study]. Lester, G.E., J.L. Jifon, and D.J. Makus. p. 117-131.
- [Global Impacts of Human Mineral Malnutrition]. Stein, A.J. p. 133-154.
- [Research on Potassium in Agriculture: Needs and Prospects]. Römheld, V., and E.A. Kirkby. p. 155-180. ■

Potassium Deficiency in Soils and Crops: Emerging Soil Fertility Constraint in Dryland Agriculture. English and Telugu. 2010. Srinivasa Rao, Ch., B. Venkateswarlu, S. Dixit, and A.K. Singh. Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad, Andhra Pradesh, India.

Download from IPI website in English and Telugu (with permission from Dr. Ch. Srinivasa Rao and CRIDA). For copies, contact Dr. Ch. Srinivasa Rao. ■



Potassium; a Key Element for Higher Crop Productivity. Srinivasa Rao, Ch., B. Venkateswarlu, and S. Dixit. 2010. English. Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad, Andhra Pradesh, India. 6 p.

Download from IPI website (with permission from Dr. Ch. Srinivasa Rao and CRIDA). For copies, contact Dr. Ch. Srinivasa Rao. ■

K in the Literature

Organic Agriculture: Why so Few Farms Convert. Ferjani, A., A. Zimmermann, and L. Reissig. 2010. Recherche Agronomique Suisse 1 (6):238-243. French.

Abstract:

Organic farming recorded significant growth in Switzerland, especially between 1990 and 2005, and won the support of both farmers and consumers. Despite this, organic farms are noticeably underrepresented in the arable farm regions; this situation is certainly due to the usually greater demands placed on farm conversion in these regions than in grassland. A survey of around 600 organic and PEP arable farms was conducted to determine which factors deter farmers from converting. The greatest fears expressed were the weeds pressure and the increased work needed for their control, the insufficient profitability resulting from too low surcharges on product prices, problems in nutrient supply and the too strict or too frequently changing guidelines. The results of the organic arable farm survey show that these fears are only partially justified. Increasing neighbourly exchanges should therefore promote the expansion of organic farming. ■

Effect of Potassium on Growth and Yield of Soybean. Morshed, R.M., M.M. Rahman, M.A. Rahman, and A.T.M. Hamidullah. 2009. Bangladesh J. Agric. and Environ. 5(2):35-42. English.

Abstract:

The experiment was conducted at the experimental space of Botany Department, Jahangirnagar University, Savar, Dhaka during Rabi season 2004-2005 to find out the effect of potassium (K) on growth and yield of soybean. The soybean variety, G-2 (Bangladesh soybean-4) was used in this experiment as test crop. The treatments were: Kl (No application of K), K_2, K_3, K_4, K_5 and K_6 were applications of 50%, 75% 100% 125% and 150%, respectively of the BARC recommended dose of K. Nitrogen, P and S were applied as blanket as per BARC recommendation. Seeds were inoculated with Bradyrhizobium inoculum before sowing. All the treatments of K application showed higher growth than that of control. Treatment K_5 (9.38 kg K ha^{-1}) showed maximum growth. The application of K (K_5 treatment) produced the highest seed yield (7.61 g plant^{-1}), which was 82.93% higher than that of control. The yield changed as a parabola curve with the increase of K application. The yield components, namely number of pods plant^{-1}, number seeds pod^{-1}, pod weight plant^{-1} and number of seeds plant^{-1} increased with the increase of K levels up to 9.38 kg K ha^{-1}. The application of K at 9.38 kg ha^{-1} (which was 25% higher over BARC recommendation) produced the highest seed yield of soybean (7.61 g plant^{-1}). So, for better yield of soybean in silty clay loam soil of Jahangirnagar University farm, application of K should be increased to 25% higher over BARC recommendation. ■

Improving Nutrient Use Efficiency by Exploiting Genetic Diversity of Potato. Trehan, S.P. 2009. Potato J. 36 (3-4):121-135. English.

