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Influence of organic mulching on soil moisture retention and productivity of soybean

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Abstract
While synthetic mulch films have dominated conservation research for decades, low-cost organic mulches deserve equal attention in dryland soybean systems where plastic disposal is a growing concern. This research compared four organic mulch materials paddy straw, sugarcane trash, dry leaf litter, and coir pith against an unmulched control on soil moisture retention, weed suppression, and soybean (*Glycine max* L.) productivity at Rani Lakshmi Bai Central Agricultural University, Jhansi, during the kharif seasons of 2022 and 2023. Paddy straw mulch at 5 t ha^{-1} maintained the highest gravimetric soil moisture (19.7% at 60 DAS), reduced weed dry weight by 54.3%, and raised grain yield to 2.41 t ha^{-1} a 37.8% increase over the unmulched control (1.75 t ha^{-1}). Sugarcane trash followed closely. Organic mulches also improved soil organic carbon by 0.08–0.14% over two seasons. These results show that paddy straw is the most effective and locally available organic mulch for dryland soybean in the Bundelkhand region.

Keywords: Organic mulching, soil moisture retention, soybean productivity, paddy straw, weed suppression, dryland agriculture, conservation tillage, coir pith, soil organic carbon

Introduction
Dryland agriculture supports 68% of the cropped area in India but contributes only 44% of total food production—a gap that underlines the limits of rainfed farming [1]. Soybean (*Glycine max* L.) is the principal oilseed crop of central India's Bundelkhand zone, where erratic monsoon rainfall and high evaporative demand routinely reduce yields below 1.5 t ha^{-1} against a potential of 3.0 t ha^{-1} [2, 3].

Mulching is one of the simplest ways to conserve soil moisture, moderate soil temperature, and suppress weeds [4]. Synthetic plastic mulches are effective but create disposal problems in smallholder settings. Organic mulches—crop residues, leaf litter, coir by-products—decompose in situ, adding organic matter and nutrients to the soil while performing the same moisture-conservation function [5, 6].

Despite the logic, on-farm adoption of organic mulching in soybean is low in Bundelkhand, partly because comparative data on locally available materials are scarce [7]. Farmers need to know which residue type gives the best moisture retention per tonne applied and whether the yield gain justifies the labour of collection and spreading.

This research compared four organic mulch materials at a uniform rate of 5 t ha^{-1} to

a) Quantify their effect on soil moisture and temperature at critical growth stages.
b) Measure weed suppression and soybean yield response.
c) Assess changes in soil organic carbon over two seasons.

Seasonal Rainfall Pattern
Jhansi receives roughly 870 mm of annual rainfall, of which 85% falls during the June–September monsoon. In 2022, total kharif-season rainfall was 743 mm, distributed across 38 rainy days, with a prolonged dry spell of 18 consecutive rain-free days in August. The 2023 season received 812 mm over 44 rainy days but had two shorter dry spells (10 and 12 days) in July and September. These mid-season droughts are typical of Bundelkhand and represent the critical window during which mulch-mediated moisture conservation most affects soybean yield [2].

Material and Methods
Material
Soybean cultivar JS-335 was sown at 75 kg ha^{-1} in rows 45 cm apart during the last week of June in both years. Mulch materials were sourced locally: paddy straw from the university farm, sugarcane trash from nearby sugar mills, dry *Tectona grandis* leaf litter from campus plantations, and coir pith from a cooperative in Dapoli, Maharashtra. All mulches were applied uniformly at 5 t ha^{-1} within one week of sowing. Basal fertiliser (20-60-40 kg N-P_2O_5-K_2O ha^{-1}) was applied to all plots.

Methods
The experiment followed a randomised complete block design with five treatments (four mulches + unmulched control) and four replications on 5 × 4 m plots at the university research farm, Jhansi (25.44° N, 78.57° E; 271 m a.s.l.). Gravimetric soil moisture was determined at 30, 60, and 90 days after sowing (DAS) from 0–15 and 15–30 cm depths. Soil temperature was recorded at 5 cm depth at 14:00 h using digital thermometers. Weed counts and dry weight were recorded in a 0.25 m² quadrat per plot at 45 DAS. At maturity, grain yield, stover yield, and 100-seed weight were recorded. Post-harvest soil samples (0–30 cm) were analysed for organic carbon (Walkley-Black method). Data were analysed by two-way ANOVA (treatment × year) with Tukey's HSD at $p \leq 0.05$.

