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Optimizing Crop Nutrition

Editorial

Dear readers,

The International Potash Institute (IPI) was formed by German and French potash producers in 1952. Clearly, the IPI founders had a vision that progressive farming requires a constant flow of scientific knowledge to share with farmers worldwide. In 2012, we will celebrate our 60th anniversary. We mark this milestone with pride, as we believe that the concepts laid down to form the Institute still hold true today.

During the second half of the 20th century, agricultural development in many parts of the world was impressive. Nevertheless, this rapid progress bypassed many regions. In this edition, we include a paper on improving fertilization practices in Indian tribal communities, where the word "Potash" had never previously been heard…

Do we share today the same vision of our IPI founders? I have no doubt that the answer is an affirmative YES. Farmers today are no less challenged than 60 years ago, if not more, and the need for science and good agronomic practices is acute. In this respect, the work that IPI conducts across various regions with scientists, extension officers and farmers goes on, with a sense of pride in what we have already achieved, and with a strong desire to continue supporting agricultural development.

I wish you all an enjoyable read.

Hillel Magen
Director

Research Findings

Maize experimental plot in Punjab. Severe lodging affected the K=0 plot. Photo by M.S. Brar.

Nitrogen Use Efficiency (NUE), Growth, Yield Parameters and Yield of Maize (*Zea mays* L.) as Affected by K Application

Brar, M.S.[1][2], Preeti Sharma[2], Amandeep Singh[2], and S.S. Saandhu[3]

Introduction

Nitrogen Use Efficiency (NUE) which is expressed as grain yield in kg per kg of N applied as fertilizer hardly exceeds 50 percent in cereal crops. Under field conditions, NUE varies from 25 to 34 percent in rice and 40 to 60 percent in other crops, with a global average of about 50 percent (Mosier, 2002), maize being no exception. Global cereal NUE has been reported to be 33 percent and it has been estimated that an increase in NUE by one percent is worth as much as USD 234 million (Magen and Nosov, 2008). Cassman (2002), on the basis of number of field experiments, reported nitrogen recovery in rice in Asia as 31 percent under farmers' practices and 40 percent under field specific management. Cassman further reported that nitrogen recovery in wheat varied from as low as 18 percent under unfavorable weather to 49 percent under favorable weather conditions. In addition to weather, NUE is controlled by many other factors such as: crop demand for N, supply of N from soil and fertilizers, and losses of N from the soil-plant system. Imbalanced and inappropriate use, not only of N but other nutrients, such as potassium in agroecosystems, can also modify NUE.

[1] Corresponding author: brarms@yahoo.co.in
[2] Department of Soil Science, Punjab Agricultural University, Ludhiana, Punjab 141004
[3] Department of Agrometerology, Punjab Agricultural University, Ludhiana, Punjab 141004

Table 1. Effect of fertilizer treatments on N and K uptake by maize grains.

Treatment[(1)]	Year					
	2003	2004	2005	2006	2007	Average
No. of fields	4	3	4	4	3	18
			N uptake (kg ha^{-1})			
K_0	23.2	39.5	37.7	50.7	49.8	40.2
K_{30}	27.4	48.9	38.8	51.4	54.4	44.2
K_{60}	30.4	55.4	37.7	51.6	52.6	45.5
K_{90}	29.0	57.9	45.7	62.9	59.1	50.9
CD (5%)	4.13	11.57	8.19	10.18	NS	
			K uptake (kg ha^{-1})			
K_0	8.4	10.3	11.9	22.2	44.1	19.4
K_{30}	12.4	13.0	13.1	20.1	45.9	20.9
K_{60}	15.7	14.9	13.7	23.3	48.4	23.2
K_{90}	15.7	16.5	15.6	34.6	51.8	26.8
CD (5%)	2.6	3.6	2.7	5.4	NS	

[(1)] N and P_2O_5 levels were 125 and 60 kg ha^{-1}

Table 2. NUE of fertilizer N (kg grain/kg N) and apparent N recovery (%) at different levels of applied potassium.

K level (kg K_2O ha^{-1})	2003	2004	2005	2006	2007	Average	% increase over K_0
			NUE (kg grain/kg applied N)				
0	21.1	32.0	26.8	38.2	45.4	32.7	-
30	24.2	37.9	27.3	39.5	47.6	35.3	7.9
60	27.0	41.8	27.4	41.3	53.3	38.0	16.2
90	26.4	40.9	30.9	48.2	48.8	39.0	19.3
			ANR (%)				
0	19	32	30	41	40	32	-
30	22	39	31	41	44	35	9.3
60	24	44	30	41	42	36	12.5
90	23	46	37	50	47	41	28.1

The NUE was calculated by dividing grain yield (kg) by the N applied (kg), and ANR (%) was calculated by dividing uptake of Nitrogen in kg by N applied in kg and multiplied by 100 (Ladha *et al*., 2005).

IPI on-farm experiments in Asia and Europe have indicated that besides yield, NUE on average can be increased by 15.5 percent in maize in Ukraine, 18 percent in maize in India, 19 percent in wheat in China and 26.3 percent in rice in Bangladesh, by application of appropriate amounts of K. Experiments conducted on pearl millet in Haryana, India showed the partial factor productivity of N was increased from 20.3 to 23.8 kg grain kg^{-1} N, with the application of 60 kg K_2O ha^{-1} (Yadav *et al*., 2007).

In India, maize is an important cereal crop. In Punjab, it is predominantly grown in the north-eastern region of the State on light textured soils of low fertility status. Balanced nutrition plays a key role in increasing crop production. Since farmers are not used to applying K to the maize crop, imbalanced nutrition seems to be one of the yield limiting factors, resulting in low productivity and low NUE in maize in the region.

Field experiments on farmers' fields were conducted in Hoshiarpur and Nawanshehar districts of Punjab for five years, using a total of 18 locations. At each location, treatments were replicated three times. The plot size of each treatment was 800 m^2. Four treatments viz. 125:60:0, 125:60:30, 125:60:60 and 125:60:90 kg ha^{-1} of N, P_2O_5 and K_2O were applied using urea, diammonium phosphate (DAP) and muriate of potash (MOP). DAP, MOP and one-third of the dose of urea were applied at sowing. The second one-third dose of urea was applied at the knee-high stage and the remaining one-third at the pre-tasseling stage. Maize was sown during the month of June and was harvested at maturity in September every year. Plant height, stem girth and leaf area were measured at maturity. Length of cob, girth of cob, cob weight and grain weight were also recorded at harvesting. Grain yield was recorded by threshing the crop after 10-15 days of air-drying the cobs. Plant samples were collected at the time of harvesting, washed in distilled water, oven dried at 65°C then ground in a stainless steel Willey mill. Plant samples were digested in a mixture of nitric and perchloric acids (ratio 3:1) then analyzed for N (Kjeldahl) and K (flame photometry).

Nitrogen uptake

Increase in NUE is the consequence of enhanced uptake and improved utilization of N by the crop. The significant increase in N uptake by maize seeds was observed with the increase in levels of applied K (Table 1). The N uptake into the grain, which on average was 40.2 kg ha^{-1} with the application of N and P, increased to 50.9 kg ha^{-1} with the application of 90 kg K_2O ha^{-1} together with the N and P. Potassium uptake also increased with the progressive increase in levels of K application.

Nitrogen use efficiency (NUE)

Application of K greatly influenced NUE (kg grain/kg applied N) in maize. At different locations/years, and with the application of K, NUE varied from 21.1 to 53.3 kg grain kg^{-1} applied N (Table 2). Averaged over the years and sites, the NUE was 32.7, 35.3, 38.0, and 39.0 kg grain kg^{-1} applied N at 0, 30, 60, and 90 kg of applied K_2O ha^{-1} respectively. The graded levels of applied K increased NUE by 7.9, 16.2 and 19.3 percent, over K_0 (No K) application. The Apparent Nitrogen Recovery (ANR, kg N uptake/kg applied N) varied from 19 to 50 percent at different locations/years and, on average, increased from 32 percent (K_0) to 41 percent (K_{90}) with the application of K indicating the beneficial effect of applied K on N utilization. The practical implication of this is the improved utilization and lower loss of applied N to cause environmental pollution.

Experimental plot with 30 kg K_2O ha^{-1}. Photo by M.S. Brar.

Table 3. Effect of fertilizer treatments on growth parameters of maize.

	Plant girth	Plant height	Leaf area
	--------------------*cm*--------------------		*cm*^{2}
$N_{125}P_{60}K_0$	6.34	229.6	5,669
$N_{125}P_{60}K_{30}$	6.71	234.1	5,966
$N_{125}P_{60}K_{60}$	7.00	240.1	6,091
$N_{125}P_{60}K_{90}$	6.95	242.3	6,334

Growth parameters

The girth of the plant is an important criterion, which determines its strength and ability to resist lodging. K application favorably influenced the girth of maize plants, which increased with level of K application, the greatest girth being observed with the application of 125:60:60 kg ha^{-1} of N, P_2O_5 and K_2O (Table 3). The increase in stem girth of maize under balanced fertilization, and especially at higher levels of K application, may be due to cell expansion, which induces sturdiness and healthiness of plants, including better root development (Walker and Parks, 1969; Singh and Tripathi, 1979; Ahmed, 1992). In plots without K application, strong winds caused the crop to lodge but no lodging took place in the NPK treated plots because of the increased stem strength and root development enhanced by balanced nutrition with potassium.

