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# Impact of different crop residue mulching on soil fertility under rainfed cotton

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## Abstract
At the Research Farm of the Cotton Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, a field experiment was undertaken during 2024-25 to study the impact of different crop residue mulching on soil fertility under rainfed cotton. A randomized block design (RBD) with four replications was adopted, wherein the treatments included the application of different crop residue mulches in combination with the general recommended dose of fertilizers (GRDF). Treatments comprised: $T_1$ (GRDF), $T_2$ (GRDF + Mulching with wheat straw @ 50% of potential yield), $T_3$ (GRDF + Mulching with cotton straw @ 50% of potential yield), $T_4$ (GRDF + Mulching with soybean straw @ 75% of potential yield) and $T_5$ (GRDF + Mulching with weed biomass).

Numerically the lowest pH (8.06) was observed in $T_4$ (GRDF + Mulching with soybean straw @ 75% of potential yield) and $T_5$ (GRDF + Mulching with weed biomass). Numerically lowest EC value (0.26 dSm$^{-1}$) was observed in $T_5$ (GRDF + Mulching with weed biomass). Significantly maximum OC (4.72 g kg$^{-1}$) was recorded in treatment $T_4$ (GRDF + Mulching with soybean straw @ 75% of potential yield), which was statistically at par with the treatment $T_2$ (GRDF + Mulching with wheat straw @ 50% of potential yield) and $T_5$ (GRDF + Mulching with weed biomass) both with a value of (4.68 g kg$^{-1}$).

Significantly highest available nitrogen was found in $T_4$ (GRDF + Mulching with soybean straw @ 75% of potential yield) (181.40 kg ha$^{-1}$), which was statistically at par with $T_5$ (GRDF + Mulching with weed biomass, 179.56 kg ha$^{-1}$) and $T_2$ (GRDF + Mulching with wheat straw @ 50% of potential yield, 178.03 kg ha$^{-1}$). The highest available phosphorus (17.04 kg ha$^{-1}$) was recorded in $T_4$ (GRDF + Mulching with soybean straw @ 75% of potential yield), which was statistically at par with $T_5$ (GRDF + Mulching with weed biomass) (16.92 kg ha$^{-1}$), $T_2$ (GRDF + Mulching with wheat straw @ 50% of potential yield) (16.70 kg ha$^{-1}$) and $T_3$ (GRDF + Mulching with cotton stalk @ 50% of potential yield) (16.28 kg ha$^{-1}$). Highest potassium content was recorded in $T_4$ (GRDF + Mulching with soybean straw @ 75% of potential yield) (367.31 kg ha$^{-1}$), which was statistically at par with $T_5$ (GRDF + Mulching with weed biomass, 365.40 kg ha$^{-1}$). Numerically highest sulphur availability was observed in $T_4$ (GRDF + Mulching with soybean straw @ 75% of potential yield) (11.33 mg kg$^{-1}$).

**Keywords:** Crop residue mulching, GRDF, soybean straw, wheat straw, cotton straw, weed biomass, soil fertility and Bt-cotton

## Introduction
Cotton is a versatile, natural cellulose fibre from cotton plants, grown globally for its soft, absorbent fibre used in textiles (clothes, sheets) and other products, supporting millions of livelihoods. India ranks first globally in terms of land area under cotton cultivation and second in production. Notably, India is the only country growing all four species of cultivated cotton, *viz*., *Gossypium hirsutum* L. (upland cotton), *G. arboretum* (Asian cotton), *G. herbaceum* L. (levant cotton), and *G. barbadense* L. (sea island cotton). During the 2023-2024 crop year, India reported a cotton production of 5528.40 million kg over an area of 12.69 million hectares, with a yield of 435.65 kg per hectare (Source: Directorate of Economics & Statistics, Govt. of India, 2024) [7]. According to the USDA, Global 2024-25 cotton area and production are projected as 31.1 million hectares (76.84 million acres) and 117.40 million bales of 217.72 kg each compared to previous year 113 lakh bales which is 4.4 lakh bales (3.89%) above the 2023-24 estimates of cotton production led by United States, Brazil, and China. China is projected at 28.20 lakh bales

