Research findings

III Potassium nutrition in balanced fertilization of a Soybean-Wheat cropping system in Madhya Pradesh, India.

Based on a report submitted to IPI by the National Research Centre for Soybean (NRCS), Indore, Madhya Pradesh, India.

Background to the work

Soybean, the second most important oilseed crop of India has only been cultivated commercially over the past three decades but is providing resilience to the country's oilseed production. During this period the productivity of the crop has shown a gradual increase, but yields over the past few years have more or less reached a plateau of about 1 t/ha. This is because of a deficit and erratic distribution of rainfall and uncertainty in the onset of the Monsoon. Being rain-fed, the productivity of oilseeds in general and soybean in particular has been far below the potential achievable yield. Constraint analyses have indicated however, that imbalanced nutrition is also one of the important reasons for stagnation in productivity.

It is a general practice among farmers of major soybean growing regions in this area to apply some N and/or P mostly as di-ammonium phosphate or single super phosphate (SSP) although at sub-optimal levels. Similarly low rates of applications are also, to a large extent, the case for K based on the misconception that K is a high status nutrient in the soil and in vertisols in particular. In fact, even recommended levels of K application can be insufficient to meet the requirement of the soybean crop as well as that of a soybean based cropping system.

An average soybean crop uptake is about 101-120 kg K/ha and there has been a discrepancy between recommendations for K application and crop requirements.

Effect of 50 kg K_2O/ha applied to soybean crop. IPI-NCSR project in Indore, MP. Photo by P. Imas.

In investigations of net depletion of K (sum total of available and non-exchangeable K) from the soil profile following repeated cropping cycles of soybean-wheat - a frequently practiced rotation in this region - losses of K from the soil were quantitatively much higher than expected. There has thus been an important need to investigate the K nutrition of a soybean-wheat cropping system so as to optimize the productivity from the system by way of making a balanced fertilization by which yields of soybean are improved without depressing those of wheat. Besides its effect on yield and crop quality, K is known to play an important physiological role including building up resistance to insect pests and crop diseases. This aspect has also been considered.

The Experiments

Two types of experiment were conducted during 2004-05 on Vertisols and associated soils in which soybean was cultivated during the rainy (Kharif) season to be then followed by a wheat crop. An experimental field trial at the Research Farm of the National Research Centre for Soybean, in a randomised block design (plot size 3.6m x 6.0m), compared nine K fertilizer treatments which were applied to both crops. Recommended dressings of N and P were made from soil analyses taken at the onset of the experiment, the basal dressing for soybean being 20 kg N and 60 kg P_2O_5/ha and for the subsequent wheat crop 120 kg N and 60 kg P_2O_5/ha. For both crops P, in the form of SSP, was applied at sowing. For soybean N, as urea, was applied at sowing while for wheat the application was divided equally between sowing and first irrigation. The cultivars used were: Soybean (cv. JS 93-05) and wheat (cv. Sujata). A second set of experiments was carried out simultaneously under farm conditions in three villages but with fewer K treatments. The soybean and wheat varieties grown were JS 335 and Sujata, respectively. Soil properties of the experimental plots are shown in Table 1.

Characteristics	NRCS farm	Village Umrikheda	Village Gokanya	Village Simrol
pH	7.8	7.8	7.7	7.9
EC (dS/m)	0.2	0.2	0.13	0.28
Organic Carbon (%)	0.48	0.60	0.87	0.74
Available N (kg/ha)	180	195	264	249
Available P (kg/ha)	8.41	8.56	11.42	9.30
Available K (kg/ha)	302	326	378	295

Table 1. Soil characteristics of NRCS farm and villages participating in the experiment (Kharif 2004).

Response to Potassium

The experimental field trial

Agronomic and economic benefits

In the 2004-2005 experiment, K application significantly improved the grain yields of both soybean and the subsequent wheat crop (Table 2) indicating that the limitation to the much needed improvement in yields was K deficiency. For both soybean and wheat the split application of potassium gave a slightly higher response than the basal application. The least effective treatment for both crops, in terms of yield**,** was the two spray foliar application. By doubling the spraying, the treatment was more effective in increasing grain yield so that in soybean it was significantly greater