Averaged over the five years, plant height varied from 223.5 to 242.3 cm and increased with the application of K, although the effect was non-significant for most of the years (Table 3). The production of photosynthates via photosynthetic activity in the leaf is ultimately the driver of crop yield and is dependent on leaf area. Any treatment increasing leaf area is thus likely to contribute towards raising crop yield. In this respect, leaf area was found to increase with the addition of graded doses of K (Table 3). On average, maximum leaf area was observed when K was applied at 90 kg ha^{-1}. As well as its effect in promoting photosynthetic activity, potassium also increases cell expansion by regulating solute potential that may increase the rate of leaf expansion and the leaf area (Rao and Madhava, 1983; Yahiya *et al.*, 1996).

Yield parameters

Cob length and girth were measured at harvesting. Data revealed that application of K at the rates of 60 and 90 kg K_2O ha^{-1} resulted in significantly bigger cobs with

Table 4. Effect of K application on yield parameters and grain yield (average of five years at 18 locations) of maize.

Treatments	Cob length	Cob girth	Grain weight of 100 cobs	Thousand grain weight	Grain yield
	-----------*cm*----------		*kg*	*g*	*mt ha^{-1}*
$N_{125}P_{60}K_0$	20.0	14.4	9.1	235	5.69
$N_{125}P_{60}K_{30}$	20.6	14.6	9.5	238	5.95
$N_{125}P_{60}K_{60}$	21.1	14.8	10.5	249	6.54
$N_{125}P_{60}K_{90}$	21.4	14.9	11.1	254	6.10

more length and girth over the NP treatment without K (Table 4). Larger cob size may be the result of enhanced photosynthetic activity followed by efficient utilization of applied N, efficient transfer of metabolites and subsequent accumulation of these metabolites in the cob.

Potassium application significantly increased the thousand-grain weight and grain weight of 100 cobs during all five years of the study (Table 4). Average grain weight of 100 cobs increased by 37 percent, and thousand grain weight by 15 percent, with the application of 90 kg K_2O ha^{-1} over the control treatment, where N alone was applied to the maize crop (data not presented in table). Similarly, there was a substantial increase in these parameters over the NP treatments as the rate of K fertilization was increased.

Grain yield

The data of five years of study (Table 3) indicate that it is not possible to obtain optimum yield of maize with the application of only N and P. The application of K is essential to obtain higher yields. With the application of 60 kg K_2O ha^{-1} the grain yield increased by 15 percent over the NP treatment. Grain yield of maize increased with application of K due to the cumulative effect on both growth and yield parameters, which were increased substantially by the application of K, along with N and P, and greater uptake and utilization of N in the presence of applied K.

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Regional Activities/India

Research Findings

Field visit to SSNM plot. Photo by Ch. Srinivasa Rao.

Impacts of Participatory Site Specific Potassium Management in Several Crops in Rainfed Regions of Andhra Pradesh, India

Srinivasa Rao, Ch.[1]

Introduction

In rainfed regions of India, declining soil fertility and nutrient imbalances are major issues affecting agricultural productivity. Organic matter levels have declined sharply in intensively cropped regions, leading to stagnant yields of major food crops. In addition to universal deficiency of nitrogen (N), deficiencies of potassium (P), sulphur (S) and micronutrients are emerging as constraints for sustaining and/or enhancing productivity under intensive crop production systems (Srinivasarao *et al.,* 2006, 2008, 2009a, 2010, 2011a). It is estimated that 29.4 m hectares (ha) of soils in India are experiencing a decline in fertility with a net negative balance of 8-10 million mt of nutrients per annum (Srinivasarao, 2011b). Poor nutrient use efficiency is another cause for concern. So far, soil fertility issues have been addressed mainly in irrigated agriculture, but recent studies have indicated that drylands are not only thirsty but also hungry (Srinivasarao *et al.,* 2011c; Srinivasarao and Vittal, 2007). Most of the soils in the rainfed regions are low in organic carbon and available N, and crops growing on these soils show multi-nutrient deficiencies, including secondary and micronutrient deficiencies.

Fertilizers contribute about 50 percent of the increased yields, as a component of improved technology. The dramatic increases in the yields of crops like wheat and rice have occurred because of the use of high yielding varieties and application of higher rates of fertilizer. However, for many dryland crops, despite the introduction of high yielding cultivars, yield potential has not been achieved because of low nutrient use. About 80 percent of the fertilizer applied in India is consumed in irrigated areas while only 20 percent is used in the rainfed areas that constitute 65 percent of the cropped area. Hence, low nutrient use in rainfed agriculture is one of the major causes of low yields (Srinivasarao

[1] Central Research Institute for Dryland Agriculture, Santoshnagar, P.O. Saidabad, Hyderabad 500 059, Andhra Pradesh, India, Email: cherukumalli2011@gmail.com

Fig. 1. Andhra Pradesh district map with the target districts marked in grey. In total, 84 villages in the target districts were identified for demonstrations.

et al., 2011c; 2009b). Efforts should therefore be made to redefine fertilizer doses so that they are synchronized with crop nutrient demand and soil water availability, particularly in the drylands.

The target area for this study comprised of eight tribal-dominated districts of Andhra Pradesh covered by the Component 3 sub-project "Sustainable rural livelihoods through enhanced farming systems productivity and efficient support systems in rainfed areas" under the World Bank-supported National Agricultural Innovative Project (NAIP) which, since September 2007, is being implemented by a consortium led by the Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad (Fig. 1). The aim of the project is to improve the livelihoods of the rural poor by improving the overall systems productivity by following good agricultural practices, improved natural resource management and addressing the issues of profitability and sustainability through efficient institutional and support systems. The project sites were selected based on the criteria of dominance of rainfed farming, tribal dominant, low household income and poor infrastructure. A general description of the study sites is given in Table 1.

Participatory soil sampling and chemical analysis

Following several meetings and discussions with farmers in these villages, farmers were sensitized to the need for soil testing. Soil samples from 1,860 farmers' fields covering 84 villages of the eight districts were collected during 2007-2011 with farmer participation in soil sampling. After conducting farmers' meetings in each village and depending upon soil type, crop, slope and agricultural management, about 30 percent of farmers' fields were selected for sampling using stratified random sampling methodology (SRSM). Those farmers whose fields were selected were given group demonstrations of soil sampling procedure. Collected soil samples were labeled with cluster, village and farmer's names. In most of the clusters, the village sarpanch or village head was involved in participatory soil sampling. Collected soil samples were analyzed for soil chemical properties (pH, EC and organic carbon) as well as nutrient analysis (N, P and K), in the Soil Chemistry Laboratory at CRIDA as per standard methods (Jackson, 1973). Available K status was determined in 1N ammonium acetate extract determined using flame photometry (Hanway and Heidel, 1952) and soil K status less than 50 mg K kg^{-1} soil was considered deficient (Srinivasarao *et al.,* 2007; Subbarao and Srinivasarao, 1996; Srinivasarao, 2011b).

Table 1. Details of study sites/villages selected in the target districts.

District	Villages	No of villages	No. of households	Area (ha)	Characteristics of the cluster	Soil type	Crops
Adilabad	Seethagondi, Garkampet, Arkapally, Old Somwarpet, Pedamalkapur, Chinamalkapur, Kotwalguda, New Somwarpet	8+2*	575	1,296	High tribal population (70%) and close to forests, very low productivity and technology adoption	Black	Cotton Pigeonpea Chickpea Vegetables
Nalgonda	New Banjara Hills, Jamal Kunta Thanda, Seetamma Thanda, Yellapa Kunta Thanda, Chinagore Kunta Thanda, Pedagore Kunta Thanda, Peda Seetharam Thanda, China Seetharam Thanda, Lalsingh Thanda	9+9	621	500	Highly drought prone area, off season employment and high migration rates, small hamlets/thandas with more than 80% tribal population	Red	Groundnut Pigeonpea Green gram Sorghum Vegetables Horticulture crops
Khammam	Bheemavaram, Koremvarigumpu, Kurvapally Kothuru, Mamillavai, Ramavaram, Thummalacheruvu Venkatapuram	7+4	650	1,000	High tribal population assigned and forest lands, poor communication and market facilities, and high indebtedness	Red and black	Cotton Sorghum Maize
Mahabubnagar	Zamistapur, Telugugudem, Kodur Thanda	3+4	734	756	Highly drought prone area, more landless families, degraded lands, high livestock population, fodder scarcity, high migration and limited livelihood opportunities	Red and black	Castor Sorghum Groundnut
Anantapur	Pampanoor, Pampanoor Thanda, Yennamkothapally	4+4	576	1,430	Most drought prone area, extensive monocropping of groundnut, repeated crop failures and water shortages, limited livelihood opportunities	Red (gravelly)	Groundnut
Kadapa	B.Yerragudi, Kapu Palli, BA. Nagireddy Palli, Madhiga Palli, Moodindla Palli, Puttakarla Palli, Puttakarla Palli Colony, Konampeta	8+5	216	1,060	Drought prone area with predominance of small and marginal farmers with maximum erodable lands. Lacks proper credit and agricultural market facilities	Red and black	Groundnut Sunflower Vegetables
Warangal	Jaffer Gudem, Kusumbai Thanda and Satynarayana Puram, Jal Thanda, Ramanna Gudem, Vepalagadda Thanda, Cherla Thanda, Lokya Thanda	7+3	689	2,070	Village with high tribal population, degraded soils with good potential for water harvesting and drought proofing measures	Red and black	Cotton Rice Pigeonpea
Ranga Reddy	Ibrahimpur, Dhadi Thanda, Roopsing Thanda, Malkaypet Thanda	4+3	409	346	Village with high migration rates and lack of irrigation facility, more forest land, high use of chemical inputs and indebtedness	Red sandy	Maize Pigeonpea Vegetables

*Extended villages


K deficiency symptoms in groundnut (left) and cluster bean (right) in SSNM plots at farmers' fields. Photos by Ch. Srinivasa Rao.