in 2024-25 followed by India (25 million bales), Brazil (16.90 million bales), United States (14.30 million bales) and Pakistan (5.50 million bales). During 2023-24, cotton area in China projected at 2.85 million hectares (7.04 million acres). For 2024-25, the United States Department of Agriculture (USDA) has projected an increase in global cotton production by 500,000 bales, bringing the total to 120.96 million bales (each weighing 480 pounds), according to its March 2025 World Supply and Demand Estimates (WASDE) report. However, global cotton ending stocks were lowered by 80,000 bales, while exports increased by 200,000 bales. Cotton exports were projected higher despite ongoing global uncertainties.

The Indian cotton sector has experienced significant fluctuations in recent years due to various biotic and abiotic stresses, as well as increasing competition from alternative crops. For the 2024-25 season, cotton production in India is estimated at 299.26 lakh bales (each 170 kg) from an area of 113.6 lakh hectares, with an average productivity of 448 kg lint/ha, according to the Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, New Delhi. It has been estimated that about 2445.4 MT of crop residues is produced worldwide (Fu *et al.*, 2021) [8]. India generates approximately 500-550 million tonnes (Mt) of crop residue annually, both on-farm and off-farm. The term “residue placement” refers to how residues are introduced into the soil, either incorporated or left on the surface, impacting the physical, chemical and biological properties of the soil (Stegarescu *et al.*, 2020) [30].

Crop residues play a vital role in enhancing soil fertility by contributing substantial quantities of macro and micronutrients. Acting as a reservoir for essential nutrients such as nitrogen (N), phosphorus (P), and potassium (K), along with various trace elements, CRs enhance overall soil productivity (Schomberg *et al.*, 1994) [28]. For instance, (Bhattacharjya *et al.*, 2019) [2] reported that the top 10 crops in India produce approximately 686 million tons of residues annually, with the potential to supply around 5.6 million tons of NPK nutrients to the soil. The addition of crop residues plays a key role in enriching soil organic carbon (SOC) and improving soil physical properties. It supports better aggregation and stability (Zhang *et al.*, 2014) [38]. Mulching reduces erosion and nutrient losses, allowing micronutrients to accumulate in the surface soil layer where roots are most active. By improving the supply of micronutrients along with other soil physical and chemical properties, crop residue mulching strengthens soil fertility and supports sustainable crop productivity over the long term.

## Materials and Methods

The field experiment on “Effect of crop residue mulch on soil fertility, yield and nutrient uptake by Bt-cotton under rainfed condition’’ was initiated during 2023-24 at Research Farm, Cotton Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (Maharashtra). The present investigation was carried out during 2024-25 (Second year) entitled “Effect of crop residue mulching on carbon dynamics under *Bt*-cotton in Inceptisols”. The site was fairly uniform and levelled in topography. The soil under study was classified as Inceptisol, having a bulk density of 1.48 Mg $m^{-3}$ and a hydraulic conductivity of 0.65 cm $hr^{-1}$. It was slightly alkaline in reaction (pH 8.08), non-saline (electrical conductivity: 0.32 $dSm^{-1}$), medium calcareous and contained a medium level of soil organic carbon (4.48 g $kg^{-1}$). The nutrient status indicated low available nitrogen (165.33 kg $ha^{-1}$), very low available phosphorus (12.14 kg $ha^{-1}$), high available potassium (343.68 kg $ha^{-1}$) and available sulphur was medium (10.52 mg $kg^{-1}$). Among micronutrients, the soil was deficient in available zinc (Zn) but sufficient in available iron (Fe), manganese (Mn), and copper (Cu).

The experiment was conducted in a Randomized Block Design (RBD) comprising five treatments with four replications. The treatments included: $T_1$ (GRDF), $T_2$ (GRDF + Mulching with wheat straw @ 50% of potential yield), $T_3$ (GRDF + Mulching with cotton straw @ 50% of potential yield), $T_4$ (GRDF + Mulching with soybean straw @ 75% of potential yield) and $T_5$ (GRDF + Mulching with weed biomass). The cotton hybrid Ajeet 199 BG-II was sown at a spacing of 90 × 45 cm. The general recommended fertilizer dose (GRDF) consisted of 90 kg N $ha^{-1}$, 45 kg $P_2O_5$ $ha^{-1}$ and 45 kg $K_2O$ $ha^{-1}$ along with FYM @ 5 t $ha^{-1}$, supplied through Urea, Single Superphosphate (SSP) and Muriate of Potash (MOP), respectively.