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Level of K_2O (kg/ha)		Soybean grain yield	Wheat grain yield	AE_K [(1)] Soybean	AE_K [(1)] Wheat	Additional returns[(2)]	Additional costs[(2)]	GRF[(2,]
Soil application		*kg/ha*	*kg/ha*	*Kg grain/kg K*		*Rs/ha*	*Rs/ha*	*Rs/ha*
0		1,510	3,579	-		-	-	-
25	basal	1,807	4,872	11.88	51.72	15,792	488	15,304
50	basal	1,983	4,984	9.46	28.10	19,264	798	18,466
75	basal	1,994	4,984	6.45	18.47	19,236	1,106	18,130
25	50% basal + 50% at flowering	1,870	4,964	14.40	55.40	17,500	668	16,832
50	50% basal + 50% at flowering	2,259	5,499	14.98	38.40	27,762	978	26,784
75	50% basal + 50% at flowering	2,062	4,980	7.36	18.68	20,328	1,286	19,042
Foliar application								
2 spray @ 0.5 % KCl at flowering and 1 week after flowering		1,736	3,955	45.20	75.20	6,552	483	6,130
4 spray @ 0.5% KCl at flowering and 1 week after flowering		1,902	4,135	39.20	55.60	10,486	725	10,002
CD (P=0.05)		279.17	543		-	-	-	-

(1) AE_K = Agronomic efficiency of K (kg grain increase / kg K applied)
(2) Additional returns, costs and calculated GRF were on the basis of the whole cropping system (Kharif soybean and Rabi wheat)
(3) GRF = gross return above fertilizer costs

Table 2. Effect of soil and foliar application of potassium on productivity of soybean and wheat and economics of potash application to the wheat-soybean cropping system.

than the control. The highest grain yield for soybean of 2,259 kg/ha was obtained from the split 50 kg K_2O/ha treatment which also produced the highest wheat grain yield of 5,499 kg/ha. The highest additional yields over the respective controls were thus 749 kg/ha for soybean and 1,920 kg/ha for wheat.

The response to K as expressed by the agronomic efficiency of K (AE_K), the ratio of the kg grain increase to the kg K applied, for soybean ranged from 6.45 (75 kg K_2O basal treatment) to 45.20 (2 sprays of 0.5% KCl). For wheat the range was between the same two treatments but the values were higher from 18.47 to 75.20. The foliar application treatments, although having high agronomic efficiency, were low in grain yields because of the associated low rates of K application. The GRF (Gross return above fertilizer costs) represents the additional returns from the yield increase less the additional costs and is calculated here on the basis of the whole cropping system (Kharif soybean and Rabi wheat). The GRF values as ranging from 6,130 to 26,784 Rs/ha (USD 1 = ~Rs 47), from the 2 spray foliar application to the split basal and flowering application of 50kg K_2O/ha, show the enormous benefit of potassium fertilization in this soybean-wheat crop sequence. Repeating the experiment for soybean in 2005, the results confirmed the findings reported here.

Resistance to Insects and Crop Disease

The benefits of potassium nutrition in providing resistance to both insect infestations and plant disease on soybean are shown very clearly in Table 3 and Fig 1. .Highest insect infestation and plant disease was found in the untreated crop plants. Applying K markedly depressed insect infestation in the case of blue beetle (*Cneorane spp)* and the defoliators expressed by the number of insects per meter row length (mrl). This was also the case for the percentage disease incidence of stem fly *Melanagromyza sojae* (Zehnt) and the Girdle beetle (*Oberia brevis*). Similarly increased K application depressed the percentage

Level of K_2O (kg/ha)		Insect infestation by				Disease incidence by	
		Blue beetle	Stem fly; Stem tunnelling	Defoliators	Girdle beetle	Collar rot	Myrothecium leaf spot
Soil application		*mrl* [(1)]	*%*	*mrl*	*%*	*% mortality*	*PDI*[(2)]
0		5.9	13.91	1.3	8.35	9.17	38.57
25	basal	2.0	3.87	1.0	2.17	6.07	28.45
50	basal	1.8	2.87	0.8	2.06	4.61	22.58
75	basal	1.3	0.00	0.7	1.91	2.22	25.41
25	50% basal + 50% at flowering	1.8	5.25	0.7	4.70	5.60	22.88
50	50% basal + 50% at flowering	1.8	3.36	0.7	3.29	4.17	26.69
75	50% basal + 50% at flowering	1.6	3.01	0.7	2.47	2.29	27.57
Foliar application							
2 spray @ 0.5 % KCl at flowering and 1 week after flowering		5.1	4.66	0.7	4.37	2.09	29.33
4 spray @ 0.5% KCl at flowering and 1 week after flowering		5.1	4.17	0.6	4.12	2.63	32.12

Table 3. Effect of soil and foliar application of potassium on insect infestation and disease incidence in soybean during Kharif 2004.

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mortality by collar rot, caused by the fungus *Sclerotium rolfsii* and leaf spot and petiole rot resulting from the pathogen *Myrothecium roridum*.

