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Editorial

Dear readers,

Sustainable agriculture is now a well-known phrase used by many, including policy-makers, donors, extension workers, and even some of our farmers. However, we need to ask ourselves whether we all share the same understanding and appreciate that our perceptions and experiences may differ.

For farmers, sustainable agriculture means that the natural resources they use, particularly land and water, remain healthy and productive and will not only sustain their livelihoods but provide a profit and a future. In addition to measuring sustainability through environmental indicators, different production levels also pose a different set of indicators. Sustainable agriculture where productivity can be marginally increased, e.g. in W. Europe, is quite different to where a significant improvement of productivity is expected (e.g. parts of Asia and sub-Saharan Africa). Managing sustainable agriculture for these two extreme scenarios may be quite different, and so are the challenges for farmers.

The state of agriculture in sub-Saharan Africa is unique in that with very little increase of inputs, farmers can often achieve substantial increases in production. Read more about how this can be achieved in a paper from Mozambique featured in this edition. Sustainable agriculture under such conditions must also be viewed according to its ability to sustain the people that rely on these systems.

I wish you all an enjoyable read. ■

Hillel Magen

Director

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Good cotton prices drove many farmers in West Bahia (Brazil) to grow more of the crop. Photo by IPI.

Content of Different Forms of Potassium in Lebanese Soils

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Abstract

The content of different forms of potassium: water soluble, exchangeable, non-exchangeable, mineral and total potassium were determined at different depths in eight soil profiles representing most soil types in Lebanon. The mineralogy of the soil samples was identified by x-ray diffraction. The results showed that the average values for water soluble-K, exchangeable-K, non-exchangeable-K, mineral-K and total K were: 0.0122, 0.2324, 1.1791, 12.478 and 13.9471 Cmol kg^{-1} soil, respectively. The values for potassium saturation percentage (KSP) ranged between 0.21-2.79, and exchangeable potassium between 0.12-1.35 Cmol kg^{-1} clay. There are wide variations in the values of various forms of potassium and among potassium indices that are associated with mineral composition in different soils. The results show that the values of K forms in most of the studied soils are quite low. Consequently the supplying power of potassium in these soils is low and a need for potassium fertilization is recommended. For further research on potassium, it is suggested that more investigations on the rate of potassium release in Lebanese soils be conducted.

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Introduction

Potassium is a major element for plant nutrition. Available soil potassium (K) in sufficient quantities is a limiting factor in many agricultural and environmental systems. Soil potassium exists in different forms: solution, exchangeable, non-exchangeable, mineral and total K. There are equilibrium and kinetic reactions between these forms that affect the level of soluble potassium at any particular time and thus, the amount of readily available potassium for plants (Sparks, 2001).

The amount of soil soluble potassium is too low to meet the requirement of K by crops, while exchangeable K is often large enough to satisfy the requirement of one crop, but too small to meet the needs of several crops (Sparks and Huang, 1985). Non-exchangeable potassium occupies internal positions of clay sites as well as hexagonal cavities of certain minerals such as illite. Non-exchangeable potassium is moderately to sparingly available to the plant (Mengel and Kirkby, 1987; Al-Zubaidi and El-Semak, 1995). The type of K-bearing minerals greatly affects the release rate of non-exchangeable potassium (Martin and Sparks, 1983). Soil type and pedoclimatic conditions affect the K supplying power of Lebanese soils (Darwish *et al.*, 2003).

Mineral or structural potassium is also known as native matrix. 90-95% of total potassium is bonded within the crystal structure of various K-bearing minerals like feldspar and mica. This form is slowly available to plants. Total potassium represents the sum of all soil potassium forms. There are several factors that affect the quantity of total potassium in soil such as parent material, climate, leaching and vegetative cover.

Improving the knowledge about K-reserve in soil is necessary to better understand potassium nutrition and potassium management. Only a few papers have been published on potassium chemistry in Lebanese soils (Sayegh *et al.*, 1990; Al-Zubaidi *et al.*, 2008). This study was therefore initiated to estimate K-contents and fractions in eight soil profiles which represent most of the agricultural soils in Lebanon.

Materials and methods

Twenty-six (26) soil samples were collected from different depths of eight profiles representing the various great soil groups of Lebanon (see map). The locations, classification and physico-chemical characteristics of the soil samples are shown in Table 1.

The contents of different potassium forms in soil samples were determined using methods described by Pratt (1965): Water soluble potassium (H_2O-K) was extracted by distilled water 1:2 soil:water extract. Exchangeable potassium was extracted by 0.5 M $CaCl_2$ solution; $CaCl_2$ solution was used instead of ammonium acetate to avoid the extraction of fixed potassium (Martin and Sparks, 1983). Non-exchangeable potassium was extracted by 1N HNO_3, total potassium was extracted by digestion with a mixture of HF 48%, H_2SO_4 97% and concentrated $HClO_4$. Mineral potassium was calculated by the formula that was suggested by Martin and Sparks in 1983:

Mineral K = Total K – (K-$CaCl_2$ + K-HNO_3)

Potassium saturation percentage (KSP) was calculated by the following formula:

KSP = (exchangeable K/total exchange-able cations)x100

Exchangeable K/100 g clay was calculated taking into account that the total exchangeable K was present in the clay fraction in the samples.

Identification of clay minerals was done by the x-ray diffraction technique as illustrated by Jackson (1958). The analyses were carried out by pre-

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treatment as deferration, saturation with K, saturation with Mg and glycolation, and heating at 500℃ using the methods described by Tan (1996). Potassium saturation and glycolation of Mg-saturated samples were used to distinguish between expanding and non-expanding minerals (Tan, 1996).

Results and discussion

Soils description

The physio-chemical characteristics of the soil samples are shown in Table 1. The results indicate that the studied soils are non-saline (EC = 0.15 to 0.54 dS m^{-1}), with no considerable change in EC values throughout the soil profile. The pH values ranged between 6.8 and 8.2, indicating that the soils are neutral to slightly alkaline, with very little change in pH values throughout the soil profile. The organic matter ranged between 0.1-4.9%. The highest value of organic matter is in the surface layer (0-30 cm) of profile No. 179. In general, the values of organic matter content decreased with increasing depth.

The $CaCO_3$ content ranged between 0-72%. Several profiles (No. 165, 206, 259 and 272) may be classified as highly calcareous soils, while the top soils (cultivated layers in profiles No. 190, 179, and 49) are considered as non-calcareous.

The clay content of the soil samples ranged between 16-70%. The textural class of six profiles (No. 165, 206, 190, 234, 49, and 272) is clayey, and that of profile No. 179 is sandy, whilst profile No. 259 is a silt clay loam.

The sum of exchangeable cations which approximately represents the CEC value, ranged between 9.1 and 34.2 Cmol kg^{-1}. The contents of clay and organic matter highly affected the values of sum of the exchangeable cations.

Map of locations of the eight soil profiles analysed.

Mineralogy of soils

The interpretation of the x-ray diffraction of the clay minerals is summarized in Table 2.

Content of different potassium forms

The content of different potassium forms in the studied soil samples are displayed in Table 1.

1) Soluble potassium

Table 1 shows that the values of soluble potassium (H_2O-K) in the studied soil samples ranged between 0.0026-0.0479 Cmol kg^{-1} corresponding to 4.05-74.6 kg ha^{-1}, which is very low and not sufficient to support plant growth, and is much lower than the requirement of most crops.

2) Exchangeable potassium

The content of exchangeable potassium as shown in Table 1 ranged between 0.0632-0.651 Cmol kg^{-1}. The average value for exchangeable potassium is

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Table 1. Profiles locations, classification, physico-chemical characteristics and contents of different potassium forms in Lebanese soils of the studied soils