Prior to sowing, surface soil samples (0-20 cm) were collected treatment-wise from the experimental field, and a similar set of samples was taken again after the harvest of the crop. The collected soils were air-dried, gently crushed with a wooden pestle to break down clods, and then sieved through appropriate mesh sizes. These processed samples were subsequently analyzed for various soil parameters using standard analytical procedures. At crop maturity, representative plant samples were collected, processed, and subjected to analysis for bulk density, hydraulic conductivity, pH, EC, organic carbon, available nitrogen, phosphorus, potassium, sulphur and available micronutrients (Zn, Fe, Mn, Cu) using the standard procedures outlined by (Blake and Hartge, 1986) [3], Klute and Dirksen (1986) [19], (Jackson, 1973) [15], Nelson and Sommers (1982) [24], (Subbiah and Asija, 1956) [31], (Olsen *et al.*, 1954) [25], Chesnin and Yien (1951) [5] and Lindsay and Norvell (1978) [22]. The data on physical and chemical properties were compiled in tabular form and statistically analyzed following the procedures outlined by Gomez and Gomez (1984) [11].

## Results and Discussion

### Chemical properties of soil

#### pH

Numerically the lowest pH (8.06) was observed in $T_4$ (GRDF + Mulching with soybean straw @ 75% of potential yield) and $T_5$ (GRDF + Mulching with weed biomass). Soybean straw, being a nitrogen-rich organic material, decomposes to release organic acids such as fulvic and humic acids. These acids, together with enhanced microbial activity, can slightly lower soil pH. GRDF supplies essential nutrients (NPK), stimulating microbial growth, and the resulting higher microbial respiration produces $CO_2$. This $CO_2$ dissolves in soil water to form carbonic acid ($H_2CO_3$), further contributing to pH reduction. Decomposition of weed biomass, being green and moisture-rich, produces organic acids and increases microbial respiration, causing mild acidification.

In general, changes in soil pH are influenced by multiple factors, including the chemical composition of the crop residues, biological activity, soil organic matter content, and soil texture, as reported by Butterly *et al.* (2010) [4]. The findings are strongly corroborated by Kabirinejad *et al.* (2014) [17] who reported that crop residues decreased soil pH with the residue treatment showing the greatest effect. Similar results were also reported by Krishnaprabhu (2019) [20].

#### Electrical Conductivity

Numerically lowest EC value (0.26 $dSm^{-1}$) was observed in $T_5$ (GRDF + Mulching with weed biomass). Weed biomass, being soft and low in lignin, decomposes quickly, stimulating microbial activity, improving soil structure, and enhancing water infiltration and salt leaching. It also releases fewer soluble salts than crop residues, which contributed to the lowest EC among treatments. Overall, the application of GRDF with organic residues improved aggregation and porosity, allowing better infiltration and percolation, which reduced soil EC.

Halemani *et al.* (2004) [13] reported that the application of organic manures in combination with inorganic nutrients led to a reduction in soil electrical conductivity under rainfed conditions. The findings are strongly corroborated by Khuspure *et al.* (2019) [18]. Similarly, Jahan and Hossain' (2024) [16] reported that the EC was decreased as a result of decomposition of rice straw and production of organic acid to a level of 1.9 mS/cm after 15 days of harvesting.

## Organic Carbon

Data presented in table 1 show that soil organic carbon (OC) content was significantly influenced by different mulching treatments. The maximum OC (4.72 g $kg^{-1}$) was recorded in treatment $T_4$ (GRDF + Mulching with soybean straw @ 75% of potential yield), which was statistically at par with the treatment $T_2$ (GRDF + Mulching with wheat straw @ 50%) and $T_5$ (GRDF + Mulching with weed biomass) both with a value of (4.68 g $kg^{-1}$). Application of GRDF with organic mulches improved soil organic carbon compared to GRDF alone. Soybean straw added both carbon and nitrogen, enhancing microbial activity; weed biomass decomposed quickly, supplying readily available substrates; while wheat straw decomposed slowly, serving as a long-term carbon source.