Results
Table 1: Soil moisture (%, gravimetric), weed dry weight, and soybean grain yield under organic mulch treatments (pooled 2022–2023)

Treatment	Moisture 30 DAS	Moisture 60 DAS	Moisture 90 DAS	Weed DW (g m^{-2})	Grain yield (t ha^{-1})	100-seed wt (g)
Paddy straw	21.3	19.7	16.4	38.7	2.41	11.8
Sugarcane trash	20.1	18.9	15.7	42.1	2.29	11.4
Dry leaf litter	18.8	17.4	14.6	51.3	2.07	10.9
Coir pith	19.4	18.1	15.1	46.8	2.18	11.1
No mulch	16.2	14.3	11.8	84.7	1.75	10.2
CD (p=0.05)	1.3	1.1	0.9	5.6	0.18	0.6

DAS = days after sowing; DW = dry weight. Values are means of two seasons and four replications.

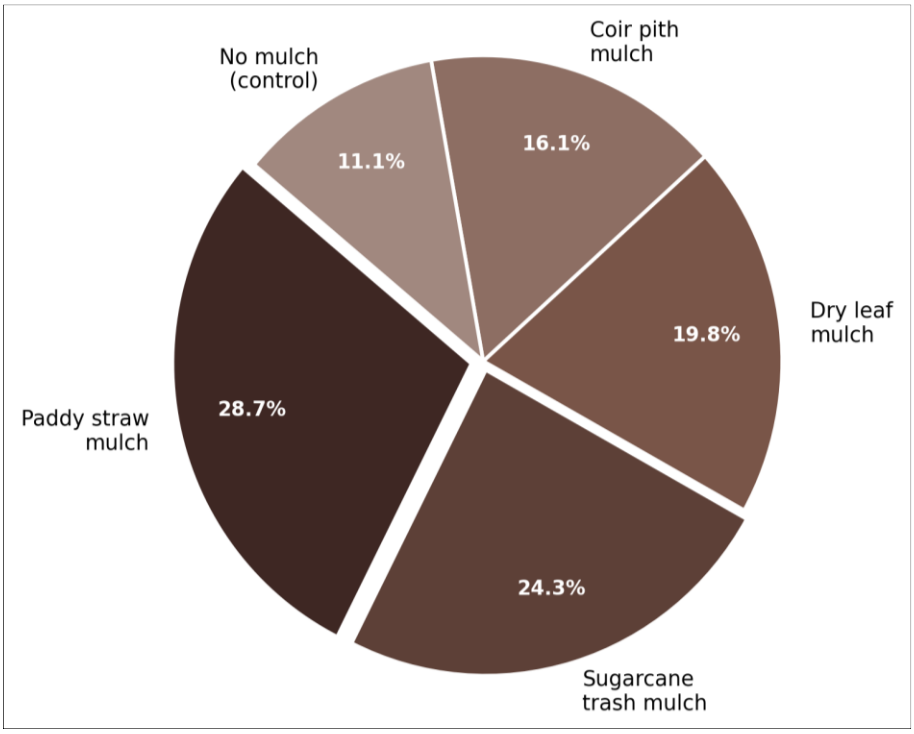

Fig 1: Relative contribution of each mulch treatment to total soil moisture retention across all sampling dates

