



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; 9(9): 180-183
Received: 08-06-2026
Accepted: 14-07-2026

SP Padhi
M.Sc. (Agri.) Student, Department
of Soil Science, Post Graduate
Institute, Dr. Panjabrao
Deshmukh Krishi Vidyapeeth,
Akola Maharashtra, India

SM Bhoyar
College of Agriculture, Dr.
Panjabrao Deshmukh Krishi
Vidyapeeth, Akola Maharashtra,
India

SD Jadhao
Department of Soil Science, Post
Graduate Institute, Dr. Panjabrao
Deshmukh Krishi Vidyapeeth,
Akola Maharashtra, India

NM Konde
Department of Soil Science, Post
Graduate Institute, Dr. Panjabrao
Deshmukh Krishi Vidyapeeth,
Akola Maharashtra, India

DN Nalge
Department of Soil Science, Post
Graduate Institute, Dr. Panjabrao
Deshmukh Krishi Vidyapeeth,
Akola Maharashtra, India

Udaya V
Project Lead, Syngenta
Foundation India, India

MD Giri
Department of Agronomy, Post
Graduate Institute, Dr. Panjabrao
Deshmukh Krishi Vidyapeeth,
Akola Maharashtra, India

Corresponding Author:
SP Padhi
M.Sc. (Agri.) Student, Department
of Soil Science, Post Graduate
Institute, Dr. Panjabrao
Deshmukh Krishi Vidyapeeth,
Akola Maharashtra, India

Effect of nutrient management on yield, nutrient content and uptake by soybean under soybean-wheat cropping sequence

SP Padhi, SM Bhoyar, SD Jadhao, NM Konde, DN Nalge, Udaya V and MD Giri

DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i9c.6491>

Abstract

A field experiment was conducted during kharif 2024-25 at the Research Farm, Department of Soil Science, Dr Panjabrao Deshmukh Krishi Vidyapeeth (Dr. PDKV), Akola, Maharashtra to study the effects of nutrient management on yield, content and total uptake of nutrients by soybean under soybean-wheat cropping sequence in Vertisol. Eight nutrient management treatments, viz., absolute control, 50% N and 100% PK, 75% N and 100% PK + FYM, 100% NPK, 100% NPK + S @ 37.5 kg ha⁻¹, FYM @ 10 t ha⁻¹, 100% NPK + residue management, and 75% N and 100% PK + residue management, were laid out in a Randomized Block Design with three replications. The results of the present experiment revealed that, application of 75% N and 100% PK + FYM significantly influenced grain and straw yields, N, P, and K content in grain and straw, and total nutrient uptake by soybean. The highest grain and straw yield was recorded with 75% N and 100% PK + FYM, which were significantly higher than the absolute control and statistically at par with rest of the nutrient management practices. The highest N, P, and K contents in grain (5.92, 0.39, and 0.54%) and straw (1.50, 0.29, and 0.75%), and the maximum total uptake of N (168.23 kg ha⁻¹), P (15.86 kg ha⁻¹), and K (30.68 kg ha⁻¹) by soybean was noticed in the conjunctive use of manure and fertilizer. The lowest yields, nutrient contents and uptake were observed under the absolute control. The results indicated that the best practice of nutrient management under the soybean-wheat cropping sequence in Vertisols is the integration of inorganic fertilizers with farmyard manure (75% N and 100% PK + FYM) to obtain higher yield and nutrient uptake by soybean.

Keywords: Soybean, nutrient management, fym, yield, nutrient uptake, vertisol

Introduction

The wide global diversity of legume-cereal rotation systems reflect variation in land suitability and the climatic adaptability of different legumes and cereals. Wheat (*Triticum aestivum* L.) is the most widely grown cereal, and soybean is the world's most important leguminous oilseed crop (Leff *et al.*, 2007) ^[10]. The most common rotation system in temperate and subtropical regions is the soybean-wheat rotation (Caviglia *et al.*, 2011) ^[3]. Soybean has been grown as a rainfed crop in Madhya Pradesh since the early 1980s, and the soybean-wheat rotation is followed in the black soils (Vertisols) of Central India. This rotation was highly profitable in the initial years and significantly increased the region's agricultural incomes (Behera *et al.*, 2007) ^[1]. It is a key contributor to biological nitrogen fixation and an essential component of sustainable agricultural systems.

