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Effect of residue management on yield and soil properties under wheat in soybean-wheat cropping sequence in Vertisols

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ABSTRACT

A field experiment was conducted during the Rabi season of 2025–26 at the Research Farm of the Department of Soil Science, Dr. Panjabrao Deshmukh Krishi Vidyapeeth (Dr. PDKV), Akola, Maharashtra to study the effect of residue management on yield and soil properties under wheat in soybean-wheat cropping sequence in vertisols. Eight treatments, comprising absolute control, 50% N + 100% PK, 75% N + 100% PK + FYM @ 5 t ha⁻¹, 100% NPK, 100% NPK + S @ 37.5 kg ha⁻¹, FYM @ 10 t ha⁻¹, 100% NPK + Residue management, and 75% N + 100% PK + Residue management, were evaluated in a Randomized Block Design (RBD) with three replications. The results revealed that wheat grain and straw yields were significantly influenced by the different management practices. Among the treatments, the application of 75% N and 100% PK along with FYM @ 5 t ha⁻¹ (T₃) recorded the highest grain and straw yields and remained statistically at par with 100% NPK + residue management (T₇) and 75% N and 100% PK + residue management (T₈) for grain yield. For straw yield, T₃ was statistically at par with T₅, T₇, T₈ and T₄. The lowest grain and straw yields were recorded under the absolute control (T₁). The available nitrogen, phosphorus, potassium and sulphur contents in the soil after wheat harvest were influenced by the different nutrient and residue management practices. Among the treatments, T₃ (75% N and 100% PK + FYM @ 5 t ha⁻¹) recorded the highest available nitrogen, phosphorus and potassium contents. These were followed by T₇ (100% NPK + residue management) and T₈ (75% N and 100% PK + residue management), which maintained comparatively higher levels of available nutrients and were statistically comparable for the respective nutrients. The absolute control (T₁) recorded the lowest available nitrogen, phosphorus, potassium and sulphur contents. In case of available sulphur, T₅ (100% NPK + S @ 37.5 kg ha⁻¹) recorded the highest content, followed by T₃ (75% N and 100% PK + FYM @ 5 t ha⁻¹) and T₇ (100% NPK + residue management). The lowest available sulphur was observed under the absolute control (T₁). Overall, the findings demonstrate that integrated nutrient and residue management through the combined use of FYM or crop residues with inorganic fertilizers can improve wheat yield while maintaining a better soil nutrient status in Vertisols under a soybean-wheat cropping system.

Keywords: Wheat, Residue management, FYM, Yield, Available nutrients, Vertisol

Introduction

Wheat (*Triticum aestivum* L.) is one of the major cereal crops cultivated across the world and serves as an important staple food for nearly 2.5 billion people globally (Ramadas *et al.*, 2019)^[1]. The soybean-wheat cropping sequence is one of the important and widely adopted cropping systems in the country. This system contributes to enhancing the productivity of both crops while helping to maintain and improve soil fertility (Virkar *et al.*, 2008)^[2]. The contrasting nature and nutrient requirements of these crops pose a considerable challenge to maintaining their productivity on a sustainable basis. Wheat is a nutrient-exhaustive crop, so regular addition of nutrients is important to maintain soil fertility and crop yield (Gosavi *et al.*, 2009)^[3].

Crop residues refer to the plant materials that remain in the field after harvesting the crop. They mainly include leaves, stems, stalks, roots, etc. (Meena *et al.*, 2020)^[4]. Today, crop residue burning has become a major concern for scientists and policymakers worldwide because it can negatively affect the environment, soil health and crop productivity. Crop residue management offers several important benefits, one of which is improving soil health by increasing organic carbon and nutrient availability (Singh *et al.*, 2019)^[5]. Recycling of crop residues can help to return a significant amount of essential plant nutrients to the soil and improve nutrient availability for subsequent crops (Maurya *et al.*, 2020)^[6]. Crop residue management has become an important component of sustainable agriculture due to its role in recycling plant nutrients.

Soybean (*Glycine max* L.) is one of the important leguminous oilseed crop in India and generates about 13.5 t crop residue annually (Hiloidhari *et al.*, 2014)^[7]. Soybean residue is rich in nutrients, containing approximately 41.4% carbon (C), 2.8% nitrogen (N), 0.5% phosphorus (P), and 1.3% potassium (K) (Almaz *et al.*,

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2017)^[8]. As the residue decomposes, these nutrients are gradually released back into the soil, enhancing nutrient recycling, increasing soil organic carbon, and improving overall soil fertility (Liu *et al.*, 2015)^[9]. Its relatively narrow C:N ratio accelerated the mineralization process, which facilitates nutrient release (Dong *et al.*, 2019)^[10]. Therefore, the residue can be used to enhance soil quality and reduce soil degradation.

