Efficient Nutrient Management of Soybean in Shrink and Swell Soils of Western India

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Application of the right source of nutrients for soybean recommends the inclusion of K and S in the fertilization program.

Critical assessment of N application rates in soybean is required to achieve and maintain optimum yield, particularly in highly deficient soils.

Split application of right rate of K, and banding it at 5 cm to the side and 5 cm below the seed are suggested to maintain soil fertility and address abiotic stresses.

Growth of soybean in the ample NPK treatment. Inset photo shows Dr. Satyanarayana along with Drs. Kharche and Katkar show the improved root growth achieved with ample NPK (right) versus N omission (left).

Soybean, referred to as the "golden bean" or "miracle bean", is the third most important oilseed crop in India (next to rapeseed/mustard and groundnut). It is a major source of vegetable oil, protein, and animal feed. In India, soybean contributes to 43% of all oilseeds and 25% of the total oil production. During the last few decades, soybean has shown phenomenal growth in planted area, increasing from 0.6 million (M) ha in 1980-81 to about 11.7 M ha in 2013-14. Consequently, soybean production increased during this time-frame from 0.5 to 11.9 M t (FAI, 2015). This sharp increase is associated with soybean's replacement of less profitable crops like sorghum and minor millets due to soybean's diverse adaptability, improved oil quality, and multiple uses.

While the progress in soybean production in India is impressive, the increased production is largely driven by area expansion. The average productivity (1 t/ha) of soybean in India is only one-third of the world average (FAI, 2015). More than 70% of soybean is grown in areas under rain-fed conditions with poor fertility and limited fertilizer use. To a large extent, the low productivity of soybean in India is due to inadequate and imbalanced fertilizer application.

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; S = sulphur; Ca = calcium; Fe = iron; Zn = zinc.

Soybean is grown as a monsoon season crop under rain-fed conditions in Vertisols and associated soils in central and western India. Soybean has increased both cropping intensity and profitability for farmers in the region. However, most farmers grow soybean without adequate fertilizer application (Behera et al., 2007), which has resulted in insufficient nutrient levels to sustain high yields or replenish crop nutrient removal. This article discusses the 4R guidelines for practicing efficient nutrient management to improve the productivity of soybean in the Vidarbha and Marathwada regions of Maharashtra.

Right Source

A survey of the fertility status of the major soybean-growing soils of Vidarbha and Marathwada showed deficiencies in N (80 to 97%), P (30 to 70%), S (20 to 50%), Zn (35 to 68%), and Fe (15 to 19%), which are posing threats to the sustainability of soybean production in the region (Katkar et al., 2013). A similar survey was also conducted by Dr. Panjabrao Deshmukh Krishi Vidyapeeth (Dr. PDKV), Akola, and the International Plant Nutrition Institute (IPNI) in the soybean-growing region of Akola, Maharashtra. Implemented over three cropping seasons at 45 locations, the survey reported 100% of soils to

