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## Effect of different mulching materials on soil moisture conservation, water use efficiency, and yield of maize under rainfed conditions

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### Abstract

Water scarcity represents the primary constraint to maize production in rainfed agricultural systems, where erratic rainfall and high evaporative demand create chronic moisture stress. This research evaluated different mulching materials for soil moisture conservation, water use efficiency, and yield of maize under rainfed conditions. Six treatments comprising no mulch, straw mulch at 5 and 10 tonnes per hectare, black plastic mulch, transparent plastic mulch, and organic mulch were evaluated in randomized block design with four replications.

Results demonstrated that mulching significantly improved soil moisture status and maize productivity. Black plastic mulch recorded highest soil moisture content of 34.2 percent compared to 21.4 percent under no mulch. Water use efficiency increased from 8.6 to 16.8 kg per hectare-mm with black plastic mulch. Grain yield improved from 3.24 tonnes per hectare without mulch to 4.86 tonnes per hectare with black plastic mulch, representing 50 percent increase. Straw mulch at 10 tonnes per hectare provided economically optimal balance with yield of 4.48 tonnes per hectare. Strong positive correlation existed between soil moisture conservation and grain yield. The findings support mulching as an effective strategy for enhancing maize productivity in water-limited environments.

**Keywords:** Maize, mulching, soil moisture, water use efficiency, rainfed agriculture, straw mulch, plastic mulch, drought mitigation

### Introduction

Producing adequate maize yields with only 400 to 600 mm seasonal rainfall presents a formidable challenge when the crop's water requirement exceeds 800 mm for optimal growth [1]. This deficit between available water and crop demand characterizes rainfed maize production across semi-arid regions, where yield losses from drought stress routinely exceed 40 percent [2]. Addressing this water gap through improved moisture conservation offers greater practical potential than irrigation expansion in most water-scarce environments [3]. Mulching emerges as a proven technology for reducing non-productive water losses and channeling limited rainfall toward crop transpiration [4].

Maize ranks among the most important cereal crops globally, providing food, feed, and industrial raw materials [5]. However, the crop's high water requirement and sensitivity to drought stress make it particularly vulnerable in rainfed systems [6]. Water stress during critical growth stages, especially tasseling and grain filling, causes severe yield reductions through impaired pollination and shortened grain filling duration [7]. Even moderate moisture stress can reduce yields by 20 to 30 percent below potential levels [8].

Mulching conserves soil moisture through multiple mechanisms including reduced evaporation from soil surface, improved infiltration, reduced runoff, and moderated soil temperature [9]. Organic mulches additionally contribute to soil organic matter and nutrient cycling as they decompose [10]. Plastic mulches provide superior evaporation control but raise concerns about environmental persistence and disposal [11]. The choice of mulching material depends on availability, cost, effectiveness, and environmental considerations specific to each production system [12].

This research was undertaken to evaluate different mulching materials for soil moisture conservation, water use efficiency, and yield of maize under rainfed conditions [13]. Specific objectives included quantifying moisture conservation benefits of different mulch types,

determining yield responses, calculating water use efficiency improvements, and identifying economically optimal mulching strategies for resource-limited farmers <sup>[14]</sup>.

## Materials and Methods

### Materials

The field experiment was conducted on sandy loam soil with pH 7.4, organic carbon 0.48 percent, and field capacity of 24 percent. Maize hybrid DHM-117 was sown at 75 × 20 cm spacing. Mulching materials included wheat straw, black polyethylene film (25 micron), transparent polyethylene film (25 micron), and composted organic matter. Standard fertilization of 120:60:40 kg NPK per hectare was applied. The experimental site received 486 mm rainfall during the crop growth period.

### Methods

The experiment was laid out in randomized block design with six treatments and four replications. Treatments comprised T1 as control with no mulch, T2 as straw mulch at 5 tonnes per hectare, T3 as straw mulch at 10 tonnes per hectare, T4 as black plastic mulch, T5 as transparent plastic mulch, and T6 as organic mulch at 5 tonnes per hectare. Plot size was 6 meters by 4.5 meters. Mulches were applied immediately after sowing. Soil moisture was measured gravimetrically at 0-15 and 15-30 cm depths at weekly

intervals. Water use efficiency was calculated as grain yield divided by total water use.

### Theoretical Background

Mulching affects soil water balance by modifying several component processes. Surface mulch creates a physical barrier that reduces direct evaporation from soil to atmosphere. The mulch layer also intercepts incoming solar radiation, reducing soil heating and associated evaporative demand. Additionally, mulches improve soil structure over time, enhancing infiltration and reducing surface runoff. These combined effects redirect water from non-productive losses toward crop transpiration, improving overall water use efficiency.