The findings align with reports by Kumar *et al.* (2008) [21] and Yaduvanshi *et al.* (2013) [37], who observed an increase in soil organic carbon content with the use of organic sources such as wheat residues (WR), FYM, and green manure (GM). The results are in close agreement with the findings of Gupta *et al.* (2024) [12], who reported that soil organic carbon content increased with crop residue retention or incorporation.

**Table 1:** Chemical properties of soil as influenced by different treatments

| Tr. No. | Treatment Details | pH (1:2.5) | EC ($dSm^{-1}$) | OC (g $kg^{-1}$) |
|---|---|---|---|---|
| $T_1$ | GRDF | 8.08 | 0.28 | 4.60 |
| $T_2$ | GRDF + Mulching with wheat straw @ 50% of potential yield | 8.10 | 0.32 | 4.68 |
| $T_3$ | GRDF + Mulching with cotton stalk @ 50% of potential yield | 8.12 | 0.34 | 4.64 |
| $T_4$ | GRDF + Mulching with soybean straw @ 75% of potential yield | 8.06 | 0.28 | 4.72 |
| $T_5$ | GRDF + Mulching with weed biomass | 8.06 | 0.26 | 4.68 |
| | SE (m) ± | 0.01 | 0.02 | 0.02 |
| | CD at 5% | NS | NS | 0.07 |
| | Initial | 8.08 | 0.32 | 4.48 |

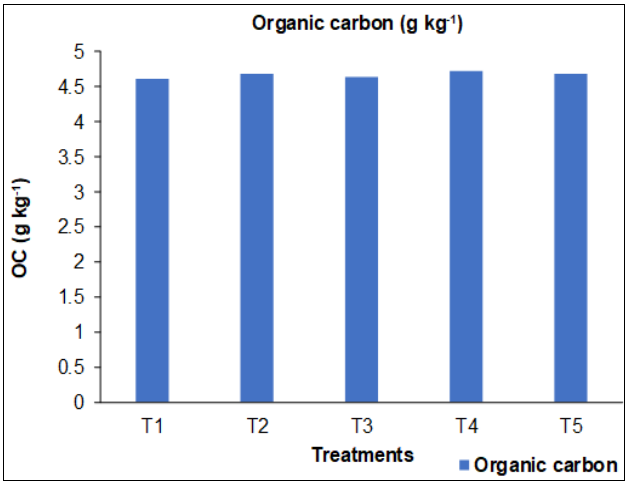


**Fig 1:** Soil organic carbon as influenced by different treatments

## Available Nitrogen

Data in table 2 showed that mulching treatments significantly influenced soil available nitrogen. The highest available nitrogen was found in $T_4$ (GRDF + Mulching with soybean straw @ 75% of potential yield) with 181.40 kg $ha^{-1}$, which was statistically at par with $T_5$ (GRDF + Mulching with weed biomass, 179.56 kg $ha^{-1}$) and $T_2$ (GRDF + Mulching with wheat straw @ 50% of potential yield, 178.03 kg $ha^{-1}$). Integrating GRDF with organic residues not only supplied readily available nitrogen but also stimulated microbial activity, improved soil structure and moisture retention, and reduced nitrogen losses, resulting in higher available N compared to GRDF alone.

The increase in available nitrogen content with the incorporation of crop residues and organic manures may be attributed to nitrogen mineralization from the organic inputs (Sharma *et al.*, 2000) [29]. Similar findings were recorded by Panwar *et al.* (2010) [26] who reported that the higher nitrate-N under organic and integrated management than chemical management in semi-arid central India. Similarly, Yadav *et al.* (2021) [36] found 25-50% greater ammonium-N and nitrate-N in residue-retained zero tillage plots of a cotton-wheat system compared to conventional tillage without residues.