Table 2. Cluster-wise fertility status in 1,860 farmers' fields in the tribal districts of Andhra Pradesh (AP), 2007-2011.

Name of the District*		pH	EC	OC	Av. N	Av. P	Av. K
			dS m^{-1}	*g kg^{-1}*		--------------mg kg^{-1}--------------	
Adilabad (139)	Range	6.2-8.8	0.08-2.66	2.7-13.3	55-159	2.7-48	20-245
	Mean	8.1	0.29	6.2	94	6.9	91
Nalgonda (420)	Range	5.3-8.8	0.07-1.60	1.4-11.3	61-133	0.1-22.4	9-154
	Mean	7.4	0.29	4.6	86	4.0	39
Khammam (161)	Range	4.8-8.6	0.03-0.82	3.2-15.0	70-153	0.1-25.8	14-382
	Mean	6.7	0.18	7.0	91	3.8	80
Mahabubnagar (121)	Range	6.0-10.2	0.01-2.37	1.3-11.3	48-120	0.1-19.6	11-563
	Mean	7.80	0.22	4.4	80	3.9	47
Anantapur (340)	Range	5.5-8.8	0.02-3.20	1.2-14.5	57-105	0.3-18.9	17-664
	Mean	7.4	0.18	4.5	78	3.75	52
Kadapa (320)	Range	6.0-8.8	0.02-1.30	1.2-13.1	28-174	0.2-6.0	7-215
	Mean	7.3	0.12	2.6	55	1.2	27
Warangal (336)	Range	6.1-9.4	0.04-1.68	0.8-8.4	34-190	0.2-23.8	9-125
	Mean	7.8	0.27	4.1	85	7.1	49
Rangareddy (125)	Range	4.7-8.2	0.02-1.16	1.5-15.6	39-151	0.2-26.7	11-180
	Mean	6.7	0.12	5.0	96	4.0	41

*In brackets, number of farmers' fields tested.

Potassium deficiencies in farmers' fields (1,860) in eight target districts

Potassium deficiency was observed in the soils of 84 villages and crops grown in farmers' fields. Deficiency was observed in groundnut, cluster bean, cotton, banana, upland rice, sunflower, maize and other crops on various soils including red soils, sandy light textured soils, degraded lands and shallow black soils in the districts of Anantapur, Nalgonda, Kadapa, Khammam, Warangal and Rangareddy (Srinivasarao *et al.*, 1997, 1998, 1999, 2000, 2001a, 2001b, 2001c, 2006, 2007, 2010, 2011b). From 1,860 farmers' fields as many as 65 percent of the soils were in the low and medium category (Table 2). In most of the districts, some of the farmers' fields were extremely low in available K status. In Adilabad districts, the K status varied from 20 to 245 mg kg^{-1} with the mean value of 91 mg kg^{-1}, corresponding to a medium K value (Srinivasarao *et al.*, 2000). In Nalgonda, from 420 farmers' fields, K status varied from 9-154 mg kg^{-1} with a mean of 39 mg kg^{-1}, a low K value. These soils are extremely low in K so that high value crops like tomato, vegetables, sweet orange, and mulberry, along with field crops like groundnut, cotton, maize, green gram, and black gram, respond to K application (Fig. 2 to 6). Soils of Khammam district are medium in K status ranging from 14-382 mg kg^{-1}. However, most of the cotton growing red soils are low in available K and significant cotton response was found with Specific Site Nutrient Management (SSNM) including K. In Mahabubnagar district, K status varied from 11-563 mg kg^{-1} with a mean of 47 mg kg^{-1} (low). Therefore, the deficient fields with cotton, castor, maize etc. require K application. In Anantapur district, the mean K status is low (52 mg kg^{-1}) although it varied from 17-664 mg kg^{-1} across 340 farmers' fields tested. In addition, other than small pockets of black soil patches, most of the groundnut growing red soils are K deficient and regular application of K is required. The soils in this district are unable to support banana cultivation, without external K application (Srinivasarao *et al.*, 2000, 2010). In Kadapa district, among the 320 farmers' fields tested, K status ranged from 7-215 mg kg^{-1} with the mean value of 27 mg kg^{-1} showing extremely low levels of soil K. In Warangal district, among 336 farmers' fields tested, K status varied from 9-125 mg kg^{-1} with a mean value of 49 mg kg^{-1} (low). In Rangareddy district, of the 125 farmers' fields tested, the mean K status was low (41 mg kg^{-1}) and in the range of 11-180 mg kg^{-1}.

K deficiency symptoms in rice at one of the SSNM plots. Photo by Ch. Srinivasa Rao.

Table 3. Farmer field specific fertilizer recommendations developed for oilseed/pulse crop (viz. groundnut, green gram, tomato and okra) based on soil test value for Dupahad cluster of Nalgonda district, AP (Similar SSNM data sheets developed for all other farmers fields across the eight districts).

Farmer No.	Village	Crop	Fertilizer requirement (kg ha^{-1})				
			Urea	DAP	MOP	Gypsum	$ZnSO_4$
1	Jalmakunta Thanda	Green gram	50	-	90	-	-
2	Jalmakunta Thanda	Groundnut	-	125	90	-	50
3	New Banjara Hills	Groundnut	50	-	65	150	50
4	Jalmakunta Thanda	Green gram	50	-	-	-	25
5	Jalmakunta Thanda	Green gram	-	125	90	150	50
6	Seetamma Thanda	Groundnut	50	-	90	-	50
7	Jalmakunta Thanda	Green gram	50	-	-	-	50
8	New Banjara Hills	Groundnut	-	125	65	150	50
9	Peddagarakunta Thanda	Green gram	50	-	90	150	50
10	Jalmakunta Thanda	Green gram	-	125	-	-	50
11	Jalmakunta Thanda	Green gram	-	125	90	-	50
12	Jalmakunta Thanda	Green gram	50	-	65	-	50
13	Jalmakunta Thanda	Green gram	-	125	90	150	50
14	Jalmakunta Thanda	Green gram	-	125	65	150	50
15	Jalmakunta Thanda	Groundnut	-	125	65	150	50
16	Jalmakunta Thanda	Groundnut	-	125	65	-	25
17	Jalmakunta Thanda	Green gram	50	-	65	-	50
18	Jalmakunta Thanda	Tomato	50	-	90	-	50
19	Jalmakunta Thanda	Okra	-	125	90	-	50
20	Peddagarakunta Thanda	Tomato	50	-	65	-	25

On-farm SSNM trials

During 2007-11, a total of 265 on-farm trials were conducted in different districts with different test crops: Adilabad (kharif cotton and rabi chickpea), Khammam (cotton), Warangal (cotton and pigeon-pea), Anantapur and Kadapa (groundnut, sunflower and vegetables), Mahbubnagar (cotton, castor and rabi groundnut), Rangareddy (maize and pigeonpea) and Nalgonda (groundnut, black gram, green gram and vegetable crops, such as tomato and okra). The objective of these tests was to demonstrate the comparative evaluation of SSNM, including micro and secondary nutrients and farmer's practice. Crops were grown on selected farmers' fields with known fertility status and SSNM-based nutrient application (Table 3).

In some of the fields across the districts (Warangal, Adilabad, Nalgonda, Khammam and Rangareddy), a build-up of phosphorous (P) in the soils was determined. In these farmers' fields, the application of P was reduced to half of the recommended P levels for various crops. Prior to this project, no farmer had applied any K fertilizer to the crops, even in cases where soils were deficient in available K. Some of the farmers did not even know about MOP fertilizer. Based on our project interventions, K fertilizer was included in SSNM package where soils testing of K was low and also for K exhaustive crops including cotton, maize, groundnut, vegetables and other horticultural crops. A model SSNM sheet is presented in Table 3 for some of the on-farm trials made in Nalgonda district on groundnut, green gram, tomato and okra. Similarly sulphur, zinc and boron were applied depending on soil test data. SSNM packages for individual farmers' fields were developed based on the crop grown and soil test data. Available N was invariably low in all the villages and recommended N was used for all crops with the exception of legumes where N was omitted as for groundnut and green gram (Table 3).