The reason for the higher incidence of damage by insects and plant pathogens in plants poorly supplied with K is still a matter of discussion. It may in part relate to the function of K in the development of thicker outer walls in the epidermal cells, thus providing protection against plant and animal attack. Additionally, K deficiency is known to impair the synthesis of high molecular weight compounds in the cell (proteins, starch and cellulose) which gives rise to the accumulation of low molecular weight compounds, such as sugars and amino acids, which can provide a ready source of nutrition to animals and plant pathogens.

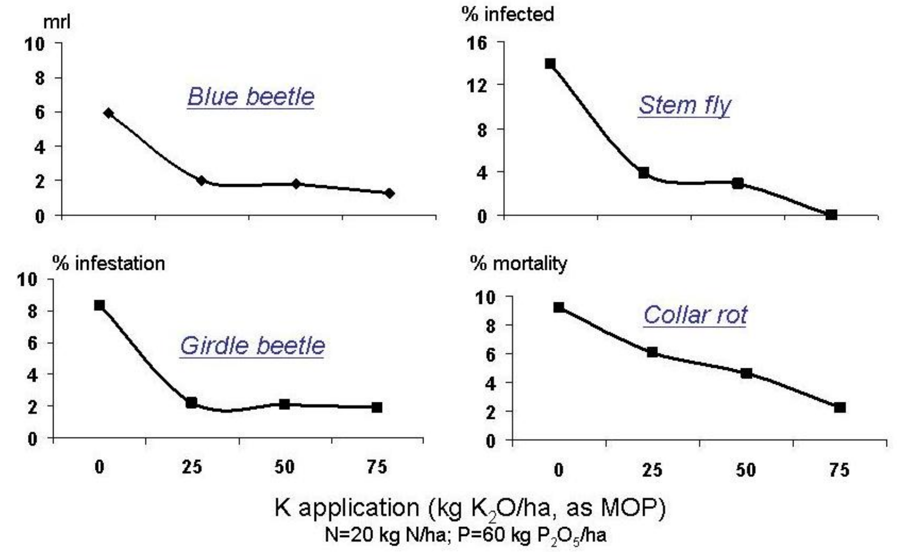

Fig. 1. Effect of K on infection of soybean from various insects and disease. Source: H. Magen; Balanced crop nutrition: Fertilizing for crop and food quality. Presented at the IFA Agriculture Conference, Kunming, 27 Feb.—2 March 2006.

Farmers' Field Trials

Agronomic and economic benefits

The benefits of potash application on the soybean/wheat crop sequence found in the research station field trial was confirmed under practical agricultural practice in the farmers' field trials. These trials demonstrated a marked response to K in terms of soybean equivalent yield (SEY) in kg/ha (Table 4). At all three locations the highest yield was obtained in the 50K_2O kg/ha split application treatment as also recorded at the NRCS research station. For the mean values obtained from the three fields, increasing rates of application of K_2O kg/ha from zero in the control to 25 basal, 50 basal, and 25 basal and 25 at flowering, raised the SEY by 13.3%, 31.1% and 33.1% respectively.

The agronomic use efficiency of K (AE_K) rose with increasing K application from 16.44 and was highest at 20.48 with the split 50 K_2O kg/ha treatment. The GRF (gross return above fertilizer costs in Rs/ha) – the most important figure and "bottom line" for the farmer – calculated by the additional returns less the additional costs in potash application, increased from 5,266 to 12,670 to 13,358 for the three potash treatments respectively. This remarkable return demonstrates at first hand to the farmer the benefits which can accrue by applying potash to these soils and to the soybean/wheat cropping system in particular.

India has almost tripled its soybean production over the last 15 years to almost 6.5 million tonnes per year. Nevertheless productivity has remained the same at around 1 tonne/ha so that all the increase in production has been achieved by increasing the area of land used for cultivation. Being an important component in the soybean-wheat cropping system, the need to improve productivity of soybean is crucial.

Edited by E. A. Kirkby.

Name of farmer	Village	Soybean equivalent yield (kg/ha) K_2O level: 0	25 (basal)	50 (basal)	25 (basal) + 25 (at flowering)
Shri Narayan	Umrikheda	2,921	3,086	3,679	3,984
Shri Radheshyam Patel	Gokanya	2,762	3,260	3,866	3,781
Shri Shivnarayan	Simrol	3,589	4,161	4,616	4,580
Mean		3,091	3,502	4,053	4,115
AE_K		-	16.44	19.24	20.48
Additional Returns (Rs/ha)		-	5,754	13,468	14,336
Additional cost (Rs/ha)		-	488	798	978
GRF (Rs/ha)		-	5,266	12,670	13,358

Table 4. Effect of potassium nutrition on productivity and economics of soybean-wheat cropping system under real farm situations during 2004-05.