2. Materials and methods

The field experiment was conducted at the Research farm of Department of Soil Science, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during Rabi season of 2025-26. 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. It has a semi-arid climate and characterized by three distinct seasons. They are summer being hot and dry from March to May, the warm rainy monsoon season from June to October and winter season with mild cold from November to February. Soil of the experimental field was classified as Vertisols, particularly montmorillonitic, hyperthermic a family of *Typic Haplustert*. It has smectite clay minerals with swell-shrink properties.

The experiment consisted of eight treatments. These included an Absolute control (T₁), 50% N and 100% PK (T₂), 75% N and 100% PK + FYM @ 5 t ha⁻¹ (T₃), 100% NPK (T₄), 100% NPK + S @ 37.5 kg ha⁻¹ (T₅), FYM @ 10 t ha⁻¹ (T₆), 100% NPK + Residue management (RM) (T₇), and 75% N and 100% PK + Residue management (RM) (T₈). The experiment was laid out in a Randomized Block Design (RBD) with eight treatments replicated for three times in wheat, resulting in a total of 24 experimental plots. Wheat variety (AKW-4627) was sown by the drilling method at a seed rate of 120 kg ha⁻¹, maintaining a spacing of 22.5 cm between row and row, respectively. The gross and net plot sizes were 4.5 × 3.5 m² and 4.05 × 3.0 m², respectively. The recommended dose of fertilizer (RDF) for wheat was 120:60:60 kg N, P₂O₅ and K₂O ha⁻¹, respectively. 60 kg dose of N and total amount of P and K should be applied at the time of sowing. The remaining 60 kg N was applied after 21 DAS. FYM (on an oven-dry-weight basis) was applied before sowing, and sulphur was supplied through Bensulf as per treatment. In T₇ and T₈, 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⁻¹. Soil samples were collected after harvest of crop, at plot-wise surface (0-30 cm depth). Collected soil samples were air dried in shade and then ground carefully with wooden pestle to break the clods without reducing the rock fragments. The 2 mm sieve was used to sieve these soil samples. Available nitrogen content was estimated by Alkaline potassium permanganate method (Subbiah *et al.*, 1956)^[11], phosphorus by the Olsen method (NaHCO₃- 0.5M pH 8.5) colorimetric (Watanabe *et al.*, 1965)^[12], potassium by Neutral normal ammonium acetate using Flame photometer (Jackson, 1973)^[13] and available sulphur by turbidimetric method (Chesnin *et al.*, 1951)^[14]. The recorded data on yield and soil properties were statistically analyzed using analysis of variance (ANOVA) for a Randomized Block Design, as described by (Gomez *et al.*, 1984)^[15]. Treatment means were compared using the critical difference (CD) at the 5 percent level of significance.

Result and Discussion

Yield of wheat

Grain and straw yields of wheat varied significantly with different residue and nutrient management practices (Fig. 1). T₃ (75% N and 100% PK + FYM @ 5 t ha⁻¹) recorded the highest grain yield, which was statistically at par with T₇ (100% NPK + residue management) and T₈ (75% N and 100% PK + residue management). The next higher grain yield was observed under T₅ (100% NPK + S @ 37.5 kg ha⁻¹), followed by T₄ (100% NPK) and T₂ (50% N and 100% PK). T₆

(FYM @ 10 t ha⁻¹) recorded comparatively lower grain yield, while the lowest grain yield was observed under T₁ (absolute control). The straw production of wheat was significantly influenced by the different nutrient and residue management treatments. T₃ (75% N and 100% PK + FYM @ 5 t ha⁻¹) recorded the highest straw yield and was statistically at par with T₅ (100% NPK + S @ 37.5 kg ha⁻¹), T₇ (100% NPK + residue management), T₈ (75% N and 100% PK + residue management), and T₄ (100% NPK). This was followed by T₂ (50% N and 100% PK). T₆ (FYM @ 10 t ha⁻¹) recorded lower straw yield, whereas the lowest straw yield was observed under T₁ (absolute control).

