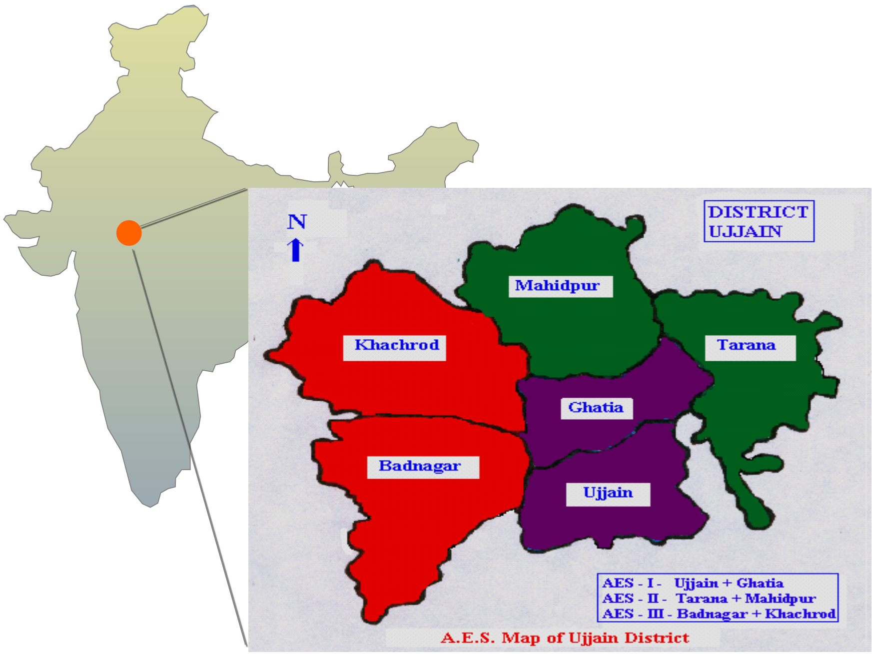
# Research Findings

## Assessment of Potassium Nutrition in Soybean for Higher Sustainable Yield in Medium Black Soils of Central India

*Dixit, A.K.[(1)(2)], D.S. Tomar[(2)], A. Saxena[(2)], and S.K. Kaushik[(2)].*




*Agro-ecological situations in the Ujjain district.*
*Source: Directorate of Agriculture, Government of Madhya Pradesh, India.*

### Introduction

Soybean is a major oil and protein crop important in both human and animal nutrition. Rising demand for oil and protein has stimulated soybean production mainly by increasing land use, as very modest growth in productivity has been achieved (Table 1). Soybean covers an area of about 98.8 million hectares (ha) worldwide, of which 90 percent is concentrated in the US, Brazil, Argentina, China and India. The latter contributes 8 percent of the world area (7.8 million ha). India's figures show the lowest productivity (1,064 kg $ha^{-1}$) compared to a world average of 2,249 kg $ha^{-1}$ (FAOSTAT, 2011). In comparison to 2007, these figures demonstrate a slight decline against the world average but reveal an increase in productivity in India.

**Table 1.** All India, Madhya Pradesh state and Ujjain district soybean production figures, 2006-2010.

| Year | All India | | | Madhya Pradesh | | | Ujjain District | | |
|---|---|---|---|---|---|---|---|---|---|
| | Area | Production | Yield | Area | Production | Yield | Area | Production | Yield |
| | *'000 ha* | *'000 mt* | *kg ha⁻¹* | *'000 ha* | *'000 mt* | *kg ha⁻¹* | *'000 ha* | *'000 mt* | *kg ha⁻¹* |
| 2006-07 | 8,320 | 8,850 | 1,063 | 4,705 | 4,789 | 1,019 | 430 | 468 | 1,087 |
| 2007-08 | 8,880 | 9,990 | 1,124 | 5,202 | 5,368 | 1,033 | 432 | 513 | 1,189 |
| 2008-09 | 9,510 | 9,910 | 1,042 | 5,295 | 5,924 | 1,120 | 444 | 628 | 1,416 |
| 2009-10 | 9,607 | 10,050 | 1,046 | 5,349 | 6,406 | 1,199 | 444 | 671 | 1,511 |

Madhya Pradesh (MP) is generally known as the soybean state of India as it is a leading region in soybean production both in terms of area and productivity (70 and 64 percent respectively) covering 4.8 million ha and producing 1,120 kg $ha^{-1}$ (Table 1). Soybean production in Ujjain district accounts for approximately 10 percent of the state area for soybean, with productivity slightly above that of the state average (Table 1). In a Participatory Rural Appraisal (PRA) conducted in 2007 by the Krishi Vigyan Kendra (KVK) in Ujjain district, the following specific factors were assessed as the cause of low yield:

1. Using a very high seed rate (up to 125 kg $ha^{-1}$) in comparison to the recommended seed rate of 70 to 80 kg $ha^{-1}$, depending upon the seed index. This results in overcrowding of plants causing poor growth, high insect pest incidence and hence a problem of non-bearing.