Profile No.	Location, soil type and texture	Depth	EC	pH	O.M	$CaCO_3$	Sand	Silt	Clay	∑ Exch. cations	H_2O - Soluble K	Exch. K	Non-exch. K	Mineral K	Total K	Mineral K /total K
		cm	*dS m⁻¹*		-------- % --------					------------	------ *Cmol kg⁻¹* ------				------------	%
165	Jbab el Homer;	0-20	0.54	7.60	1.80	15	15	36	46	33.90	0.0239	0.6225	3.97	21.20	25.82	82.14
	Calcaric Regosols;	20-60	0.54	7.50	1.00	37	18	30	50	27.85	0.0128	0.2891	0.96	15.69	16.95	92.55
	clay	60-110	0.51	7.70	0.80	34	22	24	50	30.87	0.0043	0.1431	0.86	17.32	18.33	94.48
		110-130	0.50	7.60	0.50	31	32	18	46	28.69	0.004	0.1108	1.05	16.21	17.37	93.30
206	Rachaya; Gleyic	0-25	0.47	7.70	3.10	35	13	48	38	34.20	0.0086	0.2531	0.72	14.60	15.58	93.69
	Cambisols; silty	25-70	0.33	8.10	2.20	39	12	36	50	31.56	0.0039	0.0811	0.36	12.10	12.55	96.44
	clay loam	70-100	0.40	8.10	1.60	30	19	26	54	33.23	0.0102	0.1016	0.49	13.36	13.97	95.69
		100-130	0.53	8.10	0.70	11	27	16	56	28.60	-	-	-	-	-	
259	Hasbaya Plain;	0-20	0.15	7.60	0.60	61	33	38	26	20.43	0.0101	0.0841	0.16	5.95	6.20	95.98
	Calcaric Fluvisols;	20-55	0.26	7.50	3.10	58	31	30	36	22.88	-	-	-	-	-	
	clay loam	55-80	0.25	7.30	3.30	55	33	36	28	16.45	0.0384	0.262	0.53	3.76	4.59	81.93
		80-150	0.35	7.10	1.90	60	33	38	26	17.26	0.0075	0.0817	0.17	4.70	4.95	94.81
190	Batroun; Gleyic	0-10	0.51	6.80	1.60	3	7	40	52	18.79	0.0479	0.5246	1.96	13.02	15.55	83.71
	Luvisols; clay	10-70	0.28	7.10	1.50	2	6	28	64	16.39	0.0079	0.1192	1.01	14.87	16.01	92.90
		70-130	0.29	7.20	0.10	2	5	22	70	18.04	0.0041	0.084	0.92	15.08	16.08	93.75
179	Marjheen; Eutric	0-30	0.29	7.40	4.90	1	58	18	22	15.96	0.0171	0.2191	1.06	11.14	12.44	89.57
	Arenosols; sandy	30-80	0.16	7.70	0.60	1	70	14	16	9.19	0.0079	0.0759	0.60	11.24	11.92	94.30
	clay loam	80-135	0.21	7.40	0.70	1	60	22	18	12.57	0.0059	0.0837	0.87	10.21	11.17	91.37
		135-180	0.21	7.70	0.80	1	50	18	30	24.64	0.0071	0.1524	1.12	12.68	13.95	90.84
234	El Zayniyeh;	0-10	0.28	7.30	2.10	0	7	32	60	26.01	0.0173	0.6511	3.44	20.97	25.08	83.63
	Endostagnic-vertic	10-40	0.27	7.60	1.40	0	7	26	66	26.14	0.0212	0.6445	5.01	28.21	33.88	83.26
	Cambisols; clay	40-110	0.33	7.50	0.80	0	8	26	66	28.03	0.0102	0.5634	3.48	27.26	31.32	87.05
49	Tell-Kalakh	0-20	0.49	7.80	1.60	0	18	28	54	32.95	0.0056	0.1544	0.65	6.91	7.71	89.56
	Tawile;	20-53	0.45	8.10	1.30	2	18	21	58	30.38	0.0036	0.068	0.41	5.51	6.00	91.89
	Hypocalcic	53-90	0.41	8.10	1.10	10	20	27	51	29.97	0.0026	0.0632	0.42	5.21	5.69	91.52
	Vertisols; clay	90-120	0.41	8.20	0.60	38	20	34	44	24.86	0.0032	0.0762	0.27	4.28	4.62	92.47
272	Ed Douair; Vertic	0-30	0.40	7.10	1.81	55	6	28	64	29.41	0.0237	0.4093	0.67	6.69	7.80	85.85
	Clacisols; clay	30-60	0.46	7.20	2.30	57	11	30	56	24.23	0.0102	0.2655	0.55	6.26	7.09	88.37
		60-150	0.48	7.10	2.30	72	10	34	56	15.54	0.0108	0.0913	0.14	N/A	N/A	N/A
Average											0.0122	0.2324	1.18	12.48	13.95	90.42
Maximum											0.0479	0.6511	5.01	28.21	33.88	96.44
Minimum											0.0026	0.0632	0.14	3.76	4.59	81.93

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less than the value reported by Al-Zubaidi *et al.* (2008) for some Lebanese soils. The highest values of exchangeable potassium were observed in soil profile No. 234, while the lowest values of exchangeable potassium were observed in soil profile No. 49.

If the value of 0.4 Cmol kg^{-1} for exchangeable K, which was recommended by Al-Zubaidi and Pagel in 1979, were to be considered as the critical level, then all the soil samples in the seven profiles - except profile No. 234 and topsoil layers in profiles No. 165, 190, and 272 - would be classified as poor in exchangeable potassium and expected to respond positively to potassium fertilization.

Datta and Sastry (1988) proposed the higher value of 0.626 Cmol kg^{-1} for exchangeable potassium as the threshold level for release of non-exchangeable potassium. If we compare this value with the values of exchangeable potassium obtained in this study, then all the profiles except soil profile No. 234 and surface soil sample of profile No. 190 would be lower than the critical value. This indicates that the non-exchangeable (fixed-K) contributes to potassium supply to plant growth in the studied soils.

The high values of exchangeable potassium in soil profile No. 234 may be due to high content of clay fraction with the presence of vermiculite and mica- vermiculite minerals (Table 2). The x-ray diffraction curves of this profile showed a broad peak of 10.40 Å, indicating that micas are undergoing a weathering process in this soil. The relatively low value of percentage of mineral-K to total-K in this profile (Table 1, last column) confirms this conclusion.

Table 2. Mineralogy and texture of the studied soil profiles as identified by x-ray diffraction.

Profile No.	Dominant minerals
165	Group of 14 Å, kaolinite, quartz
206	Regular interstratified chlorite-smectite, kaolinite, quartz
259	Group of 14 Å, mica, kaolinite, quartz
190	Kaolinite and quartz
179	Chloritized montmorillonite, kaolinite, quartz
234	Group of 14 Å (smectite, vermiculite, chlorite), irregular interstratified mica-vermiculite, kaolinite
49	Group of 14 Å, kaolinite
272	Chlorite, regularly interstratified chlorite-mica, mica, kaolinite, quartz

3) Non-exchangeable potassium

Acid (HNO_3) extractable potassium, which is used as an index of non-exchangeable potassium and represents the supplying power of potassium for long-term cropping (Jackson 1958) are shown in Table 1. The values of this form showed a wide variation, ranging from 0.14-5.00 Cmol kg^{-1}. If we consider the critical value for non-exchangeable potassium to be 1.00 Cmol kg^{-1} (400 mg kg^{-1}), as suggested by Pagel (1972), then the values of non-exchangeable potassium in nine soil samples are above this level (high in supplying power), and the remainder of the soil samples can be described as poor in supplying potassium. Soil samples from profile No. 234 contain a very high content of non-exchangeable potassium; which could be due to extensive weathering occurring in this profile.

4) Mineral potassium

The values of mineral potassium showed a wide variation in the studied soil samples, ranging from 3.76 to 28.21 Cmol kg^{-1} (Table 1). The content of this K-form depends on soil type, type of primary and secondary minerals and the degree of weathering (Sharpley, 1987). The lowest values of mineral-K were observed in profile No. 259, 49, and 272 and the highest values were observed in profile No. 234. The values of percentage of mineral-K of total-K ranged from 81.93% to 96.44% (Table 1). The lower values of percentage of mineral-K of total-K indicate a relatively high degree of weathering of K-bearing minerals and vice versa.

5) Total potassium

The values for total potassium in the studied soil samples showed a very wide variation. They ranged from 4.59-33.89 Cmol kg^{-1} (Table 1). The content of total potassium depends on the type of parent material, type of primary and secondary minerals and type of soil fractions. The values for total potassium in Lebanese soils are lower than those reported for Iraqi soils (Al-Zubaidi and Al-Rabai, 2002).

More than 81.9% of the total potassium in the studied soils is in the mineral phase. The high portion of total potassium in primary minerals suggests that the parent material is the origin of most K in the profiles (Martin and Sparks, 1983).

Distribution of different K-forms throughout soil depth

Table 3 shows the distribution of K-forms: exchangeable, non-exchangeable and mineral (expressed as percentage of total potassium) throughout the soil profiles. The patterns of exchangeable and non-exchangeable forms are fairly similar. In general there is a decreasing trend for potassium forms as soil depth increases, except profile No. 259, due probably to the irregular origin of fluvial sediments forming the soil layers.

The distribution of mineral-K

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Table 3. Distribution of mineral, non-exchangeable and exchangeable K-forms in seven of the soil profiles.

Profile No.	Location	Soil type	Depth	Mineral K	HNO_3-K	$CaCl_2$-K
			cm		*% of total K*	
165	Sir Ed Danieh – Jbab el Homr	Calacric Regosols	0-20	82.14	15.36	2.41
			20-60	92.55	5.67	1.71
			60-110	94.48	4.72	0.78
			110-130	93.30	6.04	0.64
206	Rachaya, Ammiq road	Gleyic Cambisols	0-25	93.69	4.63	1.62
			25-70	96.44	2.88	0.65
			70-100	95.69	3.51	0.73
259	Marjayoun, Hasbaya plain	Calcaric Fluvisols	0-20	95.98	2.50	1.36
			55-80	81.93	11.52	5.71
			80-150	94.81	3.39	1.65
190	Batroun	Gleyic Luvisols	0-10	83.71	12.61	3.37
			10-70	92.90	6.31	0.74
			70-130	93.75	5.70	0.52
179	Sir Ed Danieh, Marjheen	Eutric Arenosols	0-30	89.57	8.53	1.76
			30-80	94.30	5.00	0.64
			80-135	91.37	7.82	0.75
			135-180	90.84	8.02	1.09
234	El Zayniye, Baalbeck	Vertic Cambisols	0-10	83.63	13.71	2.60
			10-40	83.26	14.78	1.90
			40-110	87.05	11.12	1.80
49	Tell Kalakh, Tawile	Hypocalcic Vertisols	0-20	89.56	8.36	2.00
			20-53	91.89	6.92	1.13
			53-90	91.52	7.32	1.11
			90-120	92.47	5.81	1.65

throughout soil profiles No. 165, 206, 179, 234, 49, and 190 can be described as follows: increase in mineral potassium with soil depth, whereas its distribution throughout soil profile No. 259 decreases with soil depth. The distribution patterns of mineral-K throughout the soil profile are associated with the type of K-bearing minerals occurring at different soil depths and with their degree of weathering.