Chesti *et al.*, (2013)^[16] reported that the highest grain yield 4.92 t ha⁻¹ and straw yield (7.43 t ha⁻¹) of wheat were found in the treatment with application of 100% NPK along with FYM. Arora *et al.* (2022)^[17] found that among the different residue management treatments, crop residue retention recorded the highest grain yield, followed by crop residue incorporation, while the lowest grain yield was observed in the control treatment. The increase in grain and straw yields of wheat with crop residue addition may be attributed to its beneficial effect on soil organic matter content. Improved soil organic matter enhances soil fertility, promotes greater availability and higher uptake of available nutrients from the soil.

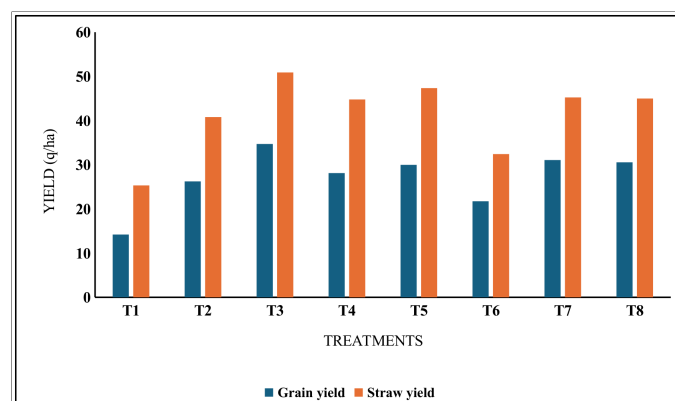


Figure 1. Grain and straw yield of wheat as influenced by residue management treatments.

Available nitrogen

The available nitrogen content in the soil after harvest of wheat varied significantly among the different residue and nutrient management treatments (fig. 2). The application of 75% N and 100% PK along with FYM @ 5 t ha⁻¹ (T₃) recorded the significantly highest available nitrogen content. It was followed by 100% NPK + Residue management (T₇) and 75% N and 100% PK + Residue management (T₈), which were statistically at par with each other. Treatment T₄ (100% NPK) and T₅ (100% NPK + S @ 37.5 kg ha⁻¹) also maintained a higher level of available nitrogen compared with the control. The application of FYM alone (T₆) resulted in a moderate improvement in available nitrogen. Application of 50% N and 100% PK (T₂) resulted in a slight improvement in available nitrogen. The absolute control (T₁) recorded the lowest available nitrogen content.

Lakra *et al.*, (2022)^[18] observed that the highest available nitrogen content in the soil (220.36 kg ha⁻¹) was recorded under the application of 100% RDF + FYM @ 5 t ha⁻¹. Singh *et al.*, (2012)^[19] found that soybean, as a leguminous crop, invariably adds substantial amount of nitrogen to the soil through its residual biomass, including leaf litter, roots, nodules, and rhizodeposition. A major portion of nitrogen added by (RBN_s) Residual biomass N of soybean is derived from atmosphere, which contributes nitrogen to the soil. Kumari *et al.*, (2017)^[20] reported that the increase in available nitrogen with the application of organic sources may be attributed to the direct addition of nitrogen through FYM, straw and green manure. These organic materials enhanced mineralization and thereby contribute to the build-up of available nitrogen in the soil.

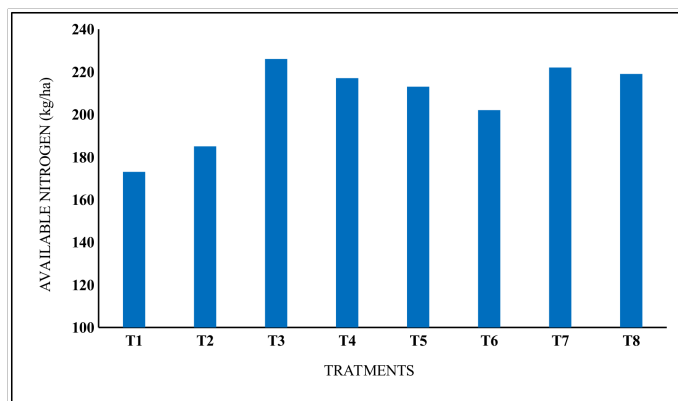


Figure 2. Effect of residue management on available nitrogen content of soil

Available phosphorus

The available phosphorus content in the soil after wheat harvest showed considerable variation among the residue and nutrient management treatments (fig. 3). T₃ (75% N and 100% PK + FYM @ 5 t ha⁻¹) recorded the highest available phosphorus content and was statistically at par with T₇ (100% NPK + residue management) and T₈ (75% N and 100% PK + residue management). The treatment receiving 100% NPK (T₄) also maintained a comparatively higher level of available phosphorus. T₅ (100% NPK + S @ 37.5 kg ha⁻¹) showed a similar improvement, whereas 50% N and 100% PK (T₂) and FYM alone (T₆) resulted in a moderate level of available phosphorus. The absolute control (T₁) recorded the lowest available phosphorus content.