2. The normal row – row spacing for early maturing, non-spreading varieties is 30 cm, and 45 cm for those which are of long duration and spreading type. Irrespective of variety, farmers use a spacing of 25-30 cm.

3. Burning stubble in the field and non-utilization of organic matter / Farm Yard Manure (FYM) at the recommended rate of 5-10 mt $ha^{-1}$ have resulted in soil compaction with reduced fertilizer use efficiency.

4. Greater use of N and P fertilizers without use of K, S and Zn.

5. Broadcasting DAP at 20-25 days after sowing at the time of intercultural operations or mixing DAP with seed at sowing.

6. Heavy weed population due to use of un-decomposed FYM, a lack of integrated weed management measures, and monocropping.

With the improvement of land productivity through the adoption of high-yielding varieties and multiple

[(1)] *Corresponding author.*
dixitak_2007@rediffmail.com.

[(2)] *Krishi Vigyan Kendra (KVK), Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya (RVSKVV) M.L. Nagar, Ujjain (M.P.), India.*

# Research Findings

cropping systems, fertilizer use has become more and more important to increase oil crop yield and quality. The slow pace of growth in soybean productivity is more or less linked to imbalanced and inadequate nutrition being provided for this energy rich crop (Joshi, 2007). Potassium is known as one of the nutrients which is closely involved in metabolic processes and improves yield (Imas and Magen, 2007 and Basseto *et al*., 2007). Long-term experiments conducted in India showed decline in crop yields as a result of potassium deficiency (Rupa *et al.*, 2003). As most of the kharif soybean is grown under rain-fed conditions, soybean experiences water and temperature stresses of varying degrees, particularly at the stage of pod filling. Yield is thus ultimately affected and the relevance of K nutrition in alleviating stress conditions assumes great importance (Tomar and Dwivedi, 2007). The annual consumption of N, P and K fertilizer per ha is in the ratio 8.5:6.9:1 against an ideal of 4:2:1. The potassium fertilizer in the district is applied at a rate of 1.4 kg $ha^{-1}$ in kharif and 6.8 kg $ha^{-1}$ in rabi.

An increased occurrence of K deficiency in soybeans and the potential widespread onset of Asian rust (SBR) (*Phakopsora pachyrhiza*) in the crop have stimulated interest in new management practices that may improve K nutrition and lower disease incidence. Yield loss estimates for this fungal disease range from 10 to 80 percent in areas where rust is established and could result in huge economic losses.

*Monitoring the experiment in the field. Photo by A.K. Dixit.*

*Potassium balance in soybean based cropping systems*

Consideration of K balance in soybean based cropping systems has served as a rationale behind promoting balanced use of K. Based on the findings of long-term fertilizer experiments across the country, the majority of cropping systems being practised result in a negative K balance since K application seldom matches K removal. Under such conditions, there is greater demand on soil K reserves to meet crop K requirement. In soybean-wheat-cowpea on Vertisols, the total uptake of K by the crops far exceeds the amount of K applied. The plots which did not receive K fertilizer (control, N and NP) under continuous cropping with soybean-wheat showed a greater contribution of soil reserve K to crop uptake, thereby indicating a state of continuous stress on the soil system to meet the K requirements of the crops. The Vertisols and vertic type of soils which predominate in the soybean growing area did have high levels of available K but low reserves of K. These soils were thus able to raise crops without fertilizer K but they are being depleted. Shallow Vertisols of Madhya Pradesh are not self -fertilizing and are hence in need of fertilizer K application (Subbarao *et al.*, 2008).

**Methodology**

KVK Ujjain is engaged in the dissemination of technology to the farming community to boost agricultural production by restoring the natural fertility status of soils. The Ujjain district is located at $20^{\circ}$ 43’ to $23^{\circ}$ 36’ latitude and longitude of $75^{\circ}$ - $76^{\circ}$ 30’ at an altitude of 527 meters above mean sea level. It falls within the $X^{th}$ Agro climatic Zone, i.e. Malwa Plateau and Agro-ecological. The study was carried out in Ujjain district of Madhya Pradesh, India during kharif 2008 in Agro-Ecological Situation I (AES-I; see map) on five farmers’ plots of the Ujjain and Ghatiya block counties of the district Madhya Pradesh.