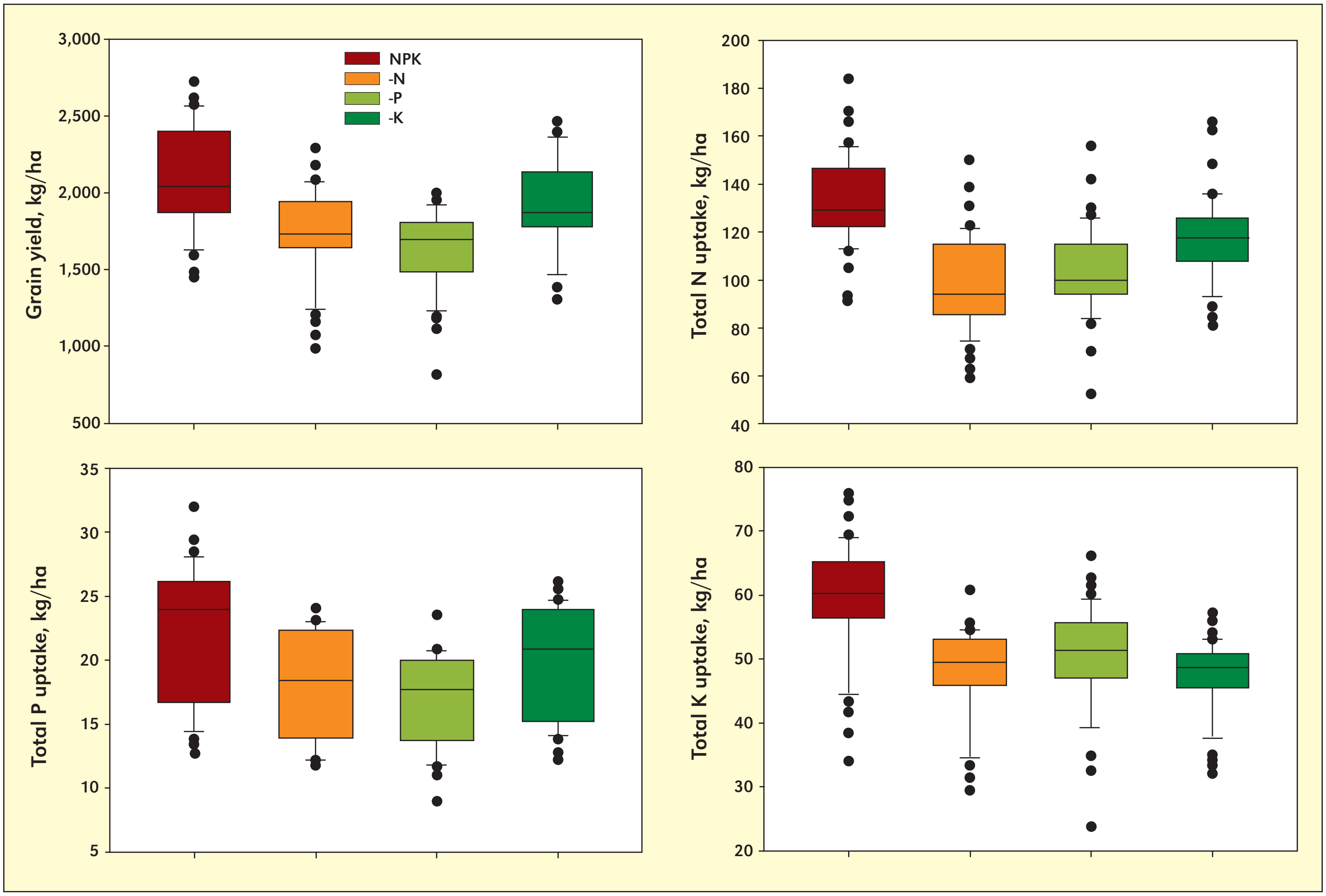

Figure 1. Yield and nutrient uptake of soybean in Maharashtra (Source: IPNI-Dr. PDKV, Akola collaborative on-farm research, 2014-15)

Table 1. Initial soil properties at the on-farm experimental sites.

	- - Observations - -	
Soil property	Mean	S.E.
pH	8.0	0.05
Organic C	0.4	0.02
Available N, kg/ha	198	6.47
Available P_2O_5, kg/ha	15	0.66
Available K_2O, kg/ha	414	5.55
Available S, kg/ha	13	0.44
Available Zn, mg/kg	0.7	0.01
Available Fe, mg/kg	10	0.79
Available Mn, mg/kg	5.2	0.56
Available Cu, mg/kg	2.6	0.31

Source: IPNI-Dr. PDKV, Akola collaborative on-farm research, 2014-15.

to be deficient in N, 13% deficient in P, and 95% deficient in S (**Table 1**).

Even though the selection of the right sources of fertilizers should be based on the native soil fertility status and the nutrient limitations therein, farmers' choice of fertilizer sources in this region depends on their own perception and availability of fertilizer sources. Farmers growing soybean in Maharashtra predominantly apply urea, diammonium phosphate (DAP), and NP complexes as N and P sources to meet the crop demand. The soil available K status is reported to be high (**Table 1**) and farmers seldom apply potash to soybean. However, the application of K to soybean not only improves yields but also influences several quality aspects such as oil content, protein content, and larger seed size. Potassium also helps in better nodulation and resistance to pests and diseases (Imas and Magen, 2008). It should be noted that soils testing high in available K may become K deficient due to heavy and continuous removal by soybean. Therefore, the inclusion of K in the fertilization program is suggested to maintain native K fertility levels in the soil. Katkar et al. (2014) reported S deficiency in the mono-cropping areas of soybean, especially where DAP is used continuously as a P source. In S-deficient soils, the application of single superphospate (SSP) as a P source provides 12% S and the application of bentonite S or gypsum may be considered as an option when DAP is used for the P source. Chaurasia et al. (2009) reported that SSP recorded higher soybean yields, followed by gypsum. The protein and oil content of the seed and its yield were significantly influenced by the addition of different sources of S (**Table 3**). SSP and gypsum are reported to be better sources of S for soybean over others due to the presence of both Ca and S. For Zn and Fe deficiencies, Katkar et al. (2013) found that zinc sulphate and ferrous sulphate may be used in areas where the limitation of these nutrients are high. Application of manure or compost, along with fertilizers, is suggested to improve soil physical properties and to enhance nutrient use efficiency.