Abstract:

Three separate field experiments were conducted to compare the nutrient efficiency indices, AUE (agronomic use efficiency), PUE (physiological use efficiency) and NUE (nutrient uptake efficiency) of ten Indian potato cultivars for the identification of nutrient efficient cultivars. Results showed wide variation in the nutrient efficiency of

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different potato cultivars. Kufri Pukhraj was the most N, P and K efficient cultivar among ten cultivars tested in the absence as well as presence of green manure. The efficient cultivars gave higher tuber yield under N, P and K stress (i.e. with less dose of N, P and K fertilizer) and had higher AUE than less efficient cultivars. Mean AUE of N of different cultivars varied between 62 and 97 kg tubers/kg N without green manure and between 68 and 100 kg tubers/kg N with green manure. Mean agronomic use efficiency of Kufri Pukhraj was 97 and 100 kg tubers per kg N without and with green manure respectively, which was significantly higher than all other cultivars. The main cause of higher nitrogen efficiency in the presence of green manure was the capacity of a genotype to use/absorb more N per unit green manured soil, i.e. the ability of the root system of a genotype to acquire more N from green manured soil (NUE). Most P efficient cv. K. Pukhraj produced yield of 300 q/ha without P whereas K. Badshah and K. Ashoka needed 100 kg P_2O_5/ha to produce yield of 270 and 304 q/ha, respectively in the same field. Similarly most K efficient cv. K. Pukhraj produced yield of 364 q/ha without K whereas K. Badshah and K. Sutlej needed 80 kg K_2O/ha to produce yield of 361 and 370 q/ha respectively in the same field. The variation in phosphorus and potassium efficiency of different potato cultivars was due to both their capability to use absorbed P and K to produce potato tubers (PUE) and to their capacity to take up more P and K per unit soil (NUE). ■

Integrated Nutrient Management in Potato Based Cropping Systems for Eastern Indo-Gangatic Plains of India. Kumar, M., M.K. Jatav, S.P. Trehan, and S.S. Lal. 2009. Potato J. 36(3-4):136-142. English.

Abstract:

In order to reduce the use of fertilizers and utilize residual fertility of potato crop, different integrated nutrient management options were examined in two most popular cropping systems *viz*., rice-potato-onion and maize-potato-green gram of eastern plains at Central Potato Research Station, Patna during 2004-2007. Besides different recommended dose of fertilizers and 100% organic treatments (farm yard manure to replace recommended dose of N to all crops), other treatments included reduced doses of nutrients to subsequent crops, recycling of crop residue and application of FYM. The maize-potato-green gram sequence gave higher potato yield due to improved soil physical conditions. However, the net return and potato equivalent yield (PEY) was higher in rice-potato-onion system due to higher returns from their component crops. Results indicated the possibility to economize fertilizer in green gram crop but not in onion by replacing 50% NPK through FYM or potato crop residue, when grown on residual fertility of potato. Residue incorporation of leguminous crop had more beneficial effect on subsequent maize crop but same effect of onion residue was not observed on rice. In organic treatment, potato yield was least, but steadily increased over the years in both the systems. Soil physical conditions improved in second system as indicated by decreased bulk density and increased organic carbon in sub soil. ■

Effect of Soil Solarization on Multiplication of *In-Vitro* Planting Materials of Potato under Field Conditions. Singh, R.K., J. Sharma, G.K. Singh, and S.P. Trehan. 2009. Potato J. 36(3-4):143-148. English.

Abstract:

A field experiment was carried out at CPRS, Jalandhar to study the effect of soil solarization on weeds and productivity of micro-tuber and mini-tuber crops of 3 potato cultivars. Mean maximum soil temperature recorded under the polyethylene mulch was 53.3°C at the surface, 50.5°C at 5 cm, 44.0°C at 10 cm and 38.6°C at 15 cm soil depth, which was higher than unsolarized plots by 10.96°C, 9.4°C, 5.6°C and 3.9°C at respective depths. Soil solarization for 4 weeks increased available nutrients (N, P, K) by 15.7, 67.3 and 49.0% at planting and 11.44, 13.1 and 32.2% at harvesting. It reduced the weed population up to 98.0% and its fresh weight up to 99.2%. Yield from micro-tuber and mini-tuber crops was higher in solarized plots (279.0 and 456.9 q/ha, respectively) as compared to unsolarized plots (193.2 and 399.2 q/ha, respectively). ■

Correlation and Calibration of Soil Potassium Availability with Soybean Yield and Trifoliolate Potassium. Slaton, N.A., B.R. Golden, R.E. DeLong, and M. Mozaffari. 2010. Soil Sci Soc Am J 74:1642-1651.