Potassium saturation percentage (KSP) and exchangeable-K as Cmol kg^{-1} clay

Two other chemical indices used for evaluating potassium supplying power in soil are potassium saturation percentage (KSP) which equals (exchangeable-K/CEC)x100 and the value of exchangeable potassium in mmol K per 100 g of clay (or Cmol K per kg of clay).

Table 4 shows the values of KSP in the studied profiles which range from 0.21 to 2.79. It seems that most of the studied soil samples, except surface samples (0-10) of soil profile No. 234 and 190 have low values and lower than the critical value (2.3) which was proposed by Pagel and Insa (1974). This indicates that the potassium ion represents a small portion of the CEC in the studied soils.

The average value of exchangeable-K in mmol per 100 g clay is 0.52 (Table 4) is very low and much lower than the values obtained in Iraqi soils (3.6) as reported by Al-Zubaidi (2003). This means that potassium fixation capacity is high in Lebanese soils and most potassium is present in the fixed phase. This data confirms the finding of Al-Zubaidi *et al.* (2008) that Lebanese soils have a high potential for potassium fixation (27.0-47.5%). These results should be taken into consideration when fertilization recommendations are made for various crops, especially K loving crops such as potato, banana and citrus trees.

Conclusion

From the obtained results, it can be concluded that most Lebanese soils are poor in potassium supplying power and may respond to potassium fertilizer application. Our previous field observations on application of potassium fertilizer to wheat and barley in some Lebanese soils (Al-Zubaidi *et al.*, 2009) confirm this conclusion. For further research on potassium status in Lebanese soils, it is suggested to measure the rate of release of potassium in these soils.

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Table 4. Potassium saturation percentage (KSP) and exchangeable K values of the soil samples.

Profile No.	Depth	KSP	Exch. K
	cm	*%*	*mmol/100 g clay*
165	0-20	1.84	1.35
	20-60	1.04	0.58
	60-110	0.46	0.28
	110-130	0.39	0.24
206	0-25	0.74	0.66
	25-70	0.26	0.22
	70-100	0.31	0.38
259	0-20	0.41	0.31
	20-55	1.15	0.72
	55-80	0.50	0.28
190	0-10	2.79	1.00
	10-70	0.73	0.18
	70-130	0.47	0.36
179	0-30	1.37	1.00
	30-80	0.83	0.50
	80-135	0.67	0.44
	135-180	0.62	0.50
234	0-10	2.5	1.08
	10-40	2.47	0.97
	40-110	2.01	0.80
49	0-20	0.47	0.28
	20-53	0.22	0.12
	53-90	0.21	0.25
	90-120	0.31	0.18
272	0-30	1.39	0.64
	30-60	1.10	0.48
	60-150	0.59	0.16
Average		0.96	0.52
Range		0.21-2.79	0.12-1.35

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The paper "Content of Different Forms of Potassium in Lebanese Soils" appears also at:

Regional Activities/West Asia and North Africa (WANA)

Maize Intensification in Mozambique: Demonstrating to Farmers the Benefits of Better Land and Crop Management

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Farmers from the association "7 de Abril - Zembe" in front of their demonstration field. Photo by O. Goujard.

Introduction

Mozambique is a developing country which, until the beginning of the 90s, suffered greatly from a protracted civil war. Eighty to ninety percent of its population is involved in agriculture; most of the farmers are subsistence smallholders cultivating less than three hectares. The most important cultivated crops are maize, cassava and legumes, the main staple foods. Productivity remains very low with an average maize yield of less of than 1.0 metric ton per hectare (mt ha^{-1}) cultivated. Agro-input markets are particularly undeveloped and the majority of smallholder farmers are not well connected to the output market and value chain. Fertilizer use in sub-Saharan Africa (SSA) is very low; on average, 8.0 kilograms per hectare (kg ha^{-1}), or less than 10 percent of the world average. For Mozambique specifically, fertilizer use is, on average, around 6 kg ha^{-1}.

The Maize Intensification in Mozambique project (MIM) began in September 2008 and is being implemented by the International Fertilizer Development Centre (IFDC). The MIM project is funded and receives technical support from the International Fertilizer Industries Association (IFA), the International Plant Nutrition Institute (IPNI), and the International Potash Institute (IPI). The project was initiated in response to the Abuja Declaration on Fertilizer for an African Green Revolution that commits governments in SSA to increase fertilizer use to an average of 50 kg ha^{-1}.

At the Africa Fertilizer Summit (Abuja, Nigeria, 13 June 2006, see link), delegates agreed that fertilizer is crucial for achieving an African Green Revolution in the face of a rapidly rising population and declining soil fertility. In response to the Abuja Declaration, the New Partnership for Africa's Development (NEPAD) has declared that the vision of economic development in Africa must be based on raising and sustaining higher rates of economic growth (seven percent per year). To realize this vision, African Heads of States and Governments adopted the Comprehensive Africa Agricultural Development Program (CAADP), which calls for six percent annual growth in agricultural production, as a framework for the restoration of agricultural growth, food security and rural development in Africa.

Project goal

The project aims to demonstrate how farmers can intensify rain-fed maize production.

Project objectives

1) To increase maize yields and nutritional value of the crop through increased and balanced use of fertilizer and improved seed varieties.

2) To increase the income and improve livelihoods of smallholder farmers in rural areas through improved purchasing power and enhanced access to input and output markets.

The project is implementing a complete value chain approach to achieve the goals of increasing maize productivity and profitability covering the following activities:

- **Increasing farmer adoption of improved maize seed varieties.** In Mozambique, traditional (i.e. farmer-saved seed) open pollinated varieties of maize, which have low productivity potential and low response to fertilizer application, are

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used extensively. The project aims to demonstrate how farmers can improve their maize yield through the use of improved seed such as Sussuma, Matuba, and hybrids such as PAN67.

- **Increasing the adoption of use of fertilizer.** Increasing fertilizer use from the current 6 kg ha^{-1} is required to increase maize yields in a sustainable manner. The project aims to demonstrate how farmers can improve their yield through increasing the use of appropriate fertilizers, conservation agriculture, use of sound agronomic practices and other inputs (e.g. seeds). The project is also facilitating the market linkage between farmers and input suppliers to ensure they have easy and timely access to fertilizer and improved seed varieties.
- **Facilitating the market linkage between farmers and agricultural commodities buyers.** By achieving this, farmers will have access to viable maize markets, allowing them to sell their produce at profitable prices and improve their capacity to purchase inputs.

Map of Mozambique with a focus on the Beira corridor, central Mozambique (marked by the circle). Source: http://www.nationsonline.org/oneworld/map/mozambique_map.htm.

Expected outputs and impact

1) About 250 smallholder farmers (five clusters of 50 smallholder farmers) to benefit directly from increased yields and incomes in the project's areas. In addition, wider dissemination of market-oriented agricultural intensification technologies to at least 5,000 smallholder farmers will be facilitated through field days and extension material.

2) Maize yield to increase by 50 percent above the baseline yield in each project area.

3) Fifty agro-dealers to be trained in input and output marketing with each agro-dealer being able to increase the supply of inputs and technology transfer to 500 farmers, enabling increased production for 25,000 farmers.

4) Producer groups to be established and linked with input and output markets.

5) Incomes of the 250 farmers participating directly in the project area to increase by 20 percent above baseline incomes in the project area.

6) Establishment and dissemination of improved fertilizer recommendations utilizing soil testing and Nutrient Management Support System (NuMaSS) for maize production in each of the project implementation zones.

7) A soil fertility management plan (Integrated Soil Fertility Management; Site Specific Nutrient Management; ISFM/SSNM) and Integrated Pest Management (IPM) plan for maize-based cropping systems (monoculture, mixed cropping, intercropping, and crop rotation with maize) to be prepared for project areas at the beginning of each cropping season.

Project sites

The MIM project is being implemented in productive clusters in Sofala, Manica and Tete provinces within the Beira Corridor (see map).

In 2008, five sites involving different farmers' associations were chosen for demonstration trials, which were then

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Table 1. Sites, co-operators and farmers at the MIM project.

Province	District	Farmer association	Project participants		
			Men	Women	Total
Sofala	Gorongosa	Nhauranga Farming	17	9	26
		Tendeni Pabodzi	10	8	18
	Nhamatanda	Fambizanai	8	8	16
		Luta Contra Pobreza	5	7	12
Manica	Gondola	7 de Abril - Zembe	29	1	30
		16 de Junho – Bengo	7	9	16
	Sussundenga	Matchipissa	1	0	1
		Muvé	10	4	14
	Manica	Chinhamancungo	11	4	15
		Cufuma Ichungo	4	2	6
	Báruè	Vila Miti	1	0	1
Tete	Angónia	Teguira ne Manja	10	13	23
	Macanga	Tithandizane	14	11	25
		Muenze	16	4	20
	Moatize	Chiande	22	8	30
Total 3	9	15	165	88	253

Table 2. MIM demonstration protocol and factors in 2008, 2009 and 2010.

		Year		
		2008	2009	2010
Demo trial number		5	10	15
Plot size (ha)		1	1	1
Seeds	Farmer-saved seeds	+	+	+
	OPV seeds	+	-	-
	Hybrid seeds	+	+	+
Fertilizers (kg ha^{-1})	NPK: 12-24-12 +6S (basal)	300	50-100	50-100
	NPK: 12-24-12 +0S (basal)	300	-	-
	Urea (topdressing)	150	50-100	50-100
Tillage	Conventional (Conv.)	+	+	+
	Conservation (Cons. + herbicide)	-	+	+

Table 3. MIM trial treatments in 2009-2010.