Right Rate

Nutrient requirements of soybean vary according to soil and climatic conditions, cultivar, yield level, cropping system, and management practices. A soybean crop yielding 3

Table 2. Yield, nutrient uptake, and post-harvest soil nutritional status of soybean in Maharashtra

Treatments	Yield, t/ha	Nutrient uptake, kg/ha N	P_2O_5	K_2O	S	Post-harvest soil status, kg/ha N	P_2O_5	K_2O	S
Ample NPK	2.1	126	48	58	15	228	21	464	13
N omission	1.7	97	43	58	13	192	20	441	12
P omission	1.6	104	40	61	11	215	18	448	12
K omission	1.9	118	47	57	15	211	21	394	13
CD (5%)	0.4	3	5	2	0.4	7	0.8	14	0.4

Source: IPNI-Dr. PDKV, Akola collaborative on-farm research, 2014-15.

t/ha extracted 240 kg N/ha, 45 kg P_2O_5/ha, and 100 kg K_2O/ha (Imas and Magen, 2008). A collaborative study by Dr. PDKV, Akola and IPNI, for two consecutive years (2014-15), reported that the application of 30 kg N, 100 kg P_2O_5, and 80 kg K_2O (ample NPK) resulted in a grain yield of 2.1 t/ha, where uptake was 126 kg N/ha, 48 kg P_2O_5/ha, and 58 kg K_2O/ha, respectively (**Figure 1**). The omission of N, P, and K from the ample NPK treatment reduced soybean yield by 18, 22, and 9%, indicating that soybean yield was primarily influenced by P application followed by N (**Table 2**). **Figure 1** also shows that soybean yield was significantly lower due to N omission, as compared to the ample NPK treatment. An earlier study by Patel and Chandravanshi (1996) showed that there is increasing requirement of N, beyond the starter dose of 25 to 30 kg N/ha due to poor and inefficient nodulation. In a recent study in the U.S.A., soybean yield was increased with the addition of fertilizer N by 8 to 15% across a wide range of management practices, thus proving that N supplied by N_2 fixation to soybean may not be sufficient enough to maximize yield (Ray et al., 2006).

Phosphorus is taken up throughout the growing season by soybean. The period of greatest demand begins just before the pod formation stage and continues until about 10 days before the seeds are fully developed. The majority of the P used in seed development is taken up early, stored temporarily in leaves, stems, and petioles and then is translocated into the seed (Imas and Magen, 2008). Phosphorus has major role in ATP-synthesis, and is thereby involved in several metabolic processes including nodule development and N_2-fixation in soybean. Singh et al. (1995) found yield improvement of over 1.2 t/ha with 60 kg P_2O_5/ha, as compared to no application of P. The largest yield loss was seen with the omission of P (**Figure 1**). Generally, 60 to 80 kg of P_2O_5 is recommended for Indian soils.

The yield reduction of soybean, due to omission of K, was 9%. Farmers seldom apply potash to soybean and the study indicated K_2O removal to be 57 kg/ha when K is not applied (**Table 2**). This resulted in the decline in initial soil K status from 414 kg/ha (**Table 1**) to 394 kg/ha (**Table 2**), indicating mining of soil K. Several on-farm studies in Central India showed that the application of 100 kg K_2O/ha can achieve and sustain 2.5 t/ha of grain yield in soybean (Bansal et al., 2001). Field demonstrations also found a strong response to K application where yield was increased on average by 29% (500 kg/ha) and 35% (624 kg/ha) with the application of 50 and 100 kg K_2O/ha (Imas and Magen, 2008). The field demonstrations indicated that adequate K fertilization was highly profitable, achieving value-cost ratios (VCRs) of 11 to 18. The benefits of K nutrition in providing resistance to both insect infestations and incidence of plant diseases in soybean were shown at field experiments in Indore, Madhya Pradesh (Imas and Magen, 2008). Applying K markedly decreases insect infestation in the case of blue beetle and the defoliators expressed by the number of insects per meter row length (mrl). This was also the case for the incidence of stem fly and the girdle beetle. Similarly, increased K application depressed the percentage mortality by collar rot (caused by the fungus *Sclerotium rolfsii*) and leaf spot and petiole rot (resulting from the pathogen *Myrothecium roridum*) in soybean. There is a clear need to educate farmers about the necessity of adequate K application, along with N and P_2O_5 for ensuring sustainable yields of soybean.

In Maharashtra, the recent official fertilizer recommendations have a revised K_2O application rate from 0 to 30 kg/ha and the final N, P_2O_5, and K_2O recommendations have now become 30, 75, and 30 kg/ha, respectively.

A study on response of soybean to variable rates of S application showed that yield of soybean, increased significantly with an increase in S up to 30 kg/ha (2,270 kg/ha) and remained at par (2,294 kg/ha) at 40 kg/ha (**Table 3**). Even though, the nutrient uptake (N, P, K, and S) increased with increasing rates of S application up to 40 kg/ha, significant response of soybean to yield and quality suggested for application of S only up to 30 kg/ha (**Table 3**). Sulphur is an essential element for

Table 3. Yield, nutrient uptake and quality of soybean as influenced by right source and right rate of application of S.