SSNM impacts on crop productivity in farmers' fields

The impacts of SSNM, based on participatory soil sampling, soil analysis at CRIDA laboratory, soil health cards, and SSNM recommendations to individual farmers depending upon crop and soil test data, were highly significant in all the tested crops in the eight districts. Response patterns of various crops in each district are discussed below:

Adilabad: In Adilabad district, the benefits of balanced nutrition through SSNM were much higher than at other sites. This could be due to a continuous cotton-based system with a mean yield of 2.37 mt ha^{-1} of seed cotton (SSNM) compared to a mean yield of 1.66 mt ha^{-1} under farmers' practice (FP), (a 43.1 percent yield increase). Low levels of fertilizer application to cotton, chickpea or cotton-pigeonpea intercropping systems over the years resulted in mining of soil nutrients. In these villages (70 percent tribal population), cotton has been grown for the last 10-15 years without much nutrient input. This is one of the reasons for higher cotton response to balanced nutrition. Among the rabi crops, chickpea (variety JG-11) showed significant response to SSNM in Seethagondi cluster of Adilabad district. Mean seed yield increased from 0.89 to 1.21 mt ha^{-1} due to balanced nutrition, a 35.1 percent yield increase. Being a pulse crop, S requirement was met from added S in the form of gypsum, besides application of other S-containing fertilizers. However, the variation in the crop response to balanced nutrition varied widely among farmers' fields. The improvement in chickpea yield with balanced nutrition varied from 15 to 58 percent over farmer's practice. These findings indicate that with improved varieties of chickpea (JG-11), a well nourished crop can yield up to 1.5 mt ha^{-1} on the deep black soils of Adilabad district.

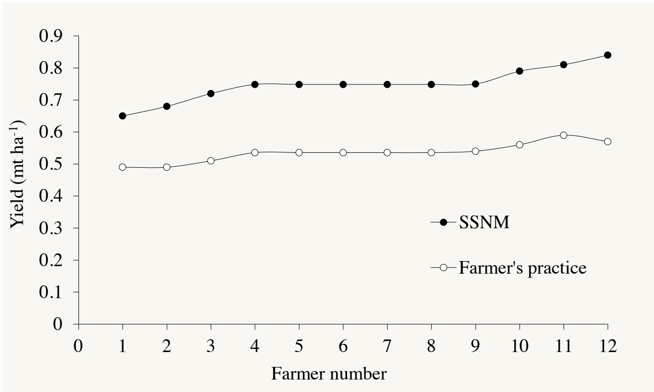

Fig. 4. Effects of balanced fertilization on green gram yield in farmers' fields of Dupahad cluster, Nalgonda district, AP, 2009-2010. (CD=0.07; p=0.05).

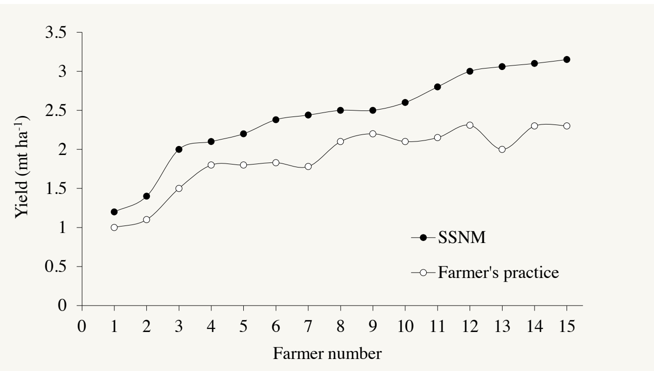

Fig. 2. Effects of balanced fertilization on Bt-cotton yield in farmers' fields of T. Cheruvu cluster, Khammam district, AP, Kharif 2009-2010. (BN=SSNM; FP=Farmer's practice only NP) (CD=0.23; p=0.05).

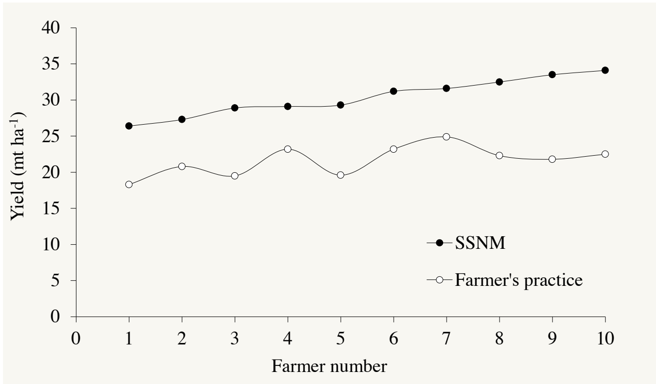

Fig. 5. Effects of balanced fertilization on tomato yield in farmers' fields of Dupahad cluster, Nalgonda district, AP, 2009-2010. (CD=0.9; p=0.05).

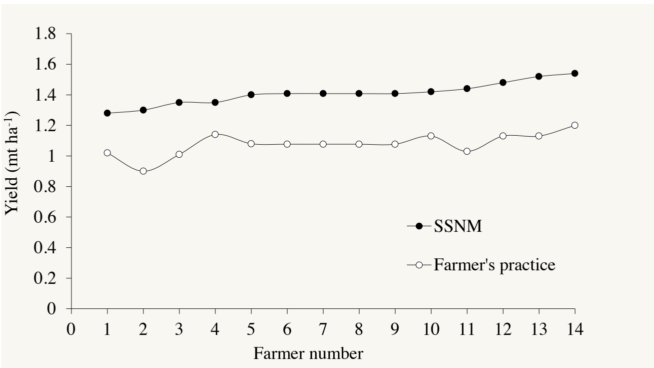

Fig. 3. Effects of balanced fertilization on groundnut yield in farmers' fields of Dupahad cluster, Nalgonda district, AP, 2009-2010. (CD=0.08; p=0.05).

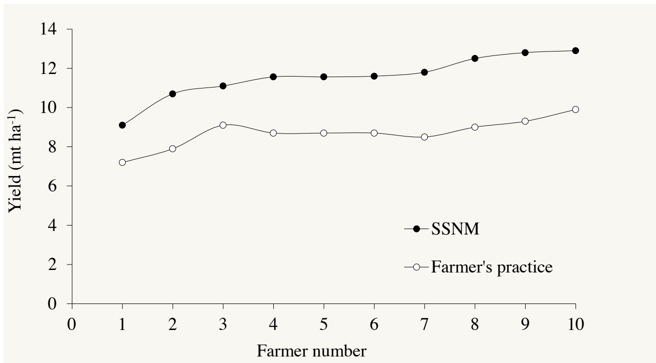

Fig. 6. Effects of balanced fertilization on okra yield in farmers' fields of Dupahad cluster, Nalgonda district, AP, 2009-2010. (CD=0.4; p=0.05).

Farmers' meeting to discuss and evaluate SSNM with research team in Anantapur.

Farmers' meeting to discuss and evaluate SSNM with research team in Adilabad.

Meeting with cotton farmers at SSNM for cotton.
Photos by Ch. Srinivasa Rao.

Khammam: Soils in Tummalacheruvu cluster in Khammam district are fine textured red soils with multi-nutrient deficiencies. Cotton yields (seed cotton) ranged from 0.9 to 2.5 mt ha^{-1} under FP with an average yield of 1.9 mt ha^{-1} whereas with SSNM, yield levels improved in the range of 1.3 to 3.2 mt ha^{-1} with an average yield of 2.4 mt ha^{-1}, a 13.6-53.0 percent increase in yield. The interesting point obtained from cotton yields from farmers' fields is that yield gaps between FP to SSNM have widened at higher productivity levels as compared to lower yield levels among 15 farmers' fields tested (Fig. 2).

Nalgonda: In the Dupahad cluster of this district, SSNM of groundnut and green gram brought about a mean yield increase from 1.08 to 1.41 mt ha^{-1} and from 0.54 mt ha^{-1} to 0.75 mt ha^{-1}, respectively, i.e. 31.1 and 39.6 percent yield increases. Green gram and groundnut yield responses also varied from 33 percent to 47 percent and 18 percent to 44 percent respectively. Among vegetable crops, tomato and okra, mean yield increased from 21.6 mt ha^{-1} to 30.4 mt ha^{-1} and 8.7 mt ha^{-1} to 11.6 mt ha^{-1}, i.e. 41 percent and 33 percent increases in yield respectively in this district (Fig. 3-6). In all the crops (oilseed, food legume and vegetables), groundnut, green gram, tomato and okra, the gaps in yields between FP and SSNM were much wider at high productivity levels, as in the case of cotton yields in Khammam district.

Warangal: In the Jaffergudem cluster, balanced nutrition improved cotton yields significantly in many farmers' fields. In some of the farmers' fields, cotton yields reached 1.6 mt ha^{-1} with balanced nutrition, with increased yields from five to 30 per cent over FP.

Kadapa: Groundnut yield increased from 0.65 mt ha^{-1} to 0.82 mt ha^{-1} due to balanced nutrition, registering a yield increase up to 15 to 18 percent.

Anantapur: As in Kadapa, groundnut yields were increased by balanced nutrition from 0.67 to 0.88 mt ha^{-1}. The response of groundnut to balanced nutrition ranged from 20 to 50 percent but generally it was around 25 percent (Srinivasarao *et al.*, 2010).

Mahabubnagar: Castor, cotton and rabi groundnut responded significantly to micronutrient application. The highest response among the crops was cotton (26 percent), followed by castor (19 percent) and groundnut (18 percent).

Rangareddy: Maize and pigeonpea responded to micro and secondary nutrient application on the light-textured sandy loam soils of Parigi cluster.