## Available Phosphorous

The data presented in table 2 show that available P in soil was significantly influenced by the mulching treatments. The highest available phosphorus (17.04 kg $ha^{-1}$) was recorded in $T_4$ (GRDF + Mulching with soybean straw at 75% of potential yield), which was statistically at par with $T_5$ (GRDF + Mulching with weed biomass) (16.92 kg $ha^{-1}$), $T_2$ (GRDF + Mulching with wheat straw @ 50% of potential yield) (16.70 kg $ha^{-1}$) and $T_3$ (GRDF + Mulching with cotton stalk @ 50% of potential yield) (16.28 kg $ha^{-1}$). Overall, the integration of GRDF with organic residues enhanced soil biological activity, minimized phosphorus fixation, and promoted its steady release, thereby increasing phosphorus availability.

These findings are consistent with Iqbal *et al.* (2011) [14] and Wang *et al.* (2011) [35] who reported that wheat and maize residue mulching reduced available P compared to bare soil. Similar results were also reported by Rakhonde *et al.* (2021) [27] highlighted that the combined use of organic manures and fertilizers helped sustain available phosphorus, likely due to the combined effects of fertilizer input, organic matter mineralization, and nutrient solubilization during decomposition.

## Available Potassium

The data presented in table 2 indicate that the application of various crop residue mulches significantly influenced the available K content in the soil. Among the treatments, the highest potassium content was recorded in $T_4$ (GRDF +

Mulching with soybean straw @ 75% of potential yield), with 367.31 kg ha⁻¹, which was statistically at par with $T_5$ (GRDF + Mulching with weed biomass, 365.40 kg ha⁻¹). When combined with GRDF, these residues created a synergistic effect by supplying both readily available and slowly released potassium sources, ensuring sustained K availability to crops throughout the growing period.

According to Chhibba (2010) [6], cereal crop residues retain nearly 75-80% of their potassium content, making them an important nutrient source when incorporated back into the soil. Similarly, Meena and Biswas (2014) [23] reported that combining inorganic fertilizers with enriched compost improved various forms of soil potassium after wheat and soybean-wheat cropping. These findings are in conformity with those of Gabhane *et al.* (2020) [9] who reported that higher available K under integrated use of organic and inorganic fertilizers, exceeding optimal NPK doses due to extra nutrient input from organics in rainfed cotton.

### Available Sulphur

The variation in available sulphur across different treatments was found to be non-significant. Numerically highest sulphur availability was observed in $T_4$ (GRDF + Mulching with soybean straw @ 75% of potential yield) (11.33 mg kg⁻¹). Consequently, the combined application of GRDF and soybean straw exerted a synergistic effect, resulting in the highest sulphur content (11.33 mg kg⁻¹). This indicates that along with supplying essential nutrients through fertilizers, the addition of soybean straw further enriched the soil by contributing organic matter and releasing sulphur during its decomposition.

These findings are supported by Thakur *et al.* (2011) [32] and Verma *et al.* (2016) [34] who reported significant increase in available soil sulphur with crop residue incorporation. Similar results were also reported by Age *et al.* (2020) [1].

**Table 2:** Available nutrient status of soil as influenced by different treatments

| Tr. No. | Treatment Details | Available Nutrients | | | |
|---|---|---|---|---|---|
| | | Nitrogen (kg ha$^{-1}$) | Phosphorus (kg ha$^{-1}$) | Potassium (kg ha$^{-1}$) | Sulphur (mg kg$^{-1}$) |
| $T_1$ | GRDF | 174.82 | 15.68 | 360.34 | 11.05 |
| $T_2$ | GRDF + Mulching with wheat straw @ 50% of potential yield | 178.03 | 16.70 | 363.23 | 11.17 |
| $T_3$ | GRDF + Mulching with cotton stalk @ 50% of potential yield | 175.28 | 16.28 | 362.08 | 11.10 |
| $T_4$ | GRDF + Mulching with soybean straw @ 75% of potential yield | 181.40 | 17.04 | 367.31 | 11.33 |
| $T_5$ | GRDF + Mulching with weed biomass | 179.56 | 16.92 | 365.40 | 11.30 |
| | SE (m) ± | 1.33 | 0.27 | 1.28 | 0.09 |
| | CD at 5% | 4.11 | 0.82 | 3.94 | NS |
| | Initial | 165.33 | 12.14 | 343.68 | 10.52 |