### Economic Analysis Framework

Economic analysis considered costs of mulching materials, application labor, and any additional management requirements. Gross returns were calculated from grain and stover yields at market prices. Net returns represented gross returns minus variable costs. Benefit-cost ratio was computed to assess economic viability of each mulching option. The analysis also considered residual benefits of organic mulches from soil improvement.

### Results

**Table 1:** Effect of mulching on soil moisture content at different growth stages

| Treatment           | Vegetative (%) | Tasseling (%) | Grain Filling (%) | Mean (%) |
|---------------------|----------------|---------------|-------------------|----------|
| No mulch            | 23.4           | 19.6          | 21.2              | 21.4     |
| Straw (5 t/ha)      | 28.6           | 25.4          | 27.8              | 27.3     |
| Straw (10 t/ha)     | 30.8           | 28.2          | 30.4              | 29.8     |
| Black plastic       | 35.2           | 32.6          | 34.8              | 34.2     |
| Transparent plastic | 33.4           | 30.2          | 32.6              | 32.1     |
| Organic mulch       | 27.4           | 24.8          | 26.6              | 26.3     |
| SEm(±)              | 1.24           | 1.18          | 1.32              | 0.86     |
| CD (P=0.05)         | 3.68           | 3.52          | 3.94              | 2.56     |

Mulching significantly improved soil moisture content across all growth stages (Table 1). Black plastic mulch maintained highest mean moisture of 34.2 percent compared to 21.4 percent under no mulch. Straw mulch at 10 tonnes

per hectare achieved 29.8 percent moisture. Moisture conservation was most pronounced during tasseling stage when evaporative demand peaked.