Based on several on-farm trails, SSNM improved productivity of various rainfed crops. The minimum mean increase in SSNM over FP was 19 percent in castor and the maximum mean increase was observed in tomato (41 percent) (Fig. 7), with other crops including cotton, chickpea, groundnut, green gram, maize and okra between these figures. Such large impacts of SSNM productivity of rainfed crops in eight districts was due to degraded soils with multi-nutrient deficiency, and where farmers seldom apply nutrients other than N and P. Potassium inclusion in the SSNM package as shown in Table 3 enhanced yield improvement as well as quality of vegetables like tomato and okra.

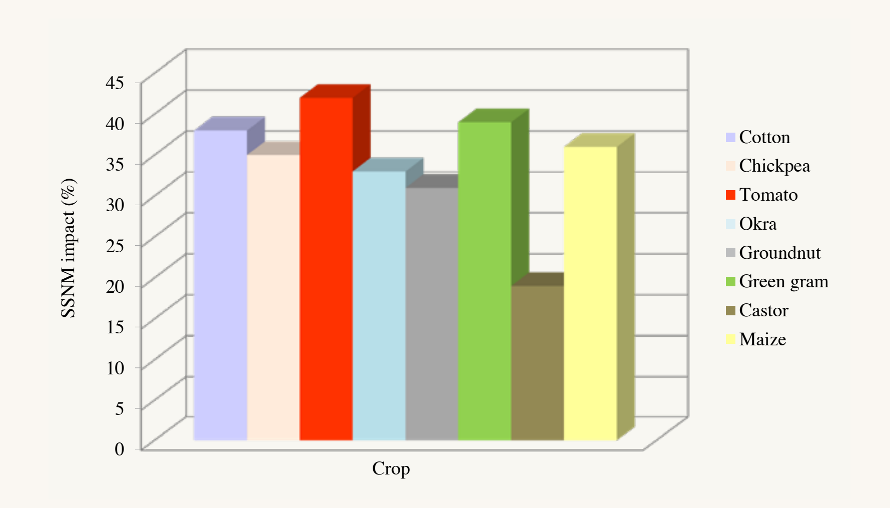

Fig. 7. Overall impacts of SSNM in different rainfed crops over farmer's practice.

Impact of SSNM on farm income

The economic viability of balanced nutrition over FP was calculated in relation to prevailing prices of input and output costs. The additional cost (Table 4) incurred in balanced nutrition as compared to FP was mainly due to the cost of the limiting nutrients and additional N and P. Net income and return per Rupee investment improved substantially through balanced nutrition.

Livelihood impacts of SSNM

Increasing crop productivity by application of improved technologies was one of the strategies for enhancing the livelihood security of the rural poor in the project. Thus, a systematic effort was made to assess the native nutrient status of soil and supplement it by application of appropriate nutrients at the required quantity. Enhancing crop productivity and household income has been adopted by the project as a short-term measure towards improving rural livelihoods. It was observed in many cases in the project area that the additional income generated due to higher productivity and profitability was mostly reinvested into farming as additional capital. Increased vegetable productivity enhanced cash flow in the family at short intervals. The families that participated in SSNM trials were shown to be higher consumers of vegetables at the household level leading to better nutritional security as well (Table 5).

Many farmers who realized higher profits due to better nutrient management used their additional income for improving housing, buying animals, educating children, meeting social obligation, etc. Pelli Venkanna of Jaffergudem says "From the additional profit I got from my cotton SSNM field, I spent Rs. 22000/- to plaster my house with cement," while Korra Harishehandra of the same cluster bought a sheep unit spending Rs. 13500/-. A relatively well to do farmer, Buke Balu invested his profit to fund his son's education (B.Tech).

In Adilabad, D. Ratan of Seethagondi cluster took up SSNM in chickpea and realized a 30 percent higher income compared to other farmers. He used this money to purchase Bt cotton seeds from a reputable company. He said, "Unlike previous years, I did not have to compromise with seed quality. Since I had extra money (Rs. 12000/-), I could go for the best in the market."

Though the anecdotes give a summary of the livelihood impacts of the SSNM interventions, they do not provide a total picture of all the farmers who adopted SSNM. However, the livelihood impacts which can be diverse and varied can only be captured through anecdotal evidence and qualitative data.

In Dupahad cluster of Nalgonda, the impact of SSNM was observed mainly in vegetables (tomatoes, okra), leafy vegetables (like palak) and flower crops (such as marigold). Though these did not translate into large gains, as in the case of cotton, the additional income nevertheless contributed to the purchase of household articles, better clothing and additional investment in purchasing better quality inputs for agriculture.

Acknowledgement

The author is grateful to the Director (CRIDA, Principal Investigator) and Dr. S. Dixit (Co-principal Investigator) of the project for their support in conducting SSNM trials. The assistance rendered by the consortium partners (CRIDA, SAIRD,

Table 4. Economic benefits due to SSNM and balanced nutrition followed in different crops in target clusters of tribal dominated districts of Andhra Pradesh.

District/Cluster	Crop	No. of trials	Cost of cultivation		Net return		Return per Rupee investment	
			BN	FP	BN	FP	BN	FP
			---------------------------*Rs./ha*---------------------------					
Adilabad (Seethagondi)	Cotton	14	23,967	21,287	30,783-55,533 (47,174)[1]	19,213-38,113 (28,540)	2.28-3.32 (2.97)	1.90-2.79 (2.34)
	Chickpea	14	11,736	9,536	5,564-14,214 (9,123)	2,228-8,110 (5,898)	1.47-2.21 (1.78)	1.23-1.85 (1.62)
Khammam (Tummalacheruvu)	Cotton	15	23,967	21,287	15,033-70,533 (49,210)	5,713-53,713 (35,828)	1.63-3.94 (3.05)	1.27-3.52 (2.68)
Nalgonda (Dupahad)	Groundnut	14	18,500	16,300	8,380-13,840 (11,068)	2,600-8,900 (6,317)	1.45-1.75 (1.60)	1.16-1.55 (1.39)
	Green gram	12	12,173	9,973	4,207-8,995 (6,691)	2,375-4,895 (3,527)	1.35-1.74 (1.55)	1.24-1.49 (1.35)
	Tomato	10	58,074	55,874	47,526-78,326 (63,486)	12,926-43,726 (30,526)	1.82-2.35 (2.09)	1.23-1.78 (1.55)
Warangal (Jaffergudem)	Bhendi	10	39,030	36,830	15,570-38,370 (30,345)	4,570-24,370 (15,370)	1.40-1.98 (1.78)	1.12-1.66 (1.42)
	Cotton	13	23,967	21,287	9,033-22,533 (16,733)	10,213-17,713 (13,613)	1.38-1.94 (1.70)	1.48-1.83 (1.64)
Kadapa (B. Yerragudi)	Groundnut	13	9,500	7,300	2,050-11,500 (6,299)	575-7,138 (3,533)	1.22-2.21 (1.66)	1.08-1.98(1.48)
Anantapur (Pampanur)	Groundnut	9	9,500	7,300	5,200-7,300 (6,345)	3,200-6,875 (5,205)	1.55-1.77 (1.67)	1.44-1.94 (1.51)

BN = SSNM, or Balanced Nutrition
FP = Farmer's practice
[1]Values in parentheses indicate mean values

Table 5. Impact of SSNM implementation on weekly consumption of vegetables in households (g day^{-1}) in three tribal districts.

District	SSNM participant farmer	Check farmer (without SSNM)
Adilabad	350	200
Nalgonda	480	210
Khammam	450	350

Average household size of five members

MARI, BAIF, KVK, Adilabad, AAKRUTI, ANGRAU, ICRISAT, and SWC agencies) in the eight districts in collecting and analyzing the samples is gratefully acknowledged. Thanks are also due to the farmers who so willingly guided the project team and provided the necessary information, logistical support and assistance during the course of investigations.

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The paper "Impacts of Participatory Site Specific Potassium Management in Several Crops in Rainfed Regions of Andhra Pradesh, India" also appears at:

Regional Activities/India

Research Findings

Thyme experimental plot in Sahili, near the city of Izmir, Turkey. Photo by IPI.

Effect of Potassium Fertilization on Essential Oils of Garden Thyme (*Thymus vulgaris* L.)

Eryüce, N.[(1)(2)], D. Anaç[(2)], Ö. Gürbüz Kılıç[(3)] and C. Ceyhun Kılıç[(4)]

Introduction

Thyme (*Thymus vulgaris* L.), a significant aromatic plant with around 100 species in the world, is widely used for medicinal purposes as well as in culinary dishes. There are around 40 thyme species in Turkey of which 14 are endemic (Anonymous, 2010). Most of these species grow in the wild and are harvested from the countryside, with only five percent cultivated commercially. Garden thyme has natural antibiotic properties as a consequence of the presence of thymol which constitutes around 50 percent of the total essential oils. Carvacrol is also of importance in this respect (Anonymous, 2009). It is well known that many extracts from aromatic plants possess antimicrobial properties (Yousef and Tawil, 1980). It has also been reported that carvacrol and thymol have antioxidant as well as antibacterial and antifungal effects (Aureli *et al.*, 1992).