In the region of the experiment, the common practice of farmers is to apply 100 kg DAP only to soybean and 125 kg of N:P:K fertilizer in the form of 12:32:16 (Indian Farmers Fertiliser Cooperative Limited, IFFCO grade) in wheat only. Hence in the soybean-wheat cropping system in the region, it is only wheat that receives a modest application of potash (approx. 20 kg $K_2O$ $ha^{-1}$). On the basis of the PRA conducted in 2007, KVK concluded that the most prominent cause of low yield (average 10.40 Q $ha^{-1}$) was the imbalanced use of fertilizers including inadequate use of potash in the soybean-wheat cropping system. Farmers do not, in fact, follow the guidelines provided by the

# Research Findings

Directorate of Soybean Research (DOSR, 2007), in which the recommended rate of N, $P_2O_5$, $K_2O$ and S is 20:80:40+20, respectively, as part of the Integrated Nutrient Management System (INMS) that is advocated.

**Table 2.** Effect of potassium fertilization on growth and yield of soybean (2008).

| Treatment | K level | Plant height | Branches / plant | Nodules / plant | Nodule dry Wt./ plant | Pods / plant | Test Wt.[1] | Grain yield | Straw yield | H.I. |
|---|---|---|---|---|---|---|---|---|---|---|
| | *kg ha⁻¹* | *cm* | *No.* | *No.* | *mg* | *No.* | *g* | ----*q ha⁻¹*---- | | *%* |
| T1 (FP) | 0 | 40.68 | 3.05 | 21.45 | 67.4 | 28 | 11.1 | 12.2 | 25.7 | 47.4 |
| T2 | 20 | 41.38 | 3.45 | 26.93 | 87.29 | 30.9 | 11.78 | 13.2 | 27.5 | 48.12 |
| T3 | 40 | 51.26 | 3.96 | 30.27 | 114.84 | 37 | 12.8 | 15.5 | 29.5 | 52.6 |
| SEm± | | 1.61 | 0.16 | 0.99 | 1.83 | 1.31 | 0.20 | 0.35 | 1.28 | 1.52 |
| t value at error DF (0.05) | | 2.31 | 2.31 | 2.31 | 2.31 | 2.31 | 2.31 | 2.31 | 2.31 | 2.31 |
| CD (P=0.05) | | 3.70 | 0.36 | 2.29 | 4.21 | 3.03 | 0.47 | 0.81 | 2.94 | 3.50 |

[1]weight of 100 seeds.

The aim of the work was to assess potash application to soybean crop and compare farmers practice (K=0), the DOSR rate (20) and a higher dose of K (40 kg $K_2O$ $ha^{-1}$). The average soil test values for available N, P and K in the soil were 186, 9.4 and 289 kg $ha^{-1}$ respectively.