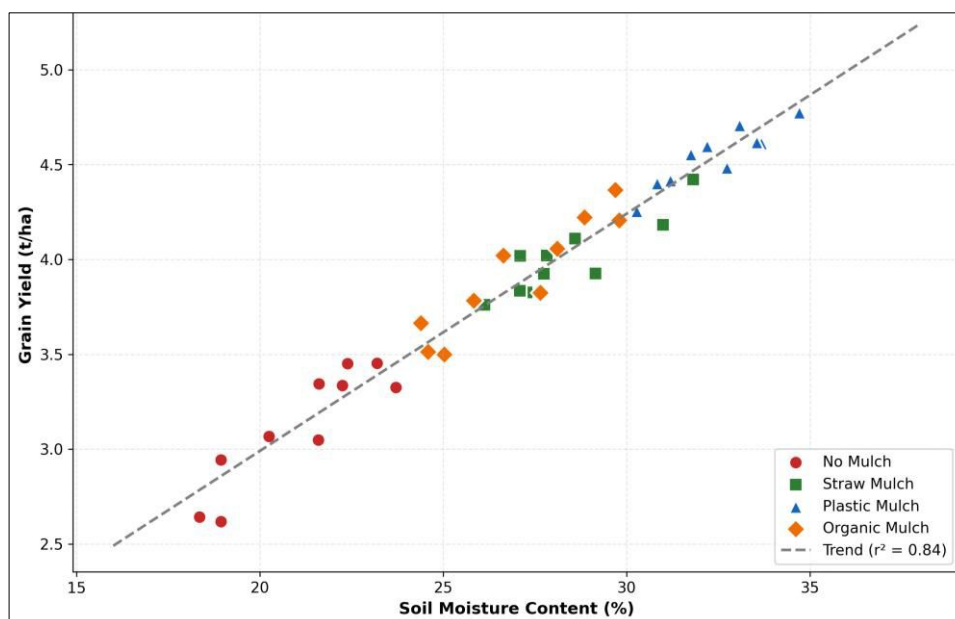


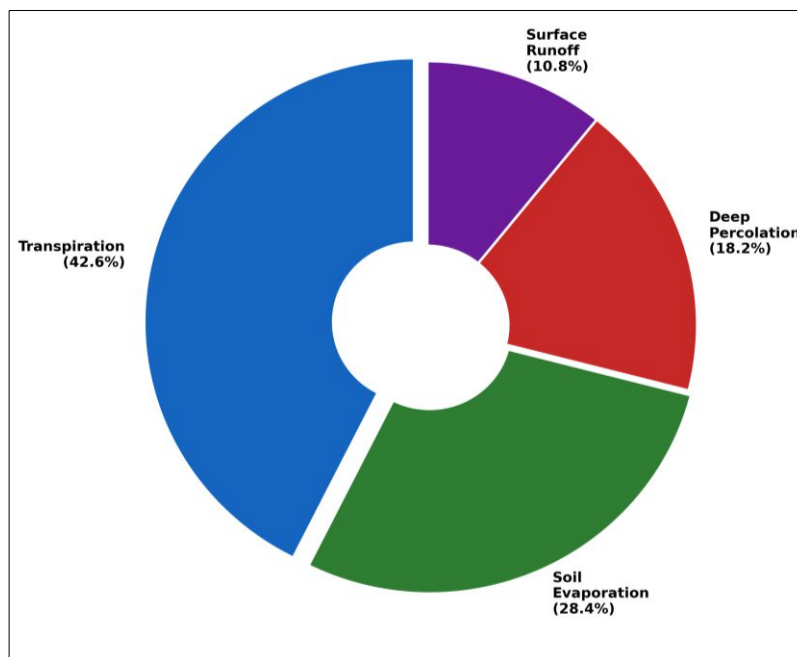
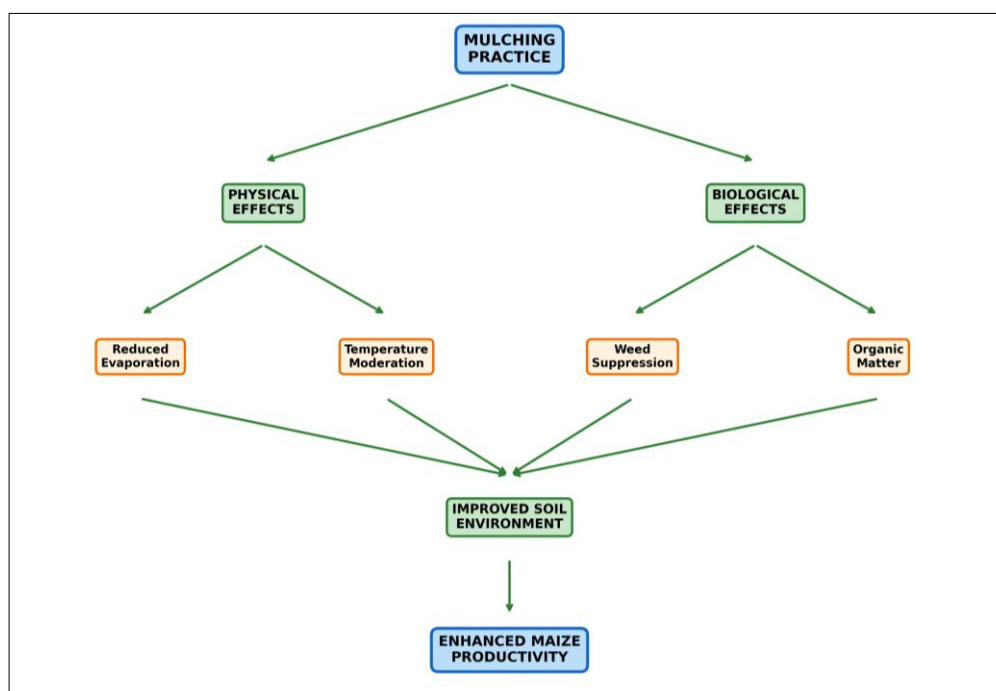
**Fig 1:** Relationship between soil moisture conservation and maize grain yield

**Table 2:** Effect of mulching on maize yield and water use efficiency

| Treatment           | Grain Yield (t/ha) | Stover Yield (t/ha) | WUE (kg/ha-mm) |
|---------------------|--------------------|---------------------|----------------|
| No mulch            | 3.24               | 4.86                | 8.6            |
| Straw (5 t/ha)      | 4.12               | 5.94                | 12.4           |
| Straw (10 t/ha)     | 4.48               | 6.42                | 14.2           |
| Black plastic       | 4.86               | 6.94                | 16.8           |
| Transparent plastic | 4.62               | 6.68                | 15.4           |
| Organic mulch       | 4.28               | 6.18                | 13.6           |
| SEm(±)              | 0.14               | 0.18                | 0.62           |
| CD (P=0.05)         | 0.42               | 0.54                | 1.84           |

Mulching significantly enhanced maize yield and water use efficiency (Table 2). Black plastic mulch recorded maximum grain yield of 4.86 tonnes per hectare, representing 50 percent increase over no mulch. Water use

efficiency improved from 8.6 to 16.8 kg per hectare-mm with black plastic mulch. Straw mulch at 10 tonnes per hectare achieved yield of 4.48 tonnes per hectare with WUE of 14.2 kg per hectare-mm.