It is widely recognised that application of mineral nutrients in fertilizers can influence the mineral and organic composition of aromatic plants, including thyme. For example at the same rate of nitrogen (N) application to thyme, ammonium nitrate treatment showed a higher percentage composition of thymol as compared with urea (Sharafzade *et al.*, 2011). In general, potassium (K) is a plant nutrient which increases yield and quality so it might therefore be considered

(1) Corresponding author: nevin.eryuce@ege.edu.tr
(2) Ege University, Agriculture Faculty, Department of Soil Science Plant Nutrition, Bornova, Izmir, Turkey
(3) Celal Bayar University, Akhisar Vocational School, 45600 Akhisar, Manisa, Turkey
(4) Ege University, Bayındır Vocational Training School, 35840 Bayındır, Izmir, Turkey

to be beneficial for production of essential oils in thyme. Some evidence of this is apparent from the findings of Hornok (1983) who reported that applying 180 kg ha^{-1} K_2O fertilizer increased total essential oil content.

The objective of this project was to examine the effect of different K rates on yield, content of macronutrient elements and essential oil compounds of garden thyme (*Thymus vulgaris* L.) and their interrelationships.

Table 1. Physical properties and fertility status of the experimental soil.

Depth	Texture	pH	Soluble salts	Organic matter	$CaCO_3$	N	P	K	Ca	Mg
cm			-------------------	%	-------------------		------------	*mg kg^{-1}*	------------	
0-20	Sandy loam	7.46	0.047	0.98	20.95	0.07	1.18	118	3,240	23
20-40	Sandy loam	7.69	<0.02	0.62	26.78	0.03	1.48	59	3,360	24

Table 2. Yield and macronutrient elements content of the dried herbal material.

K rate (basal +side dressing)	Yield	Nutrient elements				
		N	P	K	Ca	Mg
kg K_2O ha^{-1}	*kg ha^{-1} fw*	----------------	----------------	% dm	----------------	----------------
K_1 (67.5)	26,300 b	2.05	0.184	2.67	1.51	0.299
K_2 (67.5+100)	26,400 b	2.14	0.209	2.90	1.50	0.306
K_3 (67.5+200)	26,800 a	2.07	0.204	2.49	1.51	0.293
K_4 (67.5+300)	27,000 a	2.06	0.202	2.72	1.50	0.293
LSD	132.9**	ns	ns	ns	ns	ns

** Significance at P <0.01 level

Materials and methods

The soil of the experimental site was sandy loam in texture, slightly alkaline in reaction, low in organic matter, high in $CaCO_3$ and unaffected by soluble salts. The experimental soil was poor in N, P, K and Mg but rich in Ca (Table 1).

The experiment was performed in a garden thyme plantation where four different rates of K_2O (K_1, K_2, K_3 and K_4) were applied as the treatments for this study in a Randomized Block Design with four replicates per treatment. As a basal dressing, 67.5 kg ha^{-1} N, P_2O_5, and K_2O were given to all plots (each measuring 10.0 x 1.4 = 14.0 m^2) at constant amounts by incorporating 450 kg ha^{-1} 15:15:15+Zn early in spring. As a side dressing, late in the spring, an additional 67.5 kg ha^{-1} P_2O_5 was given to all of the treatment parcels in the form of phosphoric acid (H_3PO_4). To establish the K treatments, 0, 100, 200 and 300 kg ha^{-1} K_2O in the form of potassium sulphate (K_2SO_4) were also side dressed at the same time as H_3PO_4. In total, the K_2O doses were 67.5, 167.5, 267.5 and 367.5 kg ha^{-1}. Green herbal material (leaf, stalk and flower at the beginning of flowering) was collected and weighed three times during the harvesting season. Soil from the experimental site was sampled from two depths and analyzed for physical and chemical properties. Mineral nutrient elements (Ryan *et al.*, 1996) and essential oils were analyzed in the dried plant material at the second harvest. The essential oils were extracted by hydro-distillation for three hours using a Clevenger type apparatus. The composition of essential oil constituents (%) was determined using gas chromatography and mass spectrometry (GC-MS) (Toncer *et al.*, 2009).

Results

Yield and macronutrient element contents of the herbal material are presented in Table 2. The fresh yield values were between 26,300-27,000 kg ha^{-1}. The mineral nutrient contents in the dried material were as follows: N (2.05-2.14%), P (0.184-0.209%), K (2.49-2.90%), Ca (1.50-1.51%), and Mg (0.293- 0.306%).

Yield showed an increasing trend with the increasing rates of K. According to the findings, the K_3 application (267.5 kg ha^{-1} K_2O) seems to be the most appropriate rate for an economic yield (data of economic analysis not shown).

Excluding Ca content of the dried plant material which was not influenced by K treatments, other macronutrient elements (N, P, K, Mg) were almost all higher at the higher rates of K compared to the K_1 treatment where only 67.5 kg ha^{-1} K_2O was applied as a basal dressing. Macronutrient elements reached the highest values in the K_2 treatment.

The four major oil constituents found were thymol, para cymen, carvacrol and G terpinen, as also reported by Sharafzade *et al.*, 2011. According to analysis of statistical variance, the effect of K applications on the essential oils content was not significant. However, a positive correlation was observed between the rate of K application and the plant levels of thymol and carvacrol expressed in terms of percentage distribution of the essential oil constituents (0.9184 and 0.9431 respectively) (Fig. 1). Data in Fig. 1 also shows a negative correlation between K application rate and percentage of para cymen (-0.6391) but no correlation between K application and the

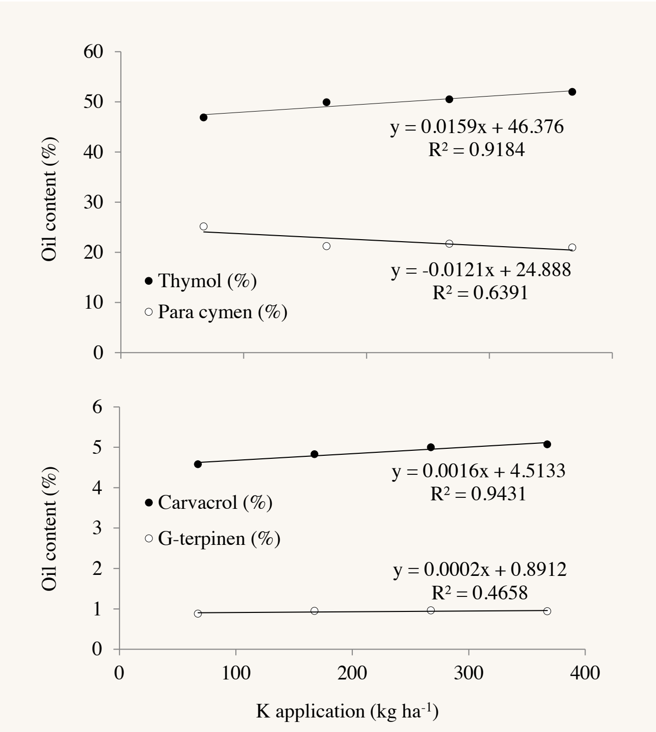

Fig. 1. Correlation between rate of K application and the levels of the four main essential oils in garden thyme (*Thymus vulgaris* L.) as percentage of the total.

Thyme was used by the ancient people of the Mediterranean, and now a "must" in many cuisines. Photo by IPI.

percentage of G-terpinen. From these data it may be suggested that either the increasing amounts of thymol and carvacrol or increasing rates of K_2O applications decreased the para cymen contents of garden thyme.

To conclude, increasing rates of K increased N, P, K and Mg contents up to K_2 rate and green herb yield up to the K_3 application. However, the results relating to the nutrient elements were not statistically significant. Since the effects of K up to the K_4 rate on the relative distribution of the four essential oil constituents differed between individual oils this might imply that further K doses should be tested to reach a stable trend.

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The paper "Effect of Potassium Fertilization on Essential Oils of Garden Thyme (*Thymus vulgaris* L.)" also appears at:

Regional Activities/WANA

IPI Events

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. Details are available on the IPI website, or contact Mr. Eldad Sokolowski, IPI Coordinator China.

Other Events

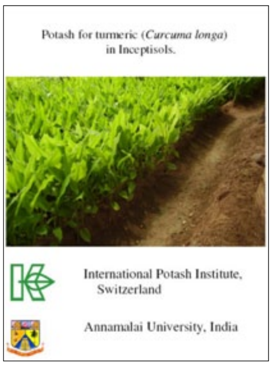
May 2012

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.

July 2012

11th International Conference on Precision Agriculture, 15-18 July 2012, Hyatt Regency, Indianapolis, Indiana, USA. For more details go to the conference website.

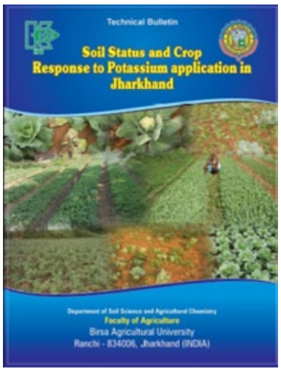
Publications



Potash for Turmeric (*Curcuma longa*) in Inceptisols. 2012.

8 p. English and Tamil. Edited by Karthikeyan, P.K., and P. Imas.

This booklet describes, with pictures and figures, potash fertilization in turmeric crop in Tamil Nadu, India. Turmeric has a high demand for potassium and yield production generally responds to increased soil fertility. The quantity of fertilizers required by the crop depends on the variety selected, as well as soil and prevailing weather conditions during crop growth. Copies are available from Dr. P.K.Karthikeyan., Ph.D., PGDBA (NZ), Assistant Professor Dept. of Soil Science and Agricultural Chemistry, Faculty of Agriculture, Annamalai University Chidambaram-608002, India or download from IPI website in English or Tamil.