Abstract:

The ability of soil tests to identify nutrient-deficient soils and recommend fertilizer rates that optimize agronomic yield is essential for profitable soybean [*Glycine max* (L.) Merr.] production. Our objectives were to correlate relative soybean yield to Mehlich-3 and 1 mol L^{-1} HNO_3–extractable soil K and trifoliolate-leaf K concentration at the R1 to R2 development stage and calibrate the K rates for Mehlich-3-extractable soil K. Experiments were established on silt loams at 34 site-years planted with a Maturity Group IV or V cultivar and fertilized at five K rates (0–148 kg K ha^{-1}). Mehlich-3-extractable soil K ranged from 46 to 167 mg K kg^{-1} and produced relative soybean yields of 59 to 100% when no K was applied. Eleven sites had Mehlich-3-extractable K <91 mg K kg^{-1} and all responded positively to K fertilization. Soybean grown in soil having 91 to 130 mg K kg^{-1} responded positively at nine of 15 sites. Mehlich-3 soil K explained 76 to

K in the Literature

79% of the variability in relative yields and had critical concentrations of 108 to 114 mg K kg^{-1}, depending on the model. The linear-plateau model predicted the critical HNO_3–extractable soil K to be 480 mg K kg^{-1}. Trifoliolate-leaf K concentration increased significantly, positively, and linearly as Mehlich-3- and HNO_3–extractable soil K increased, but Mehlich-3 soil K explained only 49 to 53% of the variation in trifoliolate-leaf K. Mehlich-3-extractable K is an excellent predictor of soil K availability for soybean grown on silt loams in eastern Arkansas. ■

Potassium Fractions in Soils as Affected by Monocalcium Phophate, Ammonium Sulfate, and Potassium Chloride Application. Wang, H.Y., J.M. Zhou, C.W. Du, and X.Q. Chen. 2010. Pedosphere 20(3):368-377.

Abstract:

Soil potassium (K) deficiency has been increasing over recent decades as a result of higher inputs of N and P fertilizers concomitant with lower inputs of K fertilizers in China; however, the effects of interactions between N, P, and K of fertilizers on K status in soils have not been thoroughly investigated for optimizing N, P, and K fertilizer use efficiency. The influence of ammonium sulfate (AS), monocalcium phosphate (MCP), and potassium chloride application on K fractions in three typical soils of China was evaluated during 90-d laboratory soil incubation. The presence of AS significantly altered the distribution of native and added K in soils, while addition of MCP did not significantly affected K equilibrium in most cases. Addition of AS significantly increased water-soluble K (WSK), decreased exchangeable K (EK) in almost all the soils except the paddy soil that contained considerable amounts of 2:1 type clay minerals with K added, retarded the formation of fixed K in the soils with K added, and suppressed the release of fixed K in the three soils without K added. These interactions might be expected to influence the K availability to plants when the soil was fertilized with AS. To improve K fertilizer use efficiency, whether combined application of AS and K was to be recommended or avoided should depend on K status of the soil, soil properties, and cropping systems. ■

Implications in Efficient K Fertility Management in Indian Agriculture. Srinivasa Rao, Ch., A. Subba Rao, K.V. Rao, B. Venkateswarlu, and A.K. Singh. 2010. Indian Journal of Fertilisers 6(7):40-54.

Abstract:

Recommendations of potassic fertiliser are made based on available (exchangeable + water soluble) K status of soils in different soil testing laboratories in India. However, recent studies employing a variety of measures of nonexchangeable K indicated a very substantial contribution of nonexchangeable fraction of soil K to crop K uptake. Present paper examines the information generated in the last 30 years on the status of nonexchangeable K in Indian soils, its contribution to crop K needs, categorization of Indian soils based on exchangeable and nonexchangeable K fractions and K recommendations considering both the fractions of soil K. Inclusion of nonexchangeable K in the soil testing aids in predicting immediate K needs of crop plants as well as long term K needs of intensive cropping systems. Based on published information on Indian soils, district wide maps were prepared for both exchangeable and nonexchangeable K, and K deficient districts of the country were identified where K application is a must. Some maintenance dose of K is required in some districts where, exchangeable K is high but nonexchangeable K is low or medium. These maps and suggested recommendations help to prioritize the K efficient zones where K application is essential and higher possibility exists for improving the K use efficiency. Special care should be taken on K fertilisation on high K requirement crops like banana, sugarcane, potato, cotton, several cereals, tobacco, intensive fodder systems, vegetables and fruit crops. Therefore, inclusion of nonexchangeable K as a soil test in the soil testing laboratories for assessing long term K supplying capacity of Indian soils under intensive cropping systems and arriving at reliable K fertiliser recommendations is essential. ■