Soybean (*Glycine max* L. Merrill) is one of the world's important oilseed and pulse crops. It is sometimes called the "Golden Bean" for its high nutritional and economic value. It belongs to the Fabaceae family and is native to East Asia, particularly China, where it was introduced in the 10th century AD via the Himalayan route, spreading through Burma (now Myanmar) and by traders from Indonesia. Soybean seed contains 38-42% protein and 18-22% oil, and it is a unique crop that serves as both a high-protein pulse and an oilseed crop (Hartman *et al.*, 2011) ^[5].

Sole reliance on the recommended dose of inorganic fertilizer, without organic amendments, has generally proved inadequate to sustain soil fertility and crop productivity over the long term. An integrated approach combining inorganic fertilizers with organic sources such as farmyard manure

(FYM), in-situ crop-residue incorporation, and secondary nutrients such as sulphur has consequently been advocated for the soybean-wheat system. Combined application of FYM with NPK fertilizers not only supplies the major nutrients but also improves soil physical properties, enhances microbial activity, and ensures a slow and steady release of nutrients throughout the crop growth period. Incorporation of crop residues recycles a substantial quantity of nitrogen, phosphorus and potassium back into the soil-plant system and reduces dependence on external fertilizer inputs. Sulphur, being a constituent of sulphur-containing amino acids and essential for chlorophyll and oil synthesis, has also assumed importance as a nutrient limiting soybean production on Vertisols, which are frequently deficient in plant-available sulphur (Suman *et al.*, 2018) [17].

While the response of soybean to individual nutrient sources has been studied fairly extensively, information on the comparative performance of inorganic fertilizers, FYM, sulphur and in-situ crop-residue management specifically with respect to the grain and straw yield, nutrient content and total nutrient uptake of soybean under soybean-wheat cropping sequence on the Vertisols of the Akola region of Maharashtra remains limited. The present investigation was therefore undertaken with the objective of studying the effect of different nutrient management practices on the yield, nutrient content and nutrient uptake of soybean under the soybean-wheat cropping sequence.

Materials and Methods

The field experiment was conducted during kharif 2025-26 at the Research farm of Department of soil science, Dr. Panjabrao Deshmukh Krishi Vidhyapeeth, Akola, Maharashtra, India. Geographically, the region is located at 20°42' 01.13" North and 77°03' 47.93" East, at an elevation of 307.8 meters above mean sea level (MSL). It has a semi-arid climate with three well-defined seasons. They are hot and dry summer from March to May, a warm, rainy monsoon from June to October, and a mild, cold winter from November to February. The average annual precipitation is 711.1 mm. The soil of the experimental site was deep, clayey black soil taxonomically classified as very fine, smectitic, calcareous, hyperthermic family of Typic Haplusterts. The experiment comprised eight nutrient management treatments, viz., Absolute control, 50% N and 100% PK, 75% N and 100% PK + FYM, 100% NPK, 100% NPK + S @ 37.5 kg ha⁻¹, FYM @ 10 t ha⁻¹, 100% NPK + Residue management (RM), and 75% N and 100% PK + Residue management (RM). The treatments were replicated thrice in a Randomized Block Design (RBD), yielding a total of 24 plots. Soybean variety PDKV-Amba was sown at a seed rate of 75 kg/ha by the drilling method at a spacing of 45 × 10 cm (row × plant). The gross and net plot sizes were 4.5 × 3.5 m² and 3.6 × 3.20 m², respectively. The recommended dose of fertilizer (RDF) for soybean was 30:60:30 kg N, P₂O₅, and K₂O per hectare. The full dose of N, P, and K, as per treatment, was applied basally at sowing; FYM (on an oven-dry-weight basis) was applied before sowing, and sulphur was supplied through Bensulf as per treatment. In residue management treatments, above and below-ground soybean biomass was incorporated in situ as residue management.