Soil Status and Crop Response to Potassium Application in Jharkhand. 2012.

8 p. English. Edited by Sarkar, A.K., R. Kumar, and S. Karmakar.

The geographical area of the State of Jharkhand is 7.9 million ha, out of which net sown area is 2.4 million ha. At present Jharkhand state is producing 3.6 million tones of vegetables. Jharkhand has the potential for higher production of vegetable crops by adoption of improved management practices and soil health care. Among the major plant nutrients (NPK), potassium requirement in vegetables is fairly high as compared to the food grains, and lack of K brings about a drastic change in production quality as well as shelf life. Available to download from the IPI website, or order a hardcopy from Dr. A.K. Sarkar, Dean (Agriculture), Birsa Agriculture University, Ranchi, India.

K in the Literature

Long-Term Effects of Soil Fertility Management on Carbon Sequestration in a Rice-Lentil Cropping System of the Indo-Gangetic Plains.

Ch., B. Venkateswarlu, R. Lal, A.K. Singh, K.P.R. Vittal, S. Kundu, S.R. Singh, and S.P. Singh. Soil Sci. Soc. 76(1):168-178. 2012

Abstract: Enrichment of soil organic carbon (SOC) stocks through sequestration of atmospheric CO_2 in agricultural soils is important because of its impacts on soil quality, agronomic production, and adaptation to and mitigation of climate change. In a 21-yr field experiment conducted under subhumid tropical conditions in India, the impacts of crop residue C inputs were assessed for the rice (*Oryza sativa* L.)–lentil (*Lens esculenta* Moench) cropping sequence. These impacts were evaluated in an experiment involving mineral fertilizers and manuring treatments on crop yield sustainability with reference to critical biomass requirements for maintenance of SOC in an Inceptisol. Application of farmyard manure (FYM) without and with mineral fertilizers increased C input and SOC concentration and stock. In comparison with the control, the 100% organic (FYM) treatment had significantly higher profile SOC (27.5 Mg ha^{-1}), and more C build up (55.0%) and C sequestration (6.6 Mg C ha^{-1}) to 1-m depth vis-à-vis the antecedent values in 1986. These parameters were also higher in 100% FYM treatment at a rate providing equivalent amount of the recommended dose of N followed by conjunctive use of FYM and mineral fertilizers. The SOC stock and rate of sequestration were positively correlated with cumulative C input, and with sustainable yield index (SYI) of upland rice and lentil. Higher grain yield (1.95 and 1.04 Mg ha^{-1} of rice and lentil, respectively) was obtained with the application of 50% organic (FYM)+50% recommended dose of fertilizer (RDF). In comparison, higher SOC sequestration rate was measured with the application of 100% organic (FYM). For every Mg increase in SOC stock in the root zone there was 0.16 and 0.18 Mg $ha^{-1}yr^{-1}$ yield increase of rice and lentil, respectively. For maintaining a stable SOC level (zero change due to cropping), a minimum quantity of 2.47 Mg C ha^{-1} yr^{-1} is required for this soil, climate, cropping system, and fertilization treatments. To achieve this quantity of C, 7.1 Mg of biomass is required to be produced every year vs. average rice and lentil yields of 1.6 and 0.7 Mg ha^{-1}, respectively. The sole application of mineral fertilizers at 50 or 100% of the RDF did not maintain the SOC stock. Thus, application of FYM (or other organics) in conjunction with mineral fertilizers is essential to maintaining and enhancing the SOC stock in the rice-based cropping systems.

Phosphorus and Potassium Fertilization Do Not Affect Soybean Storability.

Krueger, K. A.S. Goggi, R.E. Mullen, and A.P. Mallarino. Agron. J. 104(2):405-414. 2011.

Abstract: Few studies have investigated the influence of P and K fertilization on soybean [*Glycine max* L. (Merr.)] seed storability. The objectives were to determine the effect of P and K fertilizer rates and seed storage environments on soybean seed quality and seed carry-over potential. Seed lots were harvested from a long-term P and K trial. The plants were grown on replicated plots fertilized with one of four rates of P or four rates of K (0, 28, 56, 112 kg P_2O_5 ha^{-1}/0, 35, 70, 140 kg K_2O ha^{-1}) broadcast by hand in the fall. Seed samples were stored in four different storage environments: continuous climate controlled warehouse; continuous nonclimate controlled warehouse; nonclimate controlled warehouse and 1 mo at 12-h alternating temperatures of 4.5° and 15.5°C; and nonclimate controlled warehouse and 2 mo at alternating temperatures, with the first month at 4.5° and 15.5°C and second month at 10°C and 32.2°C. Most seed lots stored under ideal conditions were below the recommended value of 95% germination and 80% vigor following 13 mo of storage. Seed storage environments that experienced high temperature (>20°C) and relative humidity (RH) (>80%) rapidly decreased in seed viability and vigor to unacceptable levels. Phosphorus and K fertilization did not improve seed storability, although higher rates of K fertilization increased seed survival in poor storage environments for a short time. Seed producers should not store soybean seed for two growing seasons, regardless of storage environment and P and K fertilization levels in the seed production field.

Maize Response to Fertilizer and Nitrogen Use Efficiency in Uganda.

Krueger, K. A.S. Goggi, R.E. Mullen, and A.P. Mallarino. Agron. J. 104(2):405-414. 2011.

Abstract: Maize (*Zea mays* L.) is an important smallholder crop in Uganda. Yields are low because of low soil fertility and little fertilizer use. Yield response to nutrient application and economically optimal rates (EOxR, where x = N, P, or K) and N use efficiency (NUE) were evaluated. Twenty-two trials were conducted in four agroecological zones. Yield was consistently increased with N application. Mean maize yield with no N applied (N_0) was 1.79 Mg ha^{-1} and increased by 120% with N application. Mean EONRs were 45 to 24 kg ha^{-1} N with fertilizer use cost to grain price ratios (CPs) of 10 to 30. With N applied, the mean increase in yield due to P application was 0.28 Mg ha^{-1} and mean EOPRs were 9 to 1 kg ha^{-1} P with CPs of 10 to 50. Yield was not increased with K application. Profitability was greater for N than P application. Mean aboveground biomass N with 0 and 150 kg ha^{-1} N applied

was 46.3 and 94.3 kg ha^{-1}, respectively. Mean N concentration and N harvest index at the EONR were 1.60 and 63.8%, respectively, and higher than for N0. Mean recovery efficiency, partial factor productivity, and agronomic efficiency declined with increasing N rate and were 66%, 86 kg kg^{-1}, and 41 kg kg^{-1}, respectively, at the EONR. Fertilizer N use can be very profitable, with high NUE, for smallholder maize production in Uganda, and the financial capacity of smallholders to use fertilizer will increase with reduced CP.

Potassium Mining in Indian Agriculture.

Srinivasarao, Ch., and T. Satyanarayana. Indian J. Fert. 8(2):22-29. 2012.

Abstract: Intensive production systems in India characterized by heavy removal and inadequate replenishment of nutrients resulted in depletion of soil nutrient reserves and multiple nutrient deficiencies. For sustaining the crop productivity and to restore the soil fertility, there is a need to arrest this depletion. Clear understanding of crop nutrient balance is pre-requisite. There were many attempts to examine the potassium mining at individual plot level, long-term fertilizer experiments, state level and country level. In most of these reports, fertilizer inputs and crop removals were only considered, thus resulting in the large-scale negative K balances in Indian agriculture. In agroecosystem, K is contributed by many sources like animal manure, crop residue, compost, rice burning residue, irrigation water and rain etc. Similarly, besides crop K removal, K is lost to deeper layers by rain or irrigation water by leaching. By considering all these inputs and outputs, the holistic K balance in Indian agriculture is about 3 mt per year. This total negative balance is reduced by considering area under conservation agriculture (about 4 to 5 mha), green leaf manuring like gliricidia and other non-conventional sources of potassium being used in Indian agriculture, which reduces the overall negative balance of K to 2.8 mt annually in Indian agriculture.

Analyzing Nitrogen Use Efficiency in Long-Term Experiments in Rainfed Conditions.

Srinivasarao, Ch., B. Venkateswarlu, K.L. Sharma, P.K. Mishra, B.K. Ramachandrappa, J.J. Patel, and A.N. Deshpande. Indian J. Fert. 7(11):36-44. 2011.

Abstract: Rainfed soils are not only thrusty but also hungry. These soils are highly degraded, low in organic matter and are multi-nutrient deficient. Spectacular response to N application is seen in rainfed crops though application levels of nutrients are very low compared to irrigated agriculture. However, harnessing nutrient supply with optimum soil moisture availability is crucial for improving nutrient use efficiency in rainfed agriculture. This paper deals with N deficiency, nutrient consumption, nutrient uptake and N use efficiency in some long-term manorial trials going on under rainfed conditions.

Effects of Three Commercial Rootstocks on Mineral Nutrition, Fruit Yield, and Quality of Salinized Tomato.

Savvas, D., A. Savva, G. Ntatsi, A. Ropokis, I. Karapanos, A. Krumbein, and C. Olympios. J. Plant Nutr. Soil Sci. 174(1):154-162. 2011.