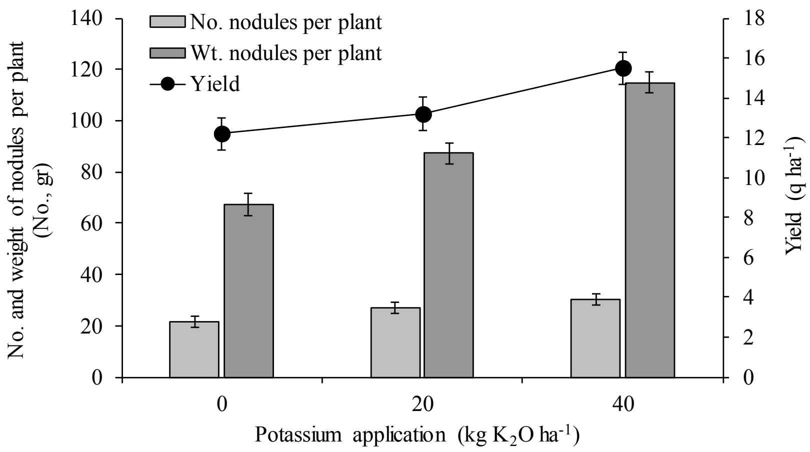



**Fig. 1.** Effect of potash application on the number and weight of plant's nodules. Error bars represent CD at P=0.05.

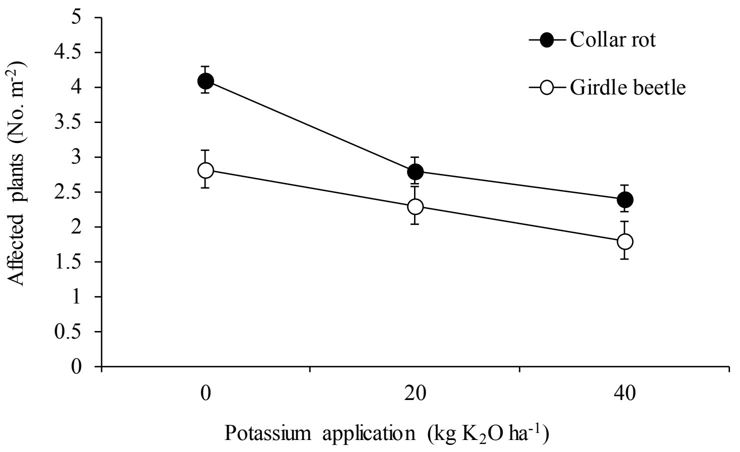



**Fig. 2.** Effect of potash application on the number of plants affected by collar rot disease and girdle beetle. Error bars represent SEM.

### Result and Discussion

The data in Table 2 reveal that all the growth parameters, i.e. plant height, branches per plant, number of nodules per plant, nodule dry weight, pods per plant, test weight (weight of 100 seeds), grain and straw yield and the harvest index were significantly affected by the application of 40 kg $K_2O$ $ha^{-1}$, in comparison to the farmers' practice where there was no application of $K_2O$. The most noticeable impact is evident in the increase in the number of nodules per plant and dry weight (Fig. 1), increasing by approx. 50 percent over K=0. This effect on nodules may allow for more biological nitrogen fixation and hence better yield (Fig. 1). The yield levels attained in the experiment (Table 2, Fig. 1) are higher than the average productivity of M.P. (Table 1).

Potassium plays a significant role in several physiological and biochemical processes in the plant: it activates more than 60 enzymes; it is essential for photosynthesis and the carbohydrates generated provide the energy needed by nodule bacteria to fix atmospheric N; it also enhances the translocation of carbohydrates to roots and is itself transported to roots where it stimulates new root hair formation as well as nodule development (Mengel and Kirkby, 1980).

The positive effect of K application on resistance of soybeans to pests and disease was already reported for the region (*e-ifc* No. 11, 3/2007). Data presented in Fig. 2 from this experiment indicate that the two major biotic stresses encountered at the earlier stages of crop growth are collar rot (*Sclerotium rolfsii*) and girdle beetle attack. The incidence of both is increasing enormously due to imbalanced nutrition and monocropping but can be controlled by the application of K. Our findings show that the number of plants per $m^2$ infected by disease and insect attack decreased in the recommended practice (RP) from 4.6 to 2.4, and 3.03 to 1.8, respectively, a drastic reduction in the incidence of these biotic stresses, which was also accompanied by yield increase.

The profitability of potash application was calculated through the agronomic efficiency of potash application and the changes in income and costs (Table 3). In our experiment, K use efficiency increased with K application, which suggests that higher application of potash should be tested. At 8.25 kg grain for each kg $K_2O$ applied, application of 40 kg $K_2O$ $ha^{-1}$ brings an additional net income of Rs. 5,970 per ha, or an Incremental Cost Benefit Ratio (ICBR) of 15.06, which should be very lucrative for farmers.

**Table 3.** Agronomic efficiency and profitability of potassium application in soybean.

| Treatment | K level | Efficiency and profitability | | |
|---|---|---|---|---|
| | | Agronomic efficiency ($AE_K$) | Net return | ICBR |
| | *kg ha⁻¹* | *kg grain / kg $K_2O$* | *Rs. ha⁻¹* | |
| T1 (FP) | 0 | 0 | 13,680 | 0 |
| T2 | 20 | 5.10 | 15,632 | 9.53 |
| T3 | 40 | 8.25 | 19,650 | 15.06 |

ICBR: Incremental Cost Benefit Ratio (Rs.). The ratio between the increment in yield's income and the cost of used potash. The cost of kg $K_2O$ is Rs. 7.71.

### Dissemination and spread of technology – a huge potential for increased income to farmers

Based on the trial under a real farm situation, the data in Table 4 indicate that by using the recommended doses of potash, together with the other two major nutrients, farmers can increase productivity 8 to 27 percent above the present levels merely by incorporating potash-based fertilizers, which cost Rs.772 per quintal of $K_2O$, i.e. Rs 154 to 308 per ha when using doses as described in treatments T2 and T3, respectively. Overall the region could expect additional revenue as shown in the last column of Table 3. It is a feasible target owing to the very negligible increase in the cost of cultivation.