At harvest, grain and straw yields were recorded plot-wise and expressed as q/ha. The plant and grain samples collected at the time of harvest of soybean were cleaned with double-distilled water and tipped with butter paper and air-dried first. The samples were then dried in an oven at 65 °C until constant weight was obtained. The samples were ground in a grinder and used to determine nitrogen, phosphorus, and potassium content. Nitrogen content was estimated by the micro-Kjeldahl method (Piper,

1966) [13], phosphorus by the vanado-molybdo-phosphoric yellow colour method using a spectrophotometer after tri-acid (HNO₃:H₂SO₄: HClO₄) digestion (Piper, 1966) [13], and potassium by flame photometry (Jackson, 1973) [6]. Total nutrient uptake (kg ha⁻¹) was computed for grain and straw separately by multiplying the nutrient content (%) with the corresponding yield (q ha⁻¹), and the total uptake (grain + straw) is reported.

The recorded data on yield, nutrient content, and nutrient uptake were statistically analyzed using analysis of variance (ANOVA) for a Randomized Block Design, as described by Gomez and Gomez (1984) [4]. Treatment means were compared using the critical difference (CD) at the 5 percent level of significance.

Result and discussion

Grain and fodder yield of soybean

Grain and straw yields of soybean varied significantly with different nutrient management practices (Fig. 1). Among the treatments, integrated application of 75% recommended nitrogen with 100% recommended phosphorus and potassium along with farmyard manure showed maximum grain yield followed by 100% NPK with residue management. This treatment was statistically at par with 100% NPK with sulphur @ 37.5 kg ha⁻¹, 100% NPK with residue management, 75% N with 100% PK and residue management, 100% NPK and 50% N with 100% PK for grain yield. It was, however, markedly better only than that of farmyard manure alone and the absolute control. The minimum grain and straw yields were recorded in the absolute control which demonstrated the necessity of balanced application of nutrients.

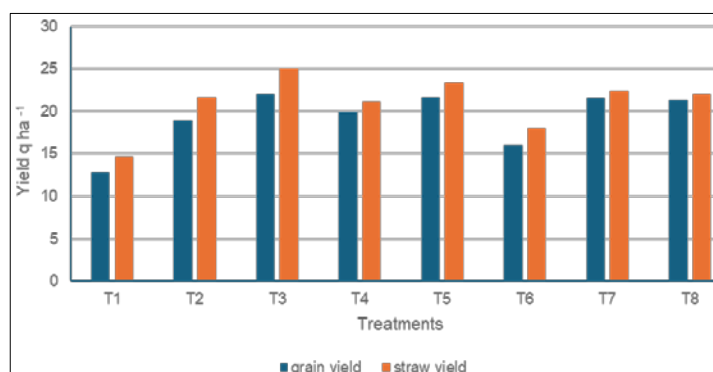


Fig 1: Grain and straw yield of soybean as influenced by nutrient management treatments.

Nutrient content & uptake by soybean under soybean-wheat cropping sequence

Nitrogen

The nitrogen content of the soybean grain varied from 5.42 to 5.92 percent and of the straw from 1.27 to 1.50 percent in the various treatments. Maximum nitrogen concentration in grain was observed with application of 75% nitrogen with 100% phosphorus and potassium along with farmyard manure (5.92%) followed by 100% NPK with residue management (5.80%), 100% NPK along with sulphur @ 37.5 kg ha⁻¹ (5.79%) and 75% N with 100% PK and residue management (5.76%). The absolute control had the lowest grain nitrogen content (5.42%). Maximum nitrogen concentration in straw (1.50%) was recorded with 75% N with 100% PK along with farmyard manure followed by 75% N with 100% PK and residue management (1.46%) and 100% NPK with sulphur @ 37.5 kg ha⁻¹ (1.44%).