Tiwari *et al.*, (2024)^[21] studied that the highest build-up of available phosphorus in the soil was recorded with the application of NPK + FYM. The results of the long-term experiment showed that the application of the recommended dose of fertilizer in combination with FYM increased the available P content by 377.24% over its initial level in 1972. This substantial improvement in soil available P may be attributed to the beneficial effects of FYM and the addition of organic matter, which enhance phosphorus availability and reduce its fixation in the soil. Bhattacharyya *et al.*, (2008)^[22] reported that the highest build-up of available P was recorded in the plots receiving NPK + FYM, showing an increase of approximately 0.006 g P kg⁻¹ over the initial soil phosphorus status. Sharma *et al.*, (2014)^[23, 24] observed that application of residues had a significant influence on the available phosphorus content of the soil. The application of SS (dry sorghum stover) and GL (fresh gliricidia loppings) significantly increased available P, and both treatments were statistically at par with each other. Among the treatments, SS application resulted in a 6.92% higher available P content compared with NR no residue. Sharma *et al.*, (2014)^[24] reported that the increase in available P with FYM application may be attributed to the reduced fixation of phosphorus due

to the inactivation of iron, aluminium, and hydroxyl-aluminium ions. Also the content of phosphorus in available pool enhance due to the direct addition of phosphorus through FYM.

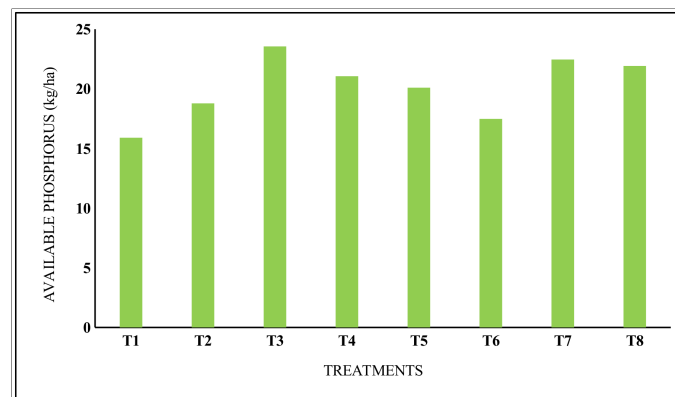


Figure 3. Effect of residue management on available phosphorus content of soil

Available potassium

The available potassium content in the soil after wheat harvest was significantly affected by the different residue and nutrient management practices (fig. 4). The highest available potassium was recorded under T₃ (75% N and 100% PK + FYM @ 5 t ha⁻¹). This treatment was statistically at par with T₇ (100% NPK with residue management) and T₈ (75% N and 100% PK with residue management). The treatment receiving 100% NPK (T₄) also maintained a comparatively high level of available potassium, followed by T₅ (100% NPK + S @ 37.5 kg ha⁻¹). while 50% N and 100% PK (T₂) and FYM applied alone (T₆) resulted in a moderate increase in available potassium. The absolute control (T₁) showed the lowest available potassium content. The combined application of organic manures and chemical fertilizers significantly increased the available potassium (K) content in the soil compared with the control (Sepehya *et al.*, 2012)^[25]. The maximum available K was recorded in the plots under NPK + farmyard manure and the lowest under control treatment (Katkar *et al.*, 2012)^[26]. Kumari *et al.*, (2017)^[20] observed that the combined application of organic manures and chemical fertilizers improved the available K₂O content of the soil compared with the control. The highest increase was recorded in T₈, where 50% RDF + 50% N through wheat straw was applied to rice followed by 100% RDF to wheat. This treatment increased the available K₂O content by about 71.4% over the control and 43.8% over the 100% NPK treatment. Urkurkar *et al.*, (2010)^[27] concluded that the increase in available potassium (K) may be attributed to the addition of organic matter, which reduced K fixation and enhanced the release of K through the interaction of organic matter with soil clay, in addition to the direct addition of potassium to the soil K pool.