Treatment No.	Seeds		Fertilizer type		Fertilizer dose	
	Farmer-saved seed	Hybrid (PAN67)	Basal N-P-K-S 12-24-12-6(S)	Top dressing urea	Basal N-P-K-S	Top dressing urea
					----------*kg ha*$^{-1}$----------	
T_1	+		-	-	0	0
T_2	+		+	+	6-12-6-3	23
T_3	+		+	+	12-24-12-6	46
T_4		+	-	-	0	0
T_5		+	+	+	6-12-6-3	23
T_6		+	+	+	12-24-12-6	46

increased to 10 sites in 2009 and 15 sites in 2010 (Table 1 and 2). The MIM project is working directly with 253 smallholder farmers of which 35 percent are women.

Demonstration protocol

Demonstrations to show the potential for maize intensification were started in 2008, targeting the use of seed varieties and fertilizer rates that easily match local growing conditions, farmers' production objectives and their capacity to invest in seed and fertilizer. Table 2 summarises the changes in studied factors during the three years of the project as the project narrowed down on best management practices. The Open Pollinated Variety (OPV) that was initially part of the demonstrations was discontinued after the first year, as results confirmed their poor performance. It was also decided to keep only the basal fertilizer that gave the greatest yield increases (NPK+S) but with reduced fertilizer application rate from 300 to 100 kg ha^{-1} (2 bags) and 50 kg ha^{-1} (1 bag) to use rates that are more affordable to farmers. Likewise the urea dose was reduced from 150 to 100 kg ha^{-1}. Cons. tillage (with application of the herbicide glyphosate before planting) was included to compare with Conv. tillage (manual or animal traction), each site being divided into two parts.

Table 3 presents the current demonstration design agreed by the project partners, this protocol being duplicated at each site with one part in conservation tillage and one part in conventional tillage.

Each demonstration field was the same size of 1.3 ha (130 m x 102 m). The field was divided into two equal parts; with one part cultivated using conventional tillage and the other with conservation tillage. Each of the two plots was further divided into six plots of 0.1 ha (50 m x 20 m) corresponding to six treatments. All plots were separated by a 2 m buffer zone. Demonstrations were implemented at the beginning of the rainy season (November) with land preparation and sowing being done in December; maize maturity and harvest occurs from April to June, depending on local weather conditions during the growing season.

Planting

The maize hybrid seed selected for testing was PAN67, the most commonly grown hybrid maize variety in Mozambique. Despite the availability of

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T_1 plot: Farmer-saved seeds without fertilizer. Photo by O. Goujard.

T_6 plot: Hybrid variety + 100 kg ha^{-1} fertilizer. Photo by O. Goujard.

more productive improved maize varieties, it is estimated that at least 95 percent of maize planted in Mozambique is farmer-saved seed. It is reported that less than one percent of maize planted is with hybrid seed and approximately four percent is with certified/commercial seed of open-pollinated varieties (OPVs).

Planting is done manually using a hand hoe (*Enxada*). Due to low germination rate, three maize seeds were placed in each planting hole of farmer-saved seeds and only two for the hybrid variety. Seedlings were then thinned to one plant per hill two weeks after plant emergence; this thinning was not done in the farmer-saved seed control plot since this is local farmers' practice. The planting density was 50,000 plants ha^{-1} for PAN67 and between 55,000 to 90,000 plants ha^{-1} for farmer-saved seeds.

Fertilization

The NPK basal fertilizer being used was 12-24-12 +6S which is manufactured (bulk-blended) and distributed locally. Basal fertilizer was applied at planting and placed 5 cm deep and 5 cm from the seed hole and covered with soil. The top dressing (urea 46%) was applied when maize vegetative growth stage was at knee height.

Analysis of soil samples from each demonstration site was carried out in 2010 to check whether fertilization was adequate in relation to soil nutrient contents. Results are shown in Table 4.

Weed and pest control

Weed competition is a key issue for maize cultivation in Mozambique reducing yields by 25 to 85 percent. Manual weeding is performed approximately three times during the period of major competition (i.e. during the first 10 to 40 days after emergence of the seedlings and when the weeds compete with maize for water, nutrients, and space). Weed control was performed on all plots, including the control plots, even though farmers typically do only limited weeding.

Insect pest pressure is also very high in Mozambique and can lead to severe crop and grain damage, not only during the cropping phase but also during grain storage. Maize stalk borer and termites are the main pests which damage maize

Table 4. MIM soil sample analysis from October 2010 performed by Omnia (RSA).

Province	District	Association	Clay	Silt	Sand	pH (KCl)	CEC	P	K	Ca	Mg
			----------%----------				$cmol_c$ kg^{-1}	---------mg kg^{-1}---------			
Sofala	Gorongosa	Nhauranga	10	8	82	4.6	2.2	3	133	256	62
		Tendene Pabhozi	6	9	85	4.4	4.7	69	150	593	138
	Nhamatanda	Fambidzai	12	23	65	4.8	10.2	11	211	1,280	387
		Luta c/ Pobreza	20	34	46	4.9	16.2	10	159	2,250	519
Manica	Gondola	16 de Junho	12	11	77	4.3	2.9	4	85	340	87
	Zembe	7 Abril	12	19	69	4.4	2.7	5	164	294	59
	Manica	Chinhamacungo	10	10	80	4.2	1.7	20	84	143	24
		Ifuma Ichungo	14	12	74	4.6	4.4	2	112	489	196
	Sussundenga	Muve	12	9	79	5.2	6.6	3	163	975	141
		Matchipisse	N/S	N/S	N/S	4.5	2.7	5	114	319	74
	Catandica	Viramite	10	1	89	5.7	7.1	56	111	1,140	125
Tete	Macanga	Titandizane	16	11	73	4.3	3.0	22	114	320	92
		Muenze	8	12	80	4.5	1.6	30	79	167	35
	Angonia	Umodzi	8	16	76	4.8	11.0	4	158	1,300	481
		Tiguirane Ne Manja	16	11	73	4.6	4.9	1	188	595	165
	Zobue	Antechito Achiambe	4	13	83	5.2	3.6	35	92	538	77

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Table 5. MIM trial sites rainfall verified in 2010 (mm).

Province	District (trial site)	Rainfall (mm/month)						Total
		January	February	March	April	May	June	
Manica	Barue	204	496	138	162	0	0	1,001
	Gondola	32	294	78	13	5.5	6	429
	Manica	79	334	139	96	7	0	655
	Sussundenga	17	172	168	145	10	0	513
Sofala	Gorongosa	155	125	145	204	148	12	789
	Nhamatanda	52	30	66	27	19	6	200
Tete	Angónia	112	249	98	24	0	0	483
	Macanga	32	386	159	98	7	6	689
	Moatize	----------------------No data------------------------						
	Tsangano	----------------------No data------------------------						

Table 6. Effect of soil tillage on maize yields in 2010 (average of 8 sites).

Treatment	Average Cons.	Average Conv.	Cons. over Conv.
			%
T_1	1.11	1.18	-5.43
T_2	1.55	1.71	-9.08
T_3	2.1	2.28	-8.16
T_4	1.67	2.05	-18.54
T_5	2.69	2.98	-9.79
T_6	3.11	3.34	-7.14
Average	2.04	2.26	-9.68

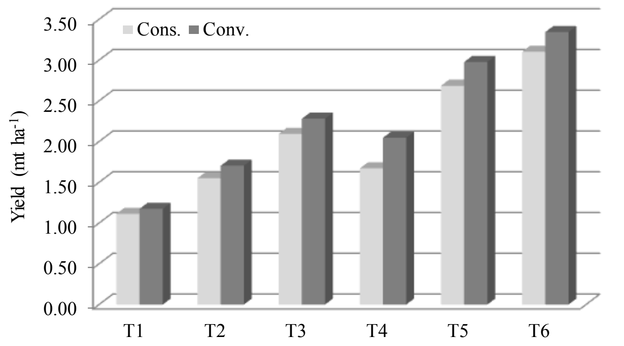

Fig 1. MIM overall average of maize yield in 2010.

plants; adequate chemical control was conducted when required on each trial site.

Trial results

This paper summarizes only one year of results of the 2009-2010 season, since the 2008-2009 protocol was different and the 2010-2011 season results have not yet been officially published by IFDC.

Due to severe drought, especially during the maize flowering growth stage, two sites out of ten could not be harvested: Nhamatanda (Sofala Province) and Gondola (Manica Province). In general, yield levels were lower than in the previous year because rainfall distribution was very erratic in early 2010 as illustrated in Table 5.

The yield data of the eight harvested sites is shown in Fig. 1. In a year with erratic weather conditions, yield data ranged from 1.1 mt ha^{-1} to 3.3 mt ha^{-1}. The control plot illustrating farmer practice in both tillage systems yielded approximately 1.1 mt ha^{-1}, similar to the yield obtained for rainfed maize in Mozambique (less than 1 mt ha^{-1}).

Influence of soil tillage

In almost all the eight harvested sites, the yields obtained with conservation tillage were lower than those with conventional tillage (Table 6). This effect of conservation tillage in the first year is possibly associated with immobilization of soil nitrogen due to addition of maize residues and sub-optimal weed control. Past research has shown that it can take at least three years for the benefits of conservation to be seen.

Influence of using improved seeds

On average, PAN67 reached only 40 percent of its yield potential (8.0 to 9.0 mt ha^{-1}). This yield gap can be explained by poor rainfall distribution, as well as poor soil fertility conditions in farmers' fields. However, conventional tillage showed higher yields in almost all treatments when compared with farmer-saved seeds grown under similar conditions (Table 7). On average amongst the demo trials, PAN67 had a 65 percent higher yield compared with farmer-saved seeds.