Total nitrogen uptake by soybean ranged from 88.29 to 168.23 kg ha⁻¹ across treatments. Highest total nitrogen uptake (168.23 kg ha⁻¹) was observed with 75% N and 100% PK with farmyard manure, followed by 100% NPK with sulphur @ 37.5 kg ha⁻¹

(159.11 kg ha⁻¹), 100% NPK with residue management (156.52 kg ha⁻¹) and 75% N with 100% PK and residue management (155.34 kg ha⁻¹). The absolute control had the lowest nitrogen uptake (88.29 kg ha⁻¹). Integrated nutrient management resulted in higher nitrogen uptake mainly due to higher biomass production and nitrogen concentration in plant tissues. In FYM-based nutrient management, the higher nitrogen

concentration was mainly attributed to gradual release of nutrients, increased availability of soil nutrients and better root growth, which improved nitrogen absorption (Kumar *et al.*, 2020)^[8]. The combination of organic and inorganic fertilizers improved soil biological activity and nitrogen mineralization which provided more nitrogen to the crop (Meena *et al.*, 2022)^[12].

Table 1: Effect of manuring and fertilization on nutrient content by soybean under soybean-wheat cropping sequence

Treatments	N content (%)		P content (%)		K content (%)	
	Grain	Straw	Grain	Straw	Grain	Straw
Absolute control	5.42	1.27	0.24	0.18	0.38	0.54
50% N and 100%PK	5.67	1.34	0.31	0.22	0.45	0.62
75% N and 100% PK + FYM	5.92	1.50	0.39	0.29	0.54	0.75
100% NPK	5.73	1.42	0.35	0.25	0.50	0.69
100% NPK+ S@37.5 Kg ha ⁻¹	5.79	1.44	0.37	0.26	0.51	0.70
Farmyard manure @10t ha ⁻¹	5.61	1.38	0.32	0.24	0.48	0.66
100% NPK + RM	5.80	1.40	0.37	0.28	0.53	0.73
75% N and 100% PK + RM	5.76	1.46	0.36	0.27	0.52	0.71
SE(m)±	0.16	0.04	0.01	0.01	0.01	0.02
CD at 5%	0.50	0.12	0.03	0.02	0.04	0.06

Phosphorus

The phosphorus content of the soybean grain ranged from 0.24 to 0.39 per cent and that of straw from 0.18 to 0.29 per cent. Grain phosphorus content was maximum (0.39%) under 75% N and 100% PK + FYM followed by 100% NPK with sulphur @ 37.5 kg ha⁻¹ (0.37%) and 100% NPK with residue management (0.37%). The lowest grain phosphorus content (0.24%) was obtained in absolute control. The highest phosphorus content in straw (0.29%) was observed with 75% N and 100% PK + farmyard manure and 100% NPK + residue management (0.28%) in a similar way.

Total phosphorus uptake varied between 5.73 and 15.86 kg ha⁻¹. Maximum phosphorus uptake (15.86 kg ha⁻¹) was recorded in the treatment receiving 75% N with 100% PK along with farmyard manure, followed by 100% NPK with residue management (14.26 kg ha⁻¹) and 100% NPK with sulphur @ 37.5 kg ha⁻¹ (14.10 kg ha⁻¹). The lowest phosphorus uptake (5.73 kg ha⁻¹) was noted in the absolute control. The higher phosphorus uptake under integrated nutrient management may be attributed to increased phosphorus availability in soil due to organic matter addition, which facilitates the release of native soil phosphorus through organic acid production during decomposition. Additionally, enhanced root development and biomass production resulting from improved nutrient availability led to higher phosphorus absorption and utilization by the crop.

The higher phosphorus concentration and uptake under integrated nutrient management were mainly associated with improved phosphorus availability, root development, and biomass production. Organic amendments enhanced microbial and phosphatase activity, promoting phosphorus mobilization and release from organic forms (Mandal *et al.*, 2020)^[11]. Sulphur application with NPK increased phosphorus solubility by lowering rhizosphere pH (Kumar *et al.*, 2021)^[9]. Better root growth increased soil exploration and phosphorus absorption by soybean (Singh *et al.*, 2021; Rana *et al.*, 2022)^[16, 14].