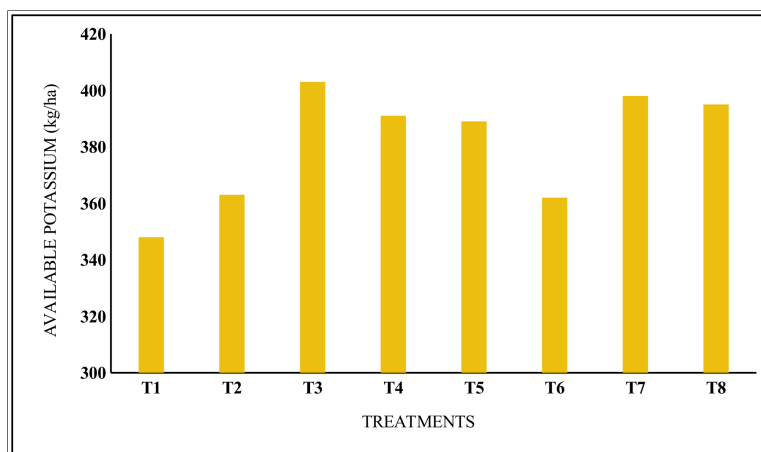


Figure 4. Effect of residue management on available potassium content of soil

Available S

The available sulphur content in the soil after wheat harvest was influenced by the different nutrient management practices (fig. 5). T₅ (100% NPK + S @ 37.5 kg ha⁻¹) recorded the highest available sulphur content. However, it was statistically at par with T₃ (75% N and 100% PK + FYM @ 5 t ha⁻¹) and T₇ (100% NPK + residue management). The treatment T₈ (75% N and 100% PK + residue management) also maintained a comparatively higher level of available sulphur. T₄ (100% NPK) and T₂ (50% N and 100% PK) recorded intermediate levels, whereas T₆ (FYM @ 10 t ha⁻¹) showed a comparatively lower level of available sulphur. The absolute control (T₁) recorded the lowest available sulphur content.

Singh *et al.* (2014)^[28] reported that sulphur application resulted in a positive sulphur balance in the soil, and the balance increased with increasing levels of sulphur application. In contrast, the control treatment showed a negative sulphur balance.

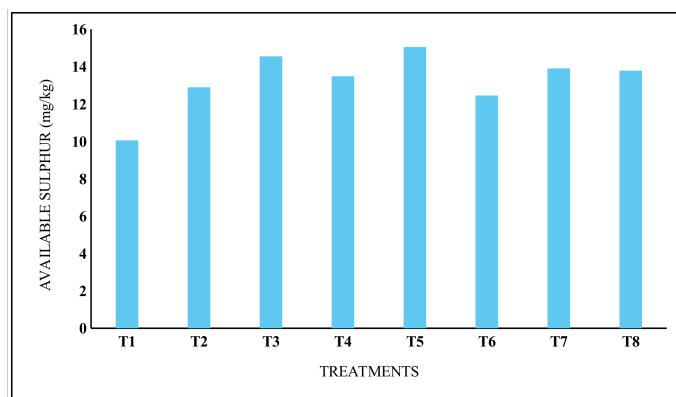


Figure 5. Effect of residue management on available sulphur content of soil

Conclusion

The results of the present investigation clearly showed that residue and nutrient management practices had a significant effect on grain and straw yield of wheat as well as soil nutrient availability under the soybean–wheat cropping sequence in Vertisols. The maximum grain and straw yield, available N, P, K content of the soil was observed in 75% N + 100% PK + FYM @ 5 t ha⁻¹ (T₃) nutrient management practice and was statistically at par with 100% NPK + Residue management and 75% N and 100% PK + Residue management. Whereas highest S content was observed under the treatment of 100% NPK + S @ 37.5 kg ha⁻¹. The absolute control treatment recorded the lowest values for all the parameters studied, highlighting the importance of balanced and judicious nutrient and residue management practices for improving soil fertility and enhancing yield of wheat.

Hence, it can be concluded that the integrated use of FYM or in situ crop residue management with inorganic fertilizers is more effective than the use of fertilizers or organic sources alone for improving soil nutrient availability and yield of wheat.

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