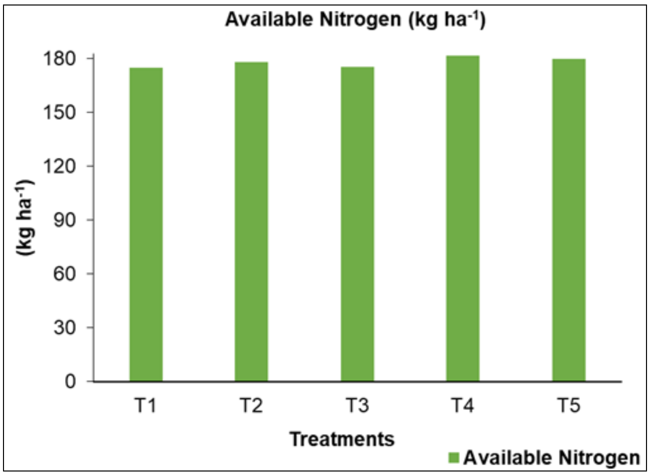


**Fig 2:** Soil available nitrogen as influenced by different treatments

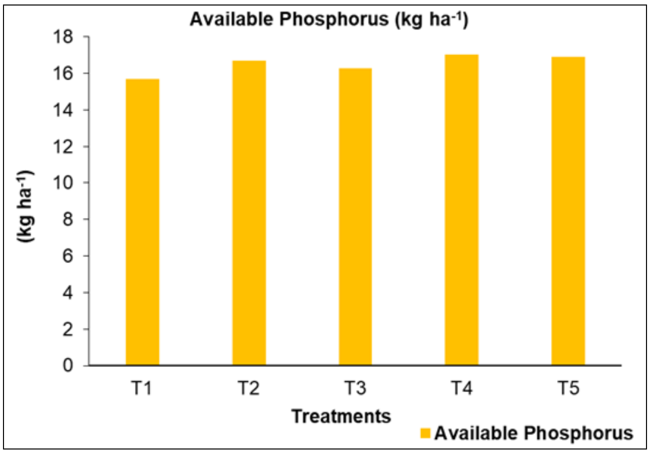


**Fig 3:** Soil available phosphorus as influenced by different treatments

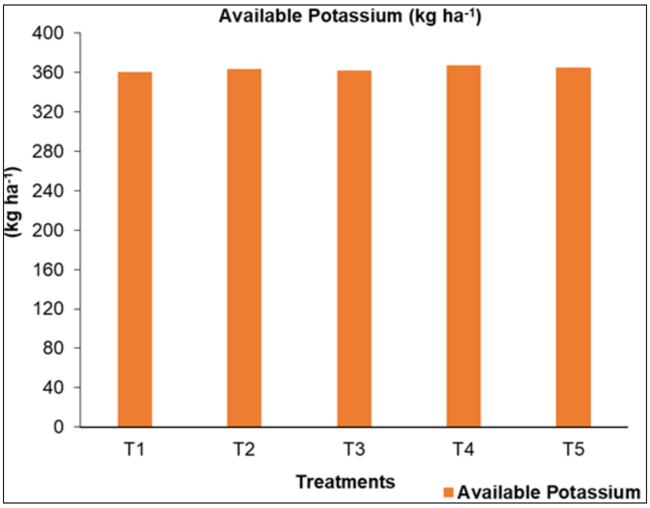


**Fig 4:** Soil available potassium as influenced by different treatments

### Conclusion

From the above experimental results, it can be concluded that application of general recommended dose of fertilizers (90:45:45 $N:P_2O_5:K_2O$ kg ha$^{-1}$ + FYM @ 5 t ha$^{-1}$) along with soybean straw mulching @ 75% of potential yield found beneficial for improving soil fertility in Bt-cotton under rainfed condition, while, weed biomass also found beneficial in improving soil fertility.

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