Influence of applying fertilizer

The influence of fertilizer application on yield can be observed by comparing the results of the average yield per treatment (Table 8). The application of basal fertilizer 12-24-12 +6S (+ urea as top dressing) boosted yield in all treatments at the two tested doses: 50 kg and 100 kg ha^{-1}. Throughout the trial locations yield increases were obtained which were very variable: in some places there were only limited yield increases (+10 percent) whereas in other sites (e.g. Sofala district), up to +200 percent yield increases were found. The application of one fertilizer bag per hectare (50 kg ha^{-1}) led to a 44 percent yield increase (+540 kg maize ha^{-1}) over local farmer practice (farmer-saved seeds with conventional tillage and no fertilizer applied). Yields were

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almost doubled (+94.2 percent) with application of two fertilizer bags (100 kg ha^{-1}). A similar trend was observed for the conservation tillage + farmer-saved seeds and hybrid variety + Cons. or Conv. From the data obtained soil tillage and seed quality does not seem to have any positive or negative cross effect with fertilization.

Table 7. Influence of seed source and nutrients in the two tillage systems on maize yields in 2010.

Fertilizer treatment	Tillage	Average yield: Farmer-saved seeds	Average yield: Hybrid variety (PAN67)	Change in yield
		--------------*mt ha^{-1}*--------------		*%*
Unfertilized	Cons.	1.22	1.55	+36
	Conv.	1.21	1.92	+61
50 kg NPK + 50 kg urea	Cons.	1.67	2.75	+68
	Conv.	1.75	3.04	+73
100 kg NPK + 100 kg urea	Cons.	2.15	3.18	+51
	Conv.	2.35	3.44	+47
Average		1.73	2.65	+65

Table 8. Influence of fertilizer application on maize in the two tillage systems on yields in 2010.

	Tillage	Control (no fertilizers)	50 kg NPK + 50 kg urea		100 kg NPK + 100 kg urea		
	1	2	3	4	5	6	7
		mt ha^{-1}	*mt ha^{-1}*	*Col. 3 minus Col. 2*	*mt ha^{-1}*	*Col. 5 minus Col. 2*	*Col. 5 minus Col. 3*
				%		----------*%*----------	
Farmer-saved seeds	Cons.	1.22	1.67	+36.9	2.15	+76.2	+28.7
	Conv.	1.21	1.75	+44.6	2.35	+94.2	+34.3
Hybrid variety	Cons.	1.55	2.75	+77.4	3.18	+105.2	+15.6
	Conv.	1.92	3.04	+58.3	3.44	+79.2	+13.2
Average		1.48	2.30	+56.1	2.78	+88.5	+20.7

Economic analysis

Gross revenue

Farmers who grow maize in Mozambique usually obtain a yield of approximately 1.0 mt ha^{-1}. The value of this production varies from place to place and also varies according to the time of year. Grain buyers typically pay the least for maize during the harvest season when quantities are most plentiful. Prices increase with time after harvest. A value of six Meticais/kg (6 MTs kg^{-1}) was reported during the time following harvest in 2010. With an exchange rate of 37.2 MTs/USD (August 2010; 25 MTs per USD during the last season), the equivalent price that could be obtained by the farmers was USD 161.29 mt^{-1} of maize grain. Gross revenue obtained in the different treatments is described in Table 9.

Input costs

Costs of agro-inputs vary greatly from year to year. One example regards fertilizer: from the 2008-2009 season to the 2009-2010 season, there was a decrease of 60 percent for the basal fertilizer (12-24-12 +6S) and 30 percent decrease for the top dressing fertilizer (urea 46 percent). The fluctuation of US

Table 9. Economic analysis of the various treatments.

Treatment		Tillage	Average yield	Gross revenue[1]	Input cost: Maize seed	Input cost: NPK 12-24-12 +6S	Input cost: Urea 46%	Input cost: Herbicide glyphosate	Gross input	Gross margin	Gross margin
			kg grain ha^{-1}	--			*MTs ha^{-1}*			---	*US\$ ha^{-1}*
T_1	Farmers seed with no fertilizer	Cons.	1,114	6,683	363	0	0	2,210	2,573	4,110	110
		Conv.	1,175	7,050	363	0	0	0	363	6,687	180
T_2	Farmers seed with 50 kg NPKS + 50 kg urea	Cons.	1,551	9,308	363	840	1,530	2,210	4,943	4,365	117
		Conv.	1,704	10,223	363	840	1,530	0	2,733	7,490	201
T_3	Farmers seed with 100 kg NPKS + 100 kg urea	Cons.	2,094	12,563	363	1,680	3,060	2,210	7,313	5,250	141
		Conv.	2,281	13,688	363	1,680	3,060	0	5,103	8,585	230
T_4	Hybrid seed with no fertilizer	Cons.	1,671	10,028	1,625	0	0	2,210	3,835	6,193	166
		Conv.	2,047	12,285	1,625	0	0	0	1,625	10,660	287
T_5	Hybrid seed with 50 kg NPKS + 50 kg urea	Cons.	2,685	16,110	1,625	840	1,530	2,210	6,205	9,905	266
		Conv.	2,976	17,858	1,625	840	1,530	0	3,995	13,863	373
T_6	Hybrid seed with 100 kg NPKS + 100 kg urea	Cons.	3,102	18,615	1,625	1,680	3,060	2,210	8,575	10,040	270
		Conv.	3,344	20,063	1,625	1,680	3,060	0	6,365	13,698	368

[1] 1 kg of maize = 6 MTs

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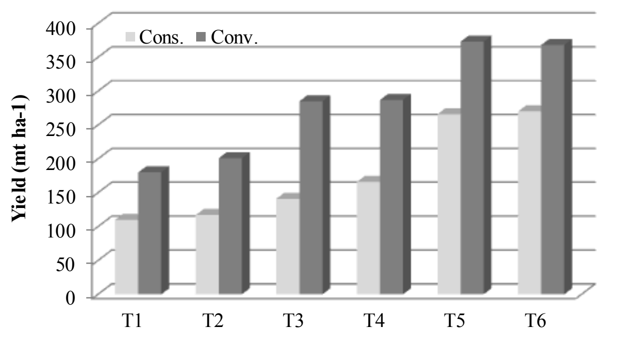

Fig 2. Gross margins approach from MIM treatments in 2010 (US$/ha).

Dollar/Meticais exchange rate can also create important variations from one year to the next. Table 9 describes all input costs per treatment within the MIM protocol.

Gross margin

Gross margin calculation is obtained by deducting cultivation cost from gross revenue; here only input costs are considered as a variable factor within overall costs.

The cost of labour for managing the multi-treatment demonstration plots are not representative of the costs that would normally be incurred by smallholder farmers who would typically cultivate one hectare of maize and utilize family labor to the greatest extent possible. Hand labor by family members has low cost implications, as opportunity costs are low. However, fertilizer application, herbicide application, weeding and other cultivation features have different labour requirements with regard to the treatments done according to the protocol. Furthermore, tillage can be done mechanically, by means of animal traction or manually by hand.

Gross margin calculation within MIM project site conditions is described in Table 9. The reference treatment (T_1 with Conv.) which represents current farmer practice in Mozambique gives a benefit of 6,687 MTs ha^{-1} which is worth around USD 180 ha^{-1}, depending on the rate of conversion. Data is also presented as a chart (Fig. 2) so that gross margin increase according to input used can be readily seen. The highest gross margin is obtained in conventional tillage (Conv.) with the two treatments, hybrid seeds + fertilizer: USD 373 per ha cultivated for the 50 kg fertilizer dose (T_5) and USD 368 for 100 kg fertilizer dose (T_6). Here, the yield effect of adding fertilizer versus unfertilized T_4 is outstanding but there is no dose effect expressed.

With reference to conservative tillage (Cons.), the dose effect between 50 kg (T_2) and 100 kg fertilizer (T_3) is much more significant.

Field days and resulting communications

During the cropping season (February to April), farmer field days were organized at some of the demonstration trial sites. The objective of these days is to invite farmers (members of a farmers' associations) to let them experience first-hand the benefits of implementing better farming practices using improved agro-inputs, such as fertilizers or improved seeds.

The other key objective of these days is to establish linkages between farmers and input/output markets.

In 2011, three sites (out of 15) were chosen for such field days; on average 180 to 200 smallholder farmers participated in each visit. Furthermore, in each of the demonstration sites, results are communicated to all the farmers belonging to the farmers' associations which are partners of the MIM project. As a result, at least 3,200 smallholder farmers were involved directly or indirectly with MIM demonstration trials and could benefit from it by learning or getting in touch with the market.

Recommendations for future activities

For forthcoming seasons, the MIM project intends to increase the number of demonstration plots from 15 to 30 in order to increase the rate of dissemination of agricultural intensification technologies. In each district it is proposed to establish three demonstration plots in such a way that each demonstration field can be considered for analytical purposes as one replication. It is also proposed that for each agro-climatic zone (The Institute of Agricultural Research of Mozambique; IIAM Classification), fertilizer rates should be based on official rates recommended by IIAM, taking into account the results of laboratory soil analysis as follows:

- T_1: Farmer-saved seed without fertilizer application.
- T_2: Farmer-saved seed with 50% of recommended fertilizer rate.
- T_3: Farmer-saved seed with 100% of recommended fertilizer rate.
- T_4: Hybrid (PAN 67) without fertilizer application.
- T_5: Hybrid (PAN 67) with 50% of recommended fertilizer rate.
- T_6: Hybrid (PAN 67) with 100% of recommended fertilizer rate.