Read on:

- **Continuous Cropping, Fertilization and Organic Manure Application Effects on Potassium in an Alfisol under Arid Conditions.** Srinivasarao, Ch., K.P.R. Vittal, S. Kundu, P.N. Gajbhiye, and M. Vijayasankar Babu. 2010. Communications in Soil Science and Plant Analysis, 41:6, 783-796. ■
- **Potassium-dependant Wood Formation in Poplar: Seasonal Aspects and Environmental Limitations.** Ache, P., J. Fromm, and R. Hedrich. 2010. Plant Biology 12(2):259-267. ■
- **The Miracle of the Cerrado**; Brazil has revolutionised its own farms. Can it do the same for others? The Economist, 26 August 2010. ■
- **Agriculture's Role in Greenhouse Gas Emissions and Capture.** American Society of Agronomy, Crop Science Society of America, Soil Science Society of America. August 2010. https://www.soils.org/files/science-policy/ghg-report-august-2010.pdf ■
- **Rising Global Interest in Farmland: Can it Yield Sustainable and Equitable Benefits?** The World Bank report, September 2010. ■
- News from International Union of Soil Sciences (IUSS). The World

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Reference Base for Soil Resources/WRB (the soil correlation system of the IUSS) has a new homepage at the FAO site: www.fao.org/nr/land/soils/soil/en/. It informs about all publications based on the second edition of WRB (2006). Especially important are: 1. the latest revised version (first update 2007), 2. the translations (up till now: Arabic, German, Polish, Russian, and Spanish), 3. the newsletters, 4. the "Guidelines for constructing small-scale map legends using the WRB". Originally designed for classifying pedons, with these Guidelines WRB can also be used for map legends (at least for scales 1:250 000 and smaller). ■

For more "K in the Literature" go to www.ipipotash.org/literature/

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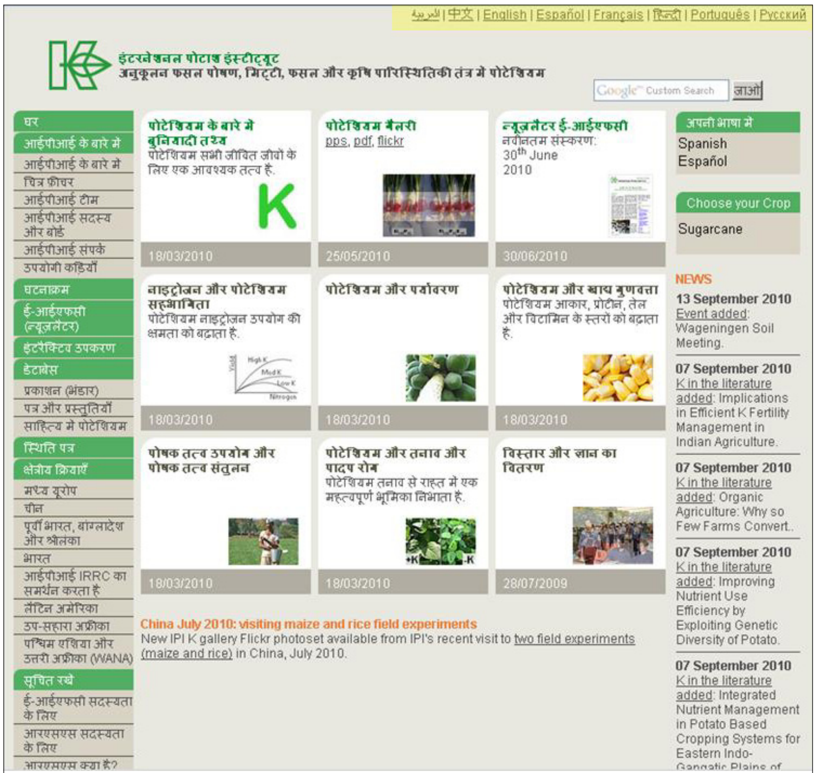

IPI website in Hindi.

IPI has now added the translation of the home page and navigators in all pages to Arabic, Chinese, French, Hindi, Portuguese, Russian, and Spanish. We do hope that this will attract more users to our website.

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