Abstract: Tomato (*Solanum lycopersicum* Mill. cv. Belladona F1) plants were either self-rooted, self-grafted, or grafted onto the commercial rootstocks “Beaufort”, “He-Man”, and “Resistar” and grown in a recirculating hydroponic system. Three nutrient solutions differing in NaCl-salinity level (2.5, 5.0, and 7.5 dS m-1, corresponding to 0.3, 22, and 45 mM NaCl) were combined with the five grafting treatments in a two-factorial (3 × 5) experimental design. At the control NaCl level (0.3 mM), fruit yield was not influenced by any of the grafting treatments. However, at low (22 mM NaCl) and moderate (45 mM NaCl) salinity levels, the nongrafted and the self-grafted plants gave significantly lower yields than the plants grafted onto He-Man. The plants grafted onto the other two rootstocks gave higher yields only in comparison with the nongrafted plants, and the differences were significant only at low (Beaufort) or moderate (Resistar) salinity. Yield differences between grafting treatments at low and moderate salinity arose from differences in fruit number per plant, while mean fruit weight was not influenced by grafting or the rootstock. NaCl salinity had no effect on the yield of plants grafted onto He-Man but restricted the yield in all other grafting treatments due to reduction of the mean fruit weight. With respect to fruit quality, salinity enhanced the titratable acidity, the total soluble solids, and the ascorbic acid concentrations, while grafting and rootstocks had no effect on any quality characteristics. The leaf Na concentrations were significantly lower in plants grafted onto the three commercial rootstocks, while those of Cl were increased by grafting onto He-Man but not altered by grafting onto Beaufort or Resistar in comparison with self-grafted or nongrafted plants. Grafting onto the three tested commercial rootstocks significantly reduced the leaf Mg concentrations, resulting in clear Mg-deficiency symptoms 19 weeks after planting.

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Soil Fertility of Tropical Intensively Managed Forage System for Grazing Cattle in Brazil.
Alberto C. de Campos Bernardi, Patrícia P.A. Oliveira and Odo Primavesi, Embrapa Pecuária Sudeste, São Carlos - SP, Brazil. *In*: Soil Fertility Improvement and Integrated Nutrient Management - A Global Perspective. p. 37-56. 2012. InTech.

Constraints and Solutions to Maintain Soil Productivity: A Case Study from Central Europe.
Grzebisz, W., and J. Diatta. Department of Agricultural Chemistry and Environmental Biogeochemistry, Poznan University of Life Sciences, Poland. *In*: Soil Fertility Improvement and Integrated Nutrient Management – A Global Perspective. p. 159-182. 2012. InTech.

Grain Yield and Carbon Sequestration Potential of Post Monsoon Sorghum Cultivation in Vertisols in the Semi Arid Tropics of Central India.
Srinivasarao, Ch., A.N. Deshpand, B. Venkateswarlu, Rattan Lal, Anil Kumar Singh, Sumanta Kundu, K.P.R. Vittal, P.K. Mishra, J.V.N.S. Prasad, U.K. Mandal, and K.L. Sharma. April 2012. Geoderma 175-176:90-97. 2012.

Cotton Shoot Plays a Major Role in Mediating Senescence Induced by Potassium Deficiency.
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Harper, D.C., D.M. Lambert, J.A. Larson, and C.O. Gwathmey. February 2012. Agricultural Systems 106(1):84-93.

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Land Degradation and Development: Long-Term Manuring and Fertilizer Effects on Depletion of Soil Organic Carbon Stocks under Pear Millet-Cluster Bean-Castor Rotation in Western India.
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Grafting onto Different Rootstocks as a Means to Improve Watermelon Tolerance to Low Potassium Stress.
Yuan Huang, Jing Li, Bin Hua, Zhixiong Liu, Molin Fan, Zhilong Bie. March 2012. Scientia Horticulturae.

Appropriate Fertilizer Use and Fertilization Technology for Sustainable Crop Production.
Kenichi Kubo. October 2010. FFTC, Extension Bulletin 635.

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- **Nitrogen and Potassium Fertilization Responses of Potato (*Solanum tuberosum*) cv. Spunta.** V. Kavvadias, C. Paschalidis, G. Akrivos & D. Petropoulos. p. 176-189. DOI: 10.1080/00103624.2012.634711
- **Influence of Salt Stress on the Nutritional State of *Cordyline fruticosa* var. Red Edge, 2: Sodium, Potassium, Calcium, and Magnesium.** Plaza, B.M., S. Jiménez, and M.T. Lao. p. 234-242. DOI: 10.1080/00103624.2011.638583.
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- **Assessment of the Nitrogen and Potassium Fertilizer in Green Bean Irrigated with Disinfected Urban Wastewater.** Segura, M.L., Juana Isabel Contreras París, Blanca María Plaza, and M.T. Lao. p. 426-433. DOI: 10.1080/00103624.2011.638604.
- **Growth and Nutritional Response of Melon to Water Quality and Nitrogen Potassium Fertigation Levels under Greenhouse Mediterranean Conditions.** Contreras, J.I., B.M. Plaza, M.T. Lao, and M.L. Segura. p. 435-444. DOI: 10.1080/00103624.2012.641821.

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

New IPI Coordinator for Southeast Asia: Mr. Aliaksei Shcharbakou

The International Potash Institute (IPI) is pleased to announce that Mr. Aliaksei Shcharbakou has joined the IPI team as Coordinator for its activities in the Southeast Asia region.

IPI activities in Southeast Asia started more that 30 years ago. It is now an opportunity for the institute to consolidate its activities in the region, said Mr. Hillel Magen, IPI Director. He also added that, besides important crops such as rice, maize and oil palm, additional crops - including soybean and other legumes, cassava, and sugarcane, amongst others – all make significant contributions to the food security, feed and fuel requirements of the region. IPI's role is to engage in improving nutrient management in these crops.

Mr. Shcharbakou was born in Armenia and at an early age moved with his family to Belarus. Mr. Shcharbakou has a diversified academic career. After studying agriculture for five years, he was awarded a Diploma in Agronomy Science from the Grodno Agricultural Institute, Belarus, in 1998. He then went on to study jurisprudence (philosophy of law), specializing in agricultural law to achieve a Diploma in Law.

Mr. Shcharbakou's professional career also started at the Grodno Agricultural Institute at the Department of Management and Organization in Agriculture. As a lecturer, his areas of expertise included agricultural raw materials and foodstuff markets and organization of the agricultural industry.

In 2004, Mr. Shcharbakou joined Belpromtechservice, Belarus, which provides a wide variety of services to the agriculture industry. As Director of Marketing, he was responsible for integrated market research, advertising, advancement of agriculture chemistry production and technical equipment in different regions, participation in international exhibitions, and teaching seminars for promotion of new products and applied science.

Mr. Shcharbakou began working with JSC Belarusian Potash Company (BPC) in 2007 as Chief Agronomist. Now as Director of Agronomy, he is responsible for the development, implementation and fulfillment of the company's global agronomic marketing programs and strategy. Mr. Shcharbakou is BPC's representative at several agricultural institutes and international organizations. Living in Singapore and well acquainted with the region, Mr. Shcharbakou's experience will be valued in the successful coordination of IPI's research and extension programs in this significant agricultural region.

Mr. Aliaksei Shcharbakou can be contacted at:

a.shcherbakov@belpc.by
c/o JSC Belarusian Potash Company
101 Thomson Road
#28-02 United Square
Singapore 307591
T +65 6251 1108
F +65 6251 1098
M +65 9848 6206

New IPI Coordinator for Eastern Europe: Dr. Gennadi Peskovski

The International Potash Institute (IPI) is pleased to announce the appointment of Dr. Gennadi Peskovski as the IPI Coordinator for Eastern Europe. His role involves initiating and managing research and dissemination activities in the Ukraine, Baltic States and other countries within the region.

Born in Belarus, Dr. Peskovski graduated with a Master of Arts in Agricultural Sciences from the Grodno Agricultural Institute before completing his PhD studies Warsaw Agricultural University, Poland.

Before joining JSC Belarusian Potash Company (BPC) in 2010, Dr. Peskovski held several positions in the agri-sector in Belarus and Poland. He is fluent in Russian, Polish and English. Dr. Peskovski works in the BPC Sales Department providing customers with agronomic advice.

"Dr. Peskovski's extensive knowledge of the agriculture sector in Eastern Europe will greatly assist IPI in raising awareness of potash fertilizer usage," says Hillel Magen, IPI Director. "This region has enormous potential to produce a greater quantity of quality agricultural products. With Dr. Peskovski's coordination, IPI is looking forward to cooperating with scientists and extension officers across the region to maximize productivity through improved plant nutrition."

Dr. Gennadi Peskovski can be contacted at:
g.peskovski@belpc.by
c/o JSC Belarusian Potash Company
2 Melnikaite Street
220004 Minsk, Belarus
T +375 17 211 04 43
F +375 17 211 29 17
M +375 44 753 48 00

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Address:	International Potash Institute P.O. Box 260 Baumgärtlistrasse 17 CH-8810 Horgen, Switzerland
Telephone:	+41 43 810 49 22
Telefax:	+41 43 810 49 25
E-mail:	ipi@ipipotash.org
Website:	www.ipipotash.org

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