Treatments 1 to 6 will be applied under both conventional and conservation tillage.

In addition, three full trials with replication will be established in cooperation with IIAM in order to identify the response to single nutrients (N, P and K).

Other activities to be undertaken by the MIM project will be:

- Training of agro-dealers on agriculture technology packages and agribusiness.

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- Training of extension agents and association members on agriculture technology packages.
- Acquisition of inputs for next cropping season.
- Selection of new associations and new demonstration fields sites (dependent on approval of proposal of increased number of demonstration sites from 15 to 30).
- Strengthening the linkage with IIAM to exchange experiences.
- Facilitation of market linkages between farmers and input suppliers and agriculture commodities buyers (value and supply chain).

Farmers association meeting. Photo by O. Goujard.

Conclusion and recommendations

The purpose of the MIM project has been to improve Mozambican smallholder farmers' livelihoods by intensifying maize production through the use of quality seeds and fertilizers, as well as by improved land management.

The preliminary results obtained from the 2009-2010 season from eight demonstration trials clearly show a significant yield increase (up to 200 percent) due to the use of NPKS fertilizer and use of a hybrid maize seed variety. Despite the fact that these improved agro-inputs are costly for local smallholder farmers, economic analysis showed a high benefit from their use.

Technology transfer is often a key issue in sub-Saharan Africa and it is a key component of the MIM project. Education for smallholder farmers starts with demonstrations, but farmer visits by extension agents, and knowledge dissemination is required as follow up. The network created within the farmer clusters aims to optimize exchange of expertise and techniques.

The other focus of the MIM project is the transition from subsistence farming to commercial maize production and marketing. The project aims to link farmers to the value and supply chain by initiating contacts during field days with agro-input suppliers and maize purchasers. The other organizations involved (extension services, farmers associations, development organizations such as IFDC, AGRA) are working together to create a dynamic environment which strengthens the whole maize value and supply chain in the target areas and other areas in Mozambique. ■

The paper "Maize Intensification in Mozambique: Demonstrating to Farmers the Benefits of Better Land and Crop Management" appears also at:

[Regional Activities/sub-Saharan Africa]

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Soluble Fertilizers in China: A Report from the 2nd International Forum on Soluble Fertilizers

Youguo, T.[(1)(2)], *W. Jiang*[(3)], *and Z. Fan* [(3)].

At the conference. Photo by Zhou Wenjun, CAPN.

More than 200 delegates gathered at the 2nd International Forum on Soluble Fertilizer held in Urumqi, the capital of Xinjiang autonomous region, China, on 13-15 of June 2011. The event was co-organized by the China Agri-Production News (CAPN), the China Co-operation Times, the Institute of Fertilizer Application and Engineering and the Chinese Academy of Agricultural Sciences (CAAS). Around 20 experts from CAAS, the National Agrotech Extension and Service Center (NATESC), the National Center for Quality Supervision and Testing of Chemical Fertilizer (Beijing and Shanghai), China Agricultural University and South China Agricultural University joined a large number of participants from the fertilizer industry.

"The soluble fertilizer industry is facing new opportunities for development. Technology innovation, combined with enabling state agricultural policies to develop marketable products, is the main challenge for the soluble fertilizer industry today. CAPN is willing to provide comprehensive services to industries, not only enterprise promoting, but technological support and marketing programs as well. And this top forum is a second try on soluble fertilizer after the success of the event last year," said Mr. Zha Yingxin, Chief Editor of the China Co-operation Times.

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(2)*National Agrotech Extension and Service Center (NATESC).*

(3)*China Agri-Production News (CAPN).*

Since drip irrigation was first introduced to China from Mexico in 1974, much attention has been paid to micro-irrigation systems (MIS). However, fertilizer application using MIS in China was not widely used until the 1990s and then only on a very small scale. Fertigation was more widely adopted in China in the early 2000s, as a result of five extensive annual training courses held during 2000-2004, sponsored and conducted by NATESC in partnership with the International Potash Institute (IPI), and the first International Symposium on Fertigation in China in 2005.

In recent years, billions of yuans have been invested by the government in the research and production of fertigation devices, fertigation demonstration and extension projects, and fertilizer development for fertigation. China now has more than 30 manufacturers who produce a wide variety of fertigation equipment including drips and douches, pipes and fittings, filters and valves - for all types of irrigation users. Xinjiang Tianye Water Saving Irrigation System Company Ltd. is one such company, which has 200 production lines producing 1.5 billion meters of drip irrigation tapes annually.

The area under MIS has also expanded in recent years in China. For example, Xinjiang now has 24 million mu (equal to 1.6 million hectare) of drip irrigation, mainly under plastic mulching, and predominantly for cotton, potato and wheat crops. Most importantly, all drip irrigation is combined with fertilization (fertigation).

The first soluble fertilizer was produced in China during the mid 1980s, which coincided with the development of compound fertilizers in China. At the time, soluble fertilizer was known as foliar fertilizer as it was mainly applied by spraying on plants' leaves. Since the 1990s, farmers have applied fertilizers by dissolving them in the flow of irrigation water provided to flood greenhouses, especially in Shandong province, the main region for vegetable production in China.

After 2006, the Ministry of Agriculture (MOA) released four soluble fertilizer standards, namely water-soluble fertilizers containing nitrogen, phosphorus and potassium (NY1107-2010); water-soluble fertilizers containing humic acids (NY1106-2010); water-soluble fertilizers containing micronutrients (NY1428-2010); and water-soluble fertilizers containing amino-acids (NY1429-2010), as well as other related technical standards for soluble fertilizer package (e.g. determination of nutrient content). The main standards have been amended almost every year since first introduced in 2006. Up to May 2011, there are 180 water-soluble fertilizers containing

Research Findings

macronutrients that have passed the MOA registration procedure.

In recent years, the soluble fertilizer industry has boomed because of its advantages in reducing fertilizer, water, labor and cost, and increasing yield and quality, accompanied by favorable policies for modern agriculture development and substantial investment in fertigation technology expansion. For example, in Xinjiang, 300,000-400,000 tons of soluble fertilizers are used annually. Application of soluble fertilizer has changed from foliar fertilization or flood irrigation in greenhouses to partial wetting and fertigation. Producers have also shifted from modest small-scale companies to large-scale enterprises. What's more, manufacturing techniques have evolved from simple blending to higher value soluble compounds. It is clear that soluble fertilizer was the fastest developing sector in the chemical fertilizer industry during the last decade in China.

Despite this increasing trend, it is still early days for soluble fertilizer producers, especially for fertigation purposes. There is much potential to develop this sector further. Some key recommendations can be drawn from the Forum discussion. Firstly, fertilizer companies, and related research institutes, should study and develop new types of soluble fertilizers suitable for the fertigation system. Secondly, the industry should create new assembly lines and produce high quality products which cater to the demand for fertigation development. Thirdly, it requires collaboration between fertilizer producers, irrigation companies and the agro-tech extension system. The fertilizer industry should know more about the fertigation system and its management, especially the requirement for soluble fertilizers. Companies should provide farmers with advanced packages of products and services. Support from the Chinese extension sector is vital. Fourthly, the administrative department needs to establish special technical standards for soluble fertilizers used for fertigation, as a practical tool for registration and quality evaluation. Finally, government should make favorable policies to encourage farmers to use fertigation and soluble fertilizers, and strengthen market supervision for quality control of soluble fertilizers.

"Irrigated land is approximately 50 percent of the total arable land of 130 million hectares in China. According to the overall planning made by the government, irrigated land will increase by 25 percent by 2030. Meanwhile, soluble fertilizer usage in China is less than 1 percent of total national fertilizer consumption. And yet fertigation can save 60 percent water, 5 percent land, 40 percent fertilizers, reduce labor costs by 70 percent and increase yields under normal conditions by 30 percent. Fertigation offers a great opportunity to bring policy-makers, academics, promoters and producers together," said Professor Wang Daolong, the director of soil and fertilizer institute, CAAS. "I strongly believe this forum will boost the rapid development of water-saving agriculture and fertilizer-saving technology in China, and advance the science and technology of soluble fertilizer production and application." ■

The paper "Soluble Fertilizers in China: A Report from the 2nd International Forum on Soluble Fertilizers" appears also at:

Regional Activities/China

IPI-NATESC Activities to Assist in Developing Fertigation in China

From 1999 to 2005, IPI and NATESC invested in various activities to introduce and demonstrate fertigation use in China. The main stay of this cooperation was the annual training course on fertigation, with theory and "hands on" experience of fertigation systems. Hundreds of technicians and policy-makers at the provincial level participated in these courses.

Through this activity and other projects, the following publications, some in Chinese, are available on on the IPI website:

- Fertigation: Optimizing the Utilization of Water and Nutrients. Fertigation Proceedings: Selected Papers of the IPI-NATESC-CAU-CAAS International Symposium on Fertigation, Beijing/China, 20-24 September 2005, 182 p. ISBN 978-3-9523243-8-7. Edited by P. Imas and M.R. Price. Available on http://www.ipipotash.org/publications/detail.php?i=269.
- Presentations from the IPI-NATESC-CAU-CAAS International Symposium on Fertigation appear on the IPI website at http://www.ipipotash.org/speech/index.php?ev=54.
- Fertigation. Chenglin Zhang, College of Resources and Environment, South China Agricultural University, Guangzhou, 510640, PR China. Published by the China Chemistry and Industry Press. 2006. This publication was supported by IPI. For a hardcopy, please contact Dr. Chenglin Zhang, Tel: 86-20-85281822.
- Fertigation and its Practice in China. Eds. T. Youguo (NATESC) and H. Magen (IPI). 115 text pages (in Chinese) and 8 color pages with pictures. Published by NATESC. 2003. For copies please contact Dr. Tian Youguo (tianyouguo@agri.gov.cn). See also at http://www.ipipotash.org/publications/detail.php?i=79.
- A leaflet on Technical Aspects of Fertigation. 2010. Edited by P. Imas, Tian Youguo and H. Magen. 8 pages. DOI: 10.3235/978-3-905887-04-4. Download at http://www.ipipotash.org/publications/detail.php?i=312.
- Fertigation Management in Young Apple Trees in Shandong, China. 2008. *e-ifc* No. 18. http://www.ipipotash.org/eifc/2008/18/2.