Potassium

Potassium concentration in soybean grain ranged from 0.38 to

0.54 per cent, whereas potassium content in straw ranged from 0.54 to 0.75 per cent. The highest concentrations of potassium in grain (0.54%) and straw (0.75%) were observed with 75% N and 100% PK along with farmyard manure. The second-highest values were recorded with 100% NPK with residue management (0.53% potassium in grain and 0.73% in straw), followed by 75% N with 100% PK and residue management (0.52% in grain and 0.71% in straw). The absolute control showed the lowest potassium content (0.38% in grain, 0.54% in straw).

Total potassium uptake ranged from 12.81 to 30.68 kg ha⁻¹. The maximum uptake of potassium was recorded with 75 per cent N and 100 percent PK along with farmyard manure (30.68 kg ha⁻¹) followed by 100 per cent NPK with residue management (27.81 kg ha⁻¹), 100 per cent NPK with sulphur @ 37.5 kg ha⁻¹ (27.45 kg ha⁻¹) and 75 per cent N with 100 percent PK with residue management (26.77 kg ha⁻¹). The absolute control had the lowest potassium uptake (12.81 kg ha⁻¹). The increased potassium uptake under integrated nutrient management may be due to improved nutrient availability from added organic matter, which increases soil cation exchange capacity and improves potassium retention and release.

Under integrated nutrient management, the improved concentration and uptake of potassium was mainly attributable to increased availability of potassium from soil, better root development and increased crop biomass. FYM inhibited potassium fixing in clay minerals and increased potassium by mineralisation of organic matter which enhanced its availability to soybean (Kaur *et al.*, 2019)^[7]. Crop residues had a major effect in recycling of potassium by releasing potassium during decomposition and minimising the losses of nutrients through leaching (Singh and Kumar, 2020; Bhatt *et al.*, 2020)^[15, 2]. Organic matter increased the cation exchange capacity of Vertisols, improving potassium retention and availability (Bhatt *et al.*, 2020)^[2]. Improved root development and root exploration also promoted potassium uptake, and the combination of organic and inorganic sources helped in the movement and uptake of potassium throughout crucial growth periods of the crop (Yadav *et al.*, 2021; Rana *et al.*, 2022)^[18, 14].

Table 2: Total nutrient uptake by soybean as influenced by nutrient management treatments

Treatments	N uptake (kg/ha)	P uptake (kg/ha)	K uptake (kg/ha)
Absolute control	88.29	5.73	12.81
50% N and 100%PK	136.14	10.62	21.94
75% N and 100% PK + FYM	168.23	15.86	30.68
100% NPK	143.83	12.24	24.55
100% NPK+ S@37.5 Kg ha ⁻¹	159.11	14.10	27.45
Farmyard manure @10t ha ⁻¹	114.89	9.46	19.59
100% NPK + RM	156.52	14.26	27.81
75% N and 100% PK + RM	155.34	13.65	26.77
SE(m)±	9.59	1.01	1.43
CD at 5%	17.50	1.22	1.57

Conclusion

The present investigation results clearly indicated that the nutrient management practices significantly impacted the grain and straw yield, nutrient content and nutrient uptake of soybean under soybean-wheat cropping sequence in Vertisols. The maximum grain and straw yield, N, P and K content and total nutrient uptake was observed in 75% N and 100% PK along with FYM nutrient management practice and was statistically at par with 100% NPK + S, 100% NPK + RM and 75% N and 100% PK + RM. The absolute control registered the lowest values for all the parameters studied confirming the need for judicious nutrient management. Hence, it can be concluded that the combined use of inorganic fertilizers with farmyard manure or alternatively with sulphur or in-situ crop-residue management in cases where FYM is not readily available, is necessary to sustain higher productivity, nutrient content and nutrient uptake of soybean and thus to maintain the long-term productivity of the soybean-wheat cropping sequence in Vertisols.

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