Treatment	Yield, kg/ha	Uptake, kg/ha N	P	K	S	Protein quality Content, %	Protein quality Yield, kg/ha	Oil quality Content, %	Oil quality Yield, kg/ha
Sources									
Gypsum	2,075	142	32	95	13	40.2	850	19.3	407
Pyrite	1,954	138	31	92	13	39.2	779	18.8	374
SSP	2,129	147	33	98	14	41.5	902	19.9	432
CD (5%)	87	4	1	3	0.4	1.1	61	0.4	29
Sulphur levels, kg/ha									
0	1,738	118	20	77	5.8	37.7	664	18.4	325
10	1,891	130	26	86	9.6	39.3	756	18.9	363
20	2,071	143	32	95	14	40.5	853	19.4	408
30	2,270	154	38	104	18	41.7	962	19.8	456
40	2,294	167	44	113	19	42.2	984	20.2	470
CD (5%)	138	12	6	9	3.3	1.1	79	0.5	36

Source: Chaurasia et al., 2009.

Joint collaborative project between Dr. PDKV, Akola and IPNI in Maharashtra is aimed at developing 4R guidelines in soybean.

oilseed crops due to its direct involvement in the synthesis of oil and is expected to increase the oil content and oil yield of soybean. Increased N, P, K, and S uptake by soybean with increasing rates of S addition is expected due to the low supply of native S from the soil (16 kg/ha) (**Table 3**). The results suggest 30 kg S/ha as the optimum rate of S application to soybean (Chaurasia et al., 2009).

Right Time

Nitrogen application in soybean at the time of planting helps in maintaining the initial vigour of the plant. The plant begins to fix substantial amounts of N approximately four weeks after germination, thus N application has to be restricted prior to the commencement of N_2 fixation. Soybean derives between 25 and 75% of its N by fixation, which is inhibited by application of high levels of N in the soil. Phosphorus plays an important role in the growth and development of soybean. An adequate supply of P in the early growth stages helps in initiating reproductive growth, hastens maturity, and improves the quality of the seed. In soybean, P is taken up throughout the growing season. The period of greatest demand starts just before the pods begin to form and continues until about 10 days before the seeds are fully developed. Much of the P used in seed development is taken up early, stored temporarily in leaves, stems, and petioles, which is then translocated into the seed (IFA, 1992).

Potassium accumulation in soybean follows a pattern similar to that of dry matter, with slow accumulation at early vegetative growth stages, and an almost constant, more rapid K accumulation at later vegetative and early to mid-reproductive stages. In highly leachable soils or soils that fix large amounts of K, potash fertilizer may be split into two or more applications, but in non-sandy soils, a single application at the time of planting meets the crop requirement (IFA, 1992). However, to avoid luxury consumption of K, split application is always better than a single basal application.

Collaborative on-farm research studies between Dr. PDKV, Akola and IPNI suggest basal application of the entire recommended dose of N and P to meet the needs of soybean during the initial grand growth stage. Application of 50% of K at the time of planting and remaining at 30 days after seeding, helped in meeting the K requirement at both grand growth and flowering, and pod development stages of soybean.

Right Place

Right placement of fertilizers ensures its ready to access by roots leading to reduced losses of fertilizer. Farmers growing soybean in India apply fertilizers through broadcasting at planting or in the standing crop. Drilling the fertilizer mixture just below the seed is recommended while planting soybean. Soybeans generally prefer broadcast placement of P. They respond best to an overall high P fertility in the root zone, which is usually best accomplished by incorporating broadcasted P. Under drier conditions and low P soils, some Canadian researchers have found banding P below the seed will produce better yields than broadcasting (IPNI, 1999). Mallarino et al. (1998) found that early growth responses of soybean to P were larger for the planter-band placement (starter), but decreased for the deep-band placement and further decreased with broadcast placement. The effects of banded P fertilizer on early growth did not translate into higher soybean yield. The researchers also found that deep-banded K fertilization increased grain yields of soybeans managed with no-tillage, as compared to broadcasted K. Soybean is very susceptible to fertilizer salt injury and if K is applied in a band at planting time, special care should be taken to locate the band at 5 cm to the side and 5 cm below the seed to avoid fertilizer injury (Imas and Magen, 2008). There are limited studies in India on the right placement of fertilizers in soybean and there is a need to focus attention in this field of study.

Summary

Nutrient management based on the 4R Nutrient Stewardship principles provide options to improve productivity of soybean in the Vertisols of central and western India. Educating farmers on the 4R principles of nutrient management and enabling them knowledge of balanced and adequate fertilization through 4R, is the key to address the current issue of stagnant soybean yields. BC-SA

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