IPI Events

IPI Awards in Hungary

For the fourth time in recent years, IPI has provided awards on potassium research to the most promising young Hungarian scientists. Twelve Bachelor theses were submitted to an evaluation team during Spring 2011 from which the three outstanding ones were selected. The following theses were awarded:

1st prize: ***Máté Mihály*** , Corvinus University of Budapest
"Potassium fertilization in sweet pepper growing";
Supervisor: Dr. Katalin Slezák

2nd prize: ***Péter Varga***, Pannon University, Keszthely
"Studies on the effects of imbalanced nutrient supply on potato crop";
Supervisor: Prof. Katalin Sárdi

3rd prize: ***János Tóth***, Szent István University, Gödöllő
"Effects of raised level potassium starter fertilization on spring sown onion";
Supervisor: Dr. habil. Attila Ombódi

IPI plans to publish the abstracts in Hungarian and English, along with graphs and tables from the theses of the three winners. The booklet will also feature the best papers from previous IPI awards.

For more details contact Dr. Thomas Popp, IPI Coordinator Central Europe.

October 2011

International Symposium on "Role of Potassium in Sustaining the Yield and its Quality", Kandy, Sri Lanka, 27-29 October 2011. The symposium will be jointly organized by the International Potash Institute, University of Sri Jayewardenepura, Sri Lanka and Department of Agriculture, Sri Lanka. It is co-sponsored by the Bangladesh Fertilizer Association (BFA) and The Fertilizer Association of India (FAI). For more details see IPI website or contact Dr. Baladzhoti Tirugnanasotkhi, IPI Coordinator East India, Bangladesh and Sri Lanka. ■

July 2012

International Symposium on "Management of Potassium in Plant and Soil Systems in China", Chengdu, Sichuan, China, 24-27 July 2012. The symposium will be jointly organized by the International Potash Institute, Soil Science Institute, Nanjing, China, Chinese Academy of Sciences and the China Agriculture University. For more details see IPI website or contact Mr. Eldad Sokolowski, IPI Coordinator China. ■

Other Events

October 2011

10th African Crop Science Society Conference, Joaquim Chissano International Conference Centre Maputo, Mozambique, 10-13 October 2011. See conference website. ■

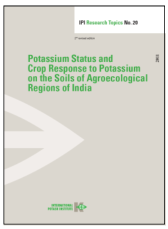
May 2012

Agritech Israel 2012. The 18th International Agricultural Exhibition, Tel Aviv, Israel, 15-17 May 2012. Agritech Israel 2012 is one of the world's most important exhibitions in the field of agricultural technologies. The exhibition program will include the conference of the International Committee for Plastics in Agriculture (CIPA). See Agritech website. ■

Publications

Proceedings of the IPI-OUAT-IPNI International Symposium on "Potassium Role and Benefits in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damages". 5-7 November 2009, Bhubaneswar, Orissa, India. The symposium was co-organized by the International Potash Institute (IPI), International Plant Nutrition Institute (IPNI) and Orissa University of Agriculture and Technology (OUAT). Volume I: Invited Papers, 638 p., ISBN 978-3-905887-05-1, DOI 10.3235/978-3-905887-05-1; Volume II: Extended Abstracts, 396 p., ISBN 978-3-905887-01-3, DOI 10.3235/978-3-905887-01-3. 2010. Edited by: M.S. Brar and S.S. Mukhopadhyay. Download the full publication from IPI website. For a hardcopy contact Dr. M.S. Brar, 130-B, Rajguru Nagar, Ludhiana-141012, India, e-mail: brarms@yahoo.co.in.

IPI Research Topic No. 20 (2nd revised edition) on "Potassium Status and Crop Response to Potassium on the Soils of Agroecological Regions of India". 2011. 185 p. A. Subba Rao, Ch. Srinivasarao, and S. Srivastava. ISBN 978-3-905887-02-0, DOI 10.3235/978-3-905887-02-0. The 2nd edition of this publication (1st edition was published in 1996) brings updated work and mapping of the various responses to potassium in the various agroecological regions of India. The authors describe in detail the various forms of soil potassium and the expected response and fertilization practices recommended at each region. With significant variation and difference between the agroecological regions of India, this book is an



Publications

important tool for scientists and extension people to optimize potassium fertilizer use. Download or order a hardcopy from IPI website.

Publications by the PDA

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

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

Potassium uptake requirements of some crops. July 2011. Fertiliser recommendations for potash (K_2O) are usually based on removal or offtake of K_2O at harvest. Some detailed results of measurements on K_2O uptake during crop growth show that greater care is needed to ensure potash supply meets crop requirement. See PDA website. ■

K in the Literature

Relation between Soil Organic Matter and Yield Levels of Nonlegume Crops in Organic and Conventional Farming Systems. Brock, C., A. Fließbach, H.R. Oberholzer, F. Schulz, K. Wiesinger, F. Reinicke, W. Koch, B. Pallutt, B. Dittman, J. Zimmer, K.J. Hülsbergen, G. Leithold. 2011. J. Plant Nutr. Soil Sci. 174(4):568–575, August 2011. http://onlinelibrary.wiley.com/doi/10.1002/jpln.201000272/abstract

Abstract

The aim of this study was to evaluate the interaction between yield levels of nonleguminous crops and soil organic matter (SOM) under the specific conditions of organic and conventional farming, respectively, and to identify implications for SOM management in arable farming considering the farming system (organic *vs.* conventional). For that purpose, correlations between yield levels of nonlegume crops and actual SOM level (C_{org}, N_t, C_{hwe}, N_{hwe}) as well as SOM-level development were examined including primary data from selected treatments of seven long-term field experiments in Germany and Switzerland. Yield levels of nonlegume crops were positively correlated with SOM levels, but the correlation was significant only under conditions of organic farming, and not with conventional farming treatments. While absolute SOM levels had a positive impact on yield levels of nonlegumes, the yield levels of nonlegumes and SOM-level development over time correlated negatively. Due to an increased demand of N from SOM mineralization, higher yield levels of nonlegumes obviously indicate an increased demand for OM supply to maintain SOM levels. Since this observation is highly significant for farming *without* mineral-N fertilization but not for farming *with* such fertilization, we conclude that the demand of SOM-level maintenance or enhancement and thus adequate SOM management is highly relevant for crop production in organic farming both from an agronomical and ecological point of view. Under conventional management, the agronomic relevance of SOM with regard to nutrient supply is much lower than under organic management. However, it has to be considered that we excluded other possible benefits of SOM in our survey that may be highly relevant for conventional farming as well. ■

Progress in Significant Soil Science Fields of China over the Last Three Decades: A Review. Zhao, Q.G., J.Z. He, X.Y. Yan, B. Zhang, G.L. Zhang, and Z.C. Cai. Pedosphere 21(1):1-10, 2011.

Abstract:

Due to continuous decreases in arable land area and continuous population increases, Chinese soil scientists face great challenges in meeting food demands, mitigating adverse environmental impacts, and sustaining or enhancing soil productivity under intensive agriculture. With the aim of promoting the application of soil science knowledge, this paper reviews the achievements of Chinese scientists in soil resource use and management, soil fertility, global change mitigation and soil biology over the last 30 years. During this period, soil resource science has provided essential support for the use and exploitation of Chinese soil resources, and has itself developed through introduction of new theories such as Soil Taxonomy and new technologies such as remote sensing. Soil fertility science has contributed to the alleviation and elimination of impeding physical and chemical factors that constrain availability of essential nutrients and water in soils, the understanding of nutrient cycling in agroecosystems, and the increase in nutrient use efficiency for sustainable crop production. Chinese soil scientist have contributed to the understanding of the cropland's role in global change, particularly to the understanding of methane and nitrous oxide emission from rice fields and the effect of elevated carbon dioxide and ozone on rice-wheat system. Soil biology research has progressed in biological N fixation, distribution of fauna in Chinese soils, and bioremediation of polluted soils. A new generation of soil scientists has arisen in the last three decades. The gaps between research and application in these soil science fields are also discussed. ■

K in the Literature

Effect of Long-Term Potassium Fertilization on Crop Yield and Potassium Efficiency and Balance Under Wheat-Maize Rotation in China. Zhang, H.M., X.Y. Yang, X.H. He, M.G. Xu, S.M. Huang, H. Liu, and B.R. Wang. Pedosphere 21(2):154-163, 2011.