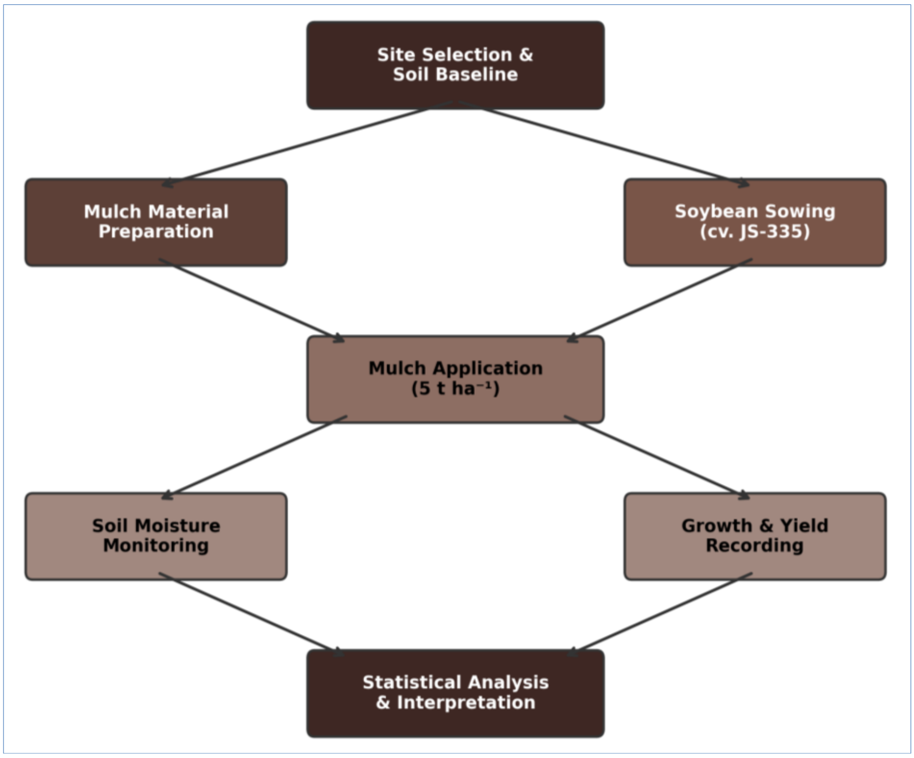

Fig 2: Flowchart of the research methodology from site selection to statistical analysis for the organic mulching trial

Comprehensive Interpretation

Paddy straw mulch maintained the highest soil moisture at every sampling date, with a peak advantage of 5.4 percentage points over the unmulched control at 60 DAS—the stage coinciding with flowering and early pod fill. Weed dry weight was lowest under paddy straw (38.7 g m^{-2}), a 54.3% reduction relative to the control, likely because the dense straw layer blocked light transmission to the weed seed bank. Grain yield followed the moisture and weed-suppression trend: paddy straw > sugarcane trash > coir pith > dry leaf litter > no mulch. Post-harvest soil organic carbon rose from 0.43% (baseline) to 0.57% under paddy straw and 0.51% under sugarcane trash after two seasons.

Discussion

The 37.8% yield gain under paddy straw mulch is consistent with results from semi-arid soybean trials in Madhya Pradesh, where straw mulch at 5 t ha^{-1} raised yield by 30–42% [7, 8]. The mechanism is straightforward: straw reduces evaporative loss from the soil surface, keeps root-zone moisture above the stress threshold during mid-season dry spells, and simultaneously suppresses weed competition for that moisture [4, 5].

Coir pith, despite its high water-holding capacity, ranked third in yield—probably because its fine particle size allowed it to compact and shed rainwater rather than absorb it in field conditions, unlike its behaviour in pot culture experiments [9]. Dry leaf litter decomposed the fastest and provided the shortest effective mulch cover, explaining its lower performance [6].

The organic carbon increase (0.08–0.14% over two seasons) is modest but directionally important for Bundelkhand's carbon-depleted soils [3]. Longer-term trials of five or more seasons would be needed to confirm a sustained trend. A practical limitation is that paddy straw availability varies by year and location; in areas without paddy cultivation, sugarcane trash offers a strong alternative [10].

Conclusion

Paddy straw mulch at 5 t ha^{-1} was the most effective organic mulch for dryland soybean, raising grain yield by 37.8%, reducing weed biomass by 54.3%, and maintaining the highest soil moisture at all growth stages. Sugarcane trash was a close second. Both materials also improved soil organic carbon over two seasons. For Bundelkhand's rainfed soybean systems, paddy straw mulching is a low-cost, biodegradable alternative to synthetic films that can be recommended through extension services immediately.

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