*Horizontal Spread*

Looking into the benefits of the technology farmers in the coming years could adopt this technology and scientific recommendation. The data in Table 4 reveal the calculated direct impact of the technology in terms of the additional production, total increase in income, and the contribution of the technology in terms of total revenue generated. This reflects the economic sustainability of the technology if adopted by farmers.

*Applicability*

As Soybean is now the most economic crop of the Malwa Plateau zone during kharif season the economic scenario for farmers has consequently changed over the last two decades. However, previous gains are not sustainable today, because of increasing costs of production and yield stagnation, although the genetic potential of varieties under cultivation is more than 2.5 mt $ha^{-1}$. Keeping this in view, and the suitable technology available for yield enhancement, farmers are realizing the importance of K nutrition in soybean in achieving excellent yield increases, as well as better economic crop returns.

*Sustainability*

Almost the entire area under soybean cultivation is sown with improved varieties of high production potential. However, as a consequence of the soybean-wheat cropping sequence and injudicious use of fertilizer, soil health has deteriorated. On the basis of soil testing data, the area has been categorized with a net negative balance for the major nutrients, as well as secondary and micro-nutrients, such as S and Zn. From on farm trials, farmers have been fully satisfied and in agreement with the importance of applying K to soybean. Hence this technology is more sustainable owing to its better performance in terms of yield, high return and low cost.

*Equitability*

The result of K application to soybean at 40 kg $K_2O$ $ha^{-1}$ assessed in different locations in similar agro-ecological situations has showed that yield increments were almost the same in all plots with a variation of 2.55 percent between minimum and maximum yield. Hence, the result has the characteristics of equitability.

### References

Basseto, M.A., P.C. Ceresini, and W.V. Valerio Filho. 2007. Severidode de mela da soja causada par *Rhizoctonia solanai* AG-1 IA em

**Table 4.** Horizontal spread of technology and the annual revenue generation in the district of Ujjain.

| Treatment | K level | Net sown area | Productivity | Total production | Additional yield | Additional expenses | Additional profit |
|---|---|---|---|---|---|---|---|
| | *kg ha⁻¹* | *ha* | *q ha⁻¹* | *q* | --------------*Rs.Crore* | ------------- | |
| T1 (base line) | 0 | 450,000 | 12.20 | 5,490,000 | 0 | 0 | 0 |
| T2 | 20 | 450,000 | 13.24 | 5,958,000 | 468,000 | 9.65 | 58.5 |
| T3 | 40 | 450,000 | 15.50 | 6,975,000 | 1,485,000 | 20.00 | 165.63 |

# Research Findings

funcao de doses de potassio. Summa Phytopathologica 33:56-62.

*e-ifc* No. 11. 2007. Potassium Nutrition in Balanced Fertilization of a Soybean-Wheat Cropping System in Madhya Pradesh, India. International Potash Institute, Horgen, Switzerland. http://www.ipipotash.org/eifc/2007/11/4.

FAO STAT (2011). FAO Statistics Division. http://faostat.fao.org.

Imas, P., and H. Magen. 2007. Role of Potassium Nutrition in Balanced Fertilization for Soybean Yield and Quality - Global Perspective. *In:* Proceedings of Regional Seminar on Recent Advances in Potassium Nutrition Management for Soybean based Cropping System. p. 1-20.

Mengel, K., and E.A. Kirkby. 1980. Potassium in Crop Production. Advances in Agronomy 33:59-110.

Rupa, T.R., S. Srivastava, A. Swarup, D. Sahoo, and B.R. Tembhare. 2003. The Availability of Potassium in Aeric Haplaquept and Typic Haplustert as Affected by Long-Term Cropping, Fertilization and Manuring. Nutrient Cycling in Agroecosystem, 65:1-11.

Subbarao, A., S. Srivastava, R.H. Wanjari, and M. Singh. 2008. Potassium Dynamics of Vertisols and Associated Soils and Its Use Efficiency. *In:* Proceedings of Regional Seminar on Recent Advances in Potassium Nutrition Management for Soybean based Cropping System. p. 37-48.

Tomar, V.S., and A.K. Dwivedi. 2008. Role of Potassium in Abiotic and Biotic Stress Management. *In:* Proceedings of Regional Seminar on Recent Advances in Potassium Nutrition Management for Soybean based Cropping System. p. 25-36. ■

**The paper "Assessment of Potassium Nutrition in Soybean for Higher Sustainable Yield in Medium Black Soils of Central India" appears also at:**

Regional Activities/India

*Farmers' day in the experiment's region. Photo by A.K. Dixit.*