Abstract:

Sustainable potassium (K) management at different soil sites requires understanding the relationships between crop productivity and long-term K fertilizations on a regional or national scale. We analyzed responses of grain yield of wheat (*Triticum aestivum* L.) and maize (*Zea mays* L.), K efficiency, and partial balance (difference between K input through fertilizer and K output in the aboveground biomass) during 15- (1990-2005) or 18-year (1990-2008) K fertilizations at five distinctive agroecological zones across China. Compared to the inorganic nitrogen (N) and phosphorus (P) fertilization, the inorganic NPK fertilization significantly increased grain yields of wheat (21%) and maize (16%-72% at Qiyang and Changping, where soils have low exchangeable and non-exchangeable K contents, but not at Ürümqi, Yangling and Zhengzhou, where soils have a high exchangeable and non-exchangeable K and/or low N/K ratio in crop plants. Compared to the inorganic NPK fertilization, the inorganic NPK (30% N) and organic manure (70% N) fertilization (NPKM) increased grain yields of wheat (14%-40%) and maize (9%-61%) at four sites, but not at Zhengzhou. For a productivity of wheat at 2-5 t ha^{-1} or maize at 3-6 t ha^{-1}, 13-26 or 9-17 kg K ha^{-1} were required to produce 1.0 t wheat or maize. The NP fertilization resulted in the lowest negative partial K balance and accumulated 52 kg K ha^{-1} $year^{-1}$ less than the NPK fertilization, which accumulated 28 kg ha^{-1} $year^{-1}$ less K than the NPKM fertilization. A re-evaluation of the site-specific fertilization effects on N/K ratio in crop plants and soil K accumulation under current NPK and NPKM fertilization is urgently needed to increase both crop yield and K use efficiency at different agroecological zones across China. ■

Effects of K and N Nutrition on Function and Production of *Ranunculus asiaticus*. Bernstein, N., M. Ioffe, G. Luria, M. Bruner, Y. Nishri, S. Philosoph-Hadas, S. Salim, I. Dori, and E. Matan. Pedosphere 21(3):288-301, 2011.

Abstract:

Potassium (K) affects a range of physiological processes in the plant and is a key factor controlling crop productivity and yield quality. Little information is available concerning effects of K nutrition on function of cut flower plants. The present study was carried out to investigate the interaction between K and N nutrition, on flower quantity and quality of *Ranunculus asiaticus* L. The plants were supplied with three levels of K Fertigation (60, 120, or 180 mg K L^{-1}) under 50 mg N L^{-1} application, and at the intermediate level of 120 mg K L^{-1}, to three levels of N applications (50, 100, or 150 mg N L^{-1}). The two lowest K treatments and the lowest N treatment excelled in flower production due to the lower incidence of stem-toppling, a disorder associated with localized Ca deficiencies in rapidly expanding tissues of the flower stem. Detrimental effects in terms of yield quality were apparent already under supply of 180 mg K L^{-1} and 50 mg N L^{-1}, and were not associated with changes in osmotic potential, relative water content or membrane stability of the plant tissue, or with changes in mineral contents of the leaves other than reduced Ca under high N application. Our results suggest a low nutritional requirement of *R. asiaticus* L. for K and N, a lack of involvement of tissue water relations in the reduced flower quality under the application of high concentrations of K and N, and an induction of stem toppling under high application of N and K by reduced availability of Ca to the expanding tissue of the flower stem. ■

Simultaneous Extraction of Phosphorus, Potassium, Calcium and Magnesium from Soils and Potassium Recommendations for Crops in Southern Brazil. Bortolon, L., C. Gianello, S. Welter, R.G.O. Almeida, and E. Giasson. Pedosphere 21(3):365-372, 2011.

Abstract:

Simultaneous multi-element extraction has been increasing worldwide to improve soil laboratory testing quality and efficiency. This study sought to investigate the applicability of the Mehlich-1, Mehlich-3 and resin methods for simultaneous extraction of soil available P, K. Ca, and Mg as well as the effect of using conversion equations on nutrient recommendations for crops. Topsoil (0-20 cm) samples were taken from the most representative soil types used for crop production in southern Brazil with a wide range of chemical, physical, and mineralogical properties. Soil P, K, Ca, and Mg were simultaneously extracted using 1.0 mol L^{-1} KCl, Mehlich-1 and Mehlich-3 solutions, and membrane resin. The amounts of P extracted with the Mehlich-1 method were, on average, 50% lower than those extracted with the resin and Mehlich-3 methods. However the resin method extracted the lowest amounts of K, Ca, and Mg. The use of conversion equations was suitable and it did not affect negatively the K recommendations for crops grown on soils of southern Brazil. ■

Nutrient Use Pattern in Rice under Irrigated Agro-ecosystem of Haryana. Lathwal, O.P. Indian J. Fert. 7(8):44-49, 2011.

Abstract:

A comprehensive survey was undertaken in potential rice growing district Kurukshetra (Haryana) during 2008 to assess the varietals distribution and nutrient use pattern in rice. The study revealed that 60% farmers grew basmati rice in 57% of total area under

K in the Literature

rice and rest of the farmers cultivated coarse rice including dwarf hybrids. The productivity of dwarf varieties remained higher than hybrids. Due to higher productivity, 42% farmers preferred evolved basmati including non-descript varieties in comparison to traditional scented basmati in spite of its higher market price. About 20-22% farmers used under dose (86-115 kg N/ha) of N-nutrient in 19-25% area whereas, more farmers (25-43%) applied excess dose (172.5 kg N/ha) of N-nutrient in larger area (22-48%) without substantial gain in productivity of dwarf rice. Contrary to N use pattern, 32-43% farmers used half of recommended dose of P-nutrient in about 25-27% area and 57-68% farmers used right dose (57.5 kg P_2O_5/ha) of P-nutrient in 51-64% area under dwarf rice. Majority of farmers did not use K-fertilisers, though the response to 37.5 kg K_2O/ha were observed in dwarf and basmati rice. Maximum number of farmers (81-84%) applied recommended dose (25 kg $ZnSO_4$/ha) of zinc sulphate in dwarf and basmati rice. Similar to dwarf rice, 42-56% farmers used excess dose of N-fertilisers resulting in yield loss in basmati rice. About 35-69% farmers applied double dose of P-nutrient. ■

Read on:

- Crop and Pasture Science 62(7):550-555. **Wheat Genotypes Differ in Potassium Accumulation and Osmotic adjustment under Drought Stress.** Damon, P.M., Q.F. Ma, and Z. Rengel.
- Soil Research 49(5):455-461. **Effect of Composted Mulch Application on Soil and Wine Grape Potassium Status.** Chan, K.Y., and D.J. Fahey.
- Soil Research 49(6):538-546. **Effect of K^+ on Na-Ca Exchange and the SAR-ESP Relationship.** Laurenson, S., E. Smith, N.S. Bolan, and M. McCarthy.
- Journal of Plant Nutrition 34:1675-1689, 2011. **Response of Non-Nodulating, Nodulating, and Super-Nodulating Soybean Genotypes to Potassium Fertilizer under Water Stress.** M.T. Abdelhamid, H.A. Kamel, and M.G. Dawood. ■

See the IPI website for more "K in the Literature".

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Clipboard

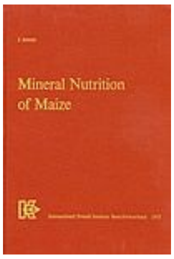
IPI library now available online

We recently completed the scanning of the majority of IPI's publications from the early days of the institute.

We felt that having valuable literature on dusty shelves does no good… so we have uploaded it to the web.

See the publications on our website which include proceedings, research topics and other crop bulletins from the 60s and 70s. Not all the data is valid, however we believe that easy access to scientific work conducted 30 to 40 years ago remains valuable.

With these new scans, along with Potash Review (1956-1995) which was uploaded in 2010, we can now provide our online users with full access to IPI's K literature. ■



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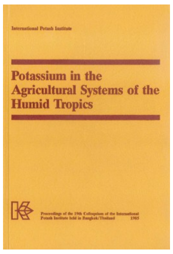
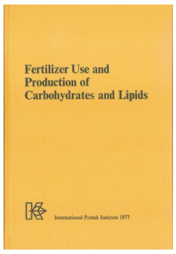


Potassium in the Agricultural Systems of the Humid Tropics



Fertilizer Use and Production of Carbohydrates and Lipids

Clipboard

Dr. Vladimir Prokoshev, IPI Coordinator for the Former Soviet Union (1993-2003) died on 26 September 2011, aged 79.

Born in 1931, Dr. Prokoshev graduated from the Perm Agricultural Institute in 1954 and later worked at the Ramenskaya Agricultural Research Station near Moscow for 22 years. His most fruitful period for his research activities was related to his work at the Lubertsy Agricultural Research Station in the same region of Russia where he did his doctorate dissertation on the Agrochemistry of Potash Fertilizers (in 1984). Dr. Prokoshev's major ideas were accumulated in a book on Potash and Potash Fertilizers (185 pages), which he wrote with co-author, Dr. I.P. Deryugin (Dr. Deryugin passed away in 2010). This publication explains that exchangeable and easily exchangeable potassium ($CaCl_2$-extracted) need to be measured and assessed in Russia to characterize the availability of soil potassium in addition to routine acid extractants. The book also summarized the efficiency of potash fertilizer use for major crops in Russia.

As an expert in his field, Dr. Prokoshev became a member of the IPI Scientific Committee in the late '80s and, in 1993, was nominated by Russian potash producers to serve as a coordinator for IPI activities in the Former Soviet Union. During the ten years he worked for IPI, he initiated many field experiments and published extensively. His work on potash fertilizers in soil and its effect on plant crops in different agroclimatic regions was fundamental and supported scientific, as well as extension and farming communities. His scientific capacity and dedication were greatly appreciated by his IPI colleagues, as well as his modesty and kindness for which he was much loved.

We shall miss him and will cherish the scientific legacy he left behind. ■

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