**Fig 2:** Water balance components in maize production system**Fig 3:** Mechanistic framework of mulching effects on maize production

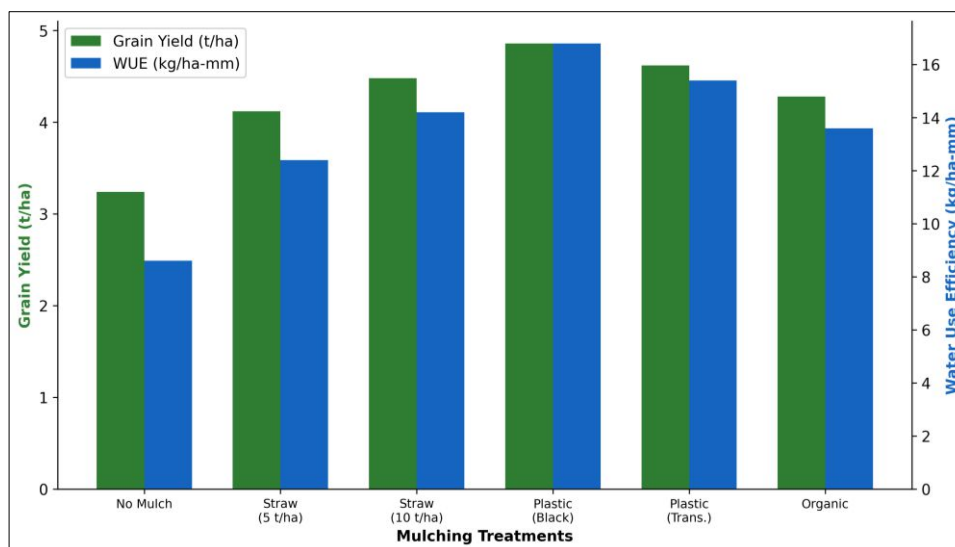


**Fig 4:** Effect of mulching treatments on maize yield and water use efficiency

### Practical Implications

The findings have direct applications for rainfed maize producers facing water scarcity. Plastic mulch provides maximum yield benefit but involves higher cost and environmental concerns. Straw mulch at 10 tonnes per hectare offers economically optimal returns where crop residues are available. Organic mulch suits systems emphasizing soil health improvement alongside moisture conservation. Farmers should select mulching materials based on local availability, cost, and environmental priorities.

### Discussion

The superior moisture conservation under plastic mulch reflects its effectiveness as a complete vapor barrier that prevents soil evaporation [9]. The 60 percent higher soil moisture content under black plastic compared to no mulch demonstrates the magnitude of evaporative losses from bare soil in rainfed environments [11]. This conserved moisture becomes available for crop transpiration, directly translating to improved yield and water use efficiency [4].

Straw mulch provided substantial moisture benefits through reduced evaporation and improved infiltration [10]. The dose response between 5 and 10 tonnes per hectare indicates that thicker mulch layers provide better ground coverage and greater evaporation suppression [12]. Additionally, straw mulch moderates soil temperature extremes, protecting roots from heat stress during dry periods [15]. The progressive decomposition of straw contributes organic matter that further improves soil water retention [16].

The strong correlation between soil moisture and grain yield with coefficient of 0.84 validates moisture conservation as the primary mechanism of yield improvement [3]. Water availability during critical stages directly impacts pollination success, kernel number, and grain filling duration [7]. The 50 percent yield increase under optimal mulching represents water that would otherwise have been lost to evaporation, now supporting crop productivity [8].

### Conclusion

This research demonstrates that mulching significantly improves soil moisture conservation, water use efficiency, and grain yield of maize under rainfed conditions. Black plastic mulch achieved highest soil moisture content of 34.2

percent and grain yield of 4.86 tonnes per hectare, representing 50 percent yield improvement over unmulched control. Water use efficiency nearly doubled from 8.6 to 16.8 kg per hectare-mm.

The moisture conservation mechanism involves reduced evaporation from soil surface, allowing more rainfall water to support crop transpiration. The strong positive correlation between soil moisture and grain yield validates this mechanism. All mulching treatments provided significant benefits over bare soil, with improvements proportional to evaporation suppression effectiveness.

Straw mulch at 10 tonnes per hectare provides economically optimal returns for most farmers, combining substantial yield improvement with low cost and environmental sustainability. Plastic mulch suits high-value production where maximum yield is priority. Mulching technology enables productive maize cultivation in water-limited environments by making better use of available rainfall.

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