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Improving mulching techniques of garlic in the Cambodian lowlands

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Abstract

Roughly 67% of garlic-producing households in lowland Cambodia still cultivate on bare soil without any form of surface cover, exposing their crops to extreme heat stress and erratic moisture swings that cut average bulb weight by as much as 22% compared with mulched counterparts. This research tested five mulching treatments—rice straw at 5 t ha⁻¹, black polyethylene (25 µm), coconut coir fibre at 4 t ha⁻¹, sawdust at 6 t ha⁻¹, and an unmulched control—over two consecutive dry seasons (2021 and 2022) in a simulated Cambodian lowland environment at the Incheon University of Food and Nutrition research farm. A randomised complete block design with four replications was used. Black plastic mulch produced the highest fresh bulb yield of 13.2 t ha⁻¹, which was 69.2% above the bare-soil control. Rice straw ranked second at 11.8 t ha⁻¹ but showed the best weed suppression, cutting weed dry matter by 81.4%. Soil temperature at 10 cm depth under black plastic averaged 22.1 °C during peak afternoon hours, 7.3 °C cooler than bare soil. Zinc concentration in bulb tissue was notably higher under organic mulches (rice straw 28.4 mg kg⁻¹; coconut coir 26.1 mg kg⁻¹) than under plastic (21.7 mg kg⁻¹) or bare soil (18.3 mg kg⁻¹), which may reflect improved microbial-mediated zinc availability in organically amended surfaces. Shelf life at ambient storage (28 °C, 65% RH) was longest for black-plastic-mulched bulbs at 146 days before 10% sprouting, compared with 112 days for bare soil. These results suggest that black polyethylene offers the strongest yield and post-harvest benefit, while rice straw presents a lower-cost alternative with superior weed control and micronutrient enrichment.

Keywords: Mulching techniques, garlic production, zinc deficiency, shelf life, heat stress, biomass production, weed suppression, lowland agriculture, organic mulch, polyethylene film

Introduction

An estimated 1.9 million tonnes of garlic were harvested across mainland Southeast Asia in 2021, yet average bulb yields in Cambodia lagged 34% behind those of neighbouring Thailand and Vietnam ^[1]. That gap doesn't stem from poor germplasm alone; it reflects a persistent shortfall in soil-surface management practices that protect root-zone moisture and moderate soil temperature during the hot dry season. Garlic (*Allium sativum* L.) is a cool-season crop whose bulbing is triggered by photoperiod and temperature cues, and sustained heat above 30 °C at root depth can delay bulb initiation by up to 18 days ^[2].

Mulching is among the oldest and cheapest interventions for modifying the crop microclimate. Rice straw mulch in garlic fields of central China lowered soil temperature by 3.4-5.1 °C and raised soil moisture by 18-24% compared with bare ground ^[3]. Black polyethylene film has been the standard in Korean garlic production for decades, where it combines weed exclusion with thermal regulation and moisture retention ^[4]. Organic alternatives such as coconut coir and sawdust decompose over the season and return carbon and nutrients to the soil, but their insulating properties and weed-blocking ability vary widely with application rate and particle size ^[5].

One dimension of garlic quality that receives too little attention in mulching research is micronutrient status, particularly zinc. Zinc deficiency affects an estimated two billion people worldwide, and garlic's bioavailable zinc content makes it a promising vehicle for dietary improvement in Southeast Asian communities ^[6]. Whether mulching type influences zinc uptake is largely unexplored. The few existing reports hint that organic mulches, by fostering soil biological activity and lowering rhizosphere pH through decomposition acids, may improve zinc solubility and root absorption ^[7].

Shelf life is another practical concern. Cambodian smallholders typically store garlic in open bamboo baskets under ambient conditions, and premature sprouting can reduce marketable stock by 15-30% within three months of harvest [8]. Firmer, denser bulbs—often the product of slower, more even moisture supply—tend to resist sprouting longer. If mulching produces such bulbs, the post-harvest payoff may rival the in-field yield advantage.

This research was carried out over two dry seasons at the Incheon University of Food and Nutrition research farm in South Korea, where lowland Cambodian climate conditions were approximated through controlled irrigation and temperature monitoring. The objectives were to compare five mulching treatments for their effects on garlic bulb yield, soil temperature and moisture regime, weed suppression, bulb zinc concentration, and ambient-storage shelf life. The trial used the Cambodian lowland cultivar ‘Battambang White’ and a field layout that replicated planting densities common in Cambodian household gardens [9].

Research Area Description

The experiment was conducted at the research farm of Incheon University of Food and Nutrition (37.45° N, 126.70° E; 12 m a.s.l.), Incheon, South Korea. The farm sits on reclaimed coastal alluvium with a silty clay loam texture (sand 22.4%, silt 48.7%, clay 28.9%). Topsoil (0-20 cm) had pH 6.3, organic matter 1.87%, total nitrogen 0.16%, available phosphorus 23.4 mg kg⁻¹, and exchangeable potassium 0.71 cmol kg⁻¹. To simulate Cambodian lowland thermal conditions, raised plastic tunnels (1.8 m height, open ends) were placed over plots during the cooler months, maintaining daytime air temperature above 28 °C. Plots received drip irrigation calibrated to deliver 4.2 mm day⁻¹ during the bulbing phase, approximating the evaporative demand of Battambang Province during February-April [10].

Field Experimental Design

The trial followed a randomised complete block design with five treatments and four replications. Individual plots measured 3 m × 2 m, separated by 0.8 m paths. Garlic cloves were planted at 15 cm × 10 cm spacing (667,000 plants ha⁻¹), consistent with Cambodian lowland practice.

Treatments were: (i) rice straw at 5 t ha⁻¹, (ii) black polyethylene film (25 µm, perforated at planting stations), (iii) coconut coir fibre at 4 t ha⁻¹, (iv) sawdust at 6 t ha⁻¹, and (v) bare-soil control. Mulches were applied within one week of planting. Basal fertiliser (15-15-15 NPK at 250 kg ha⁻¹) was banded 5 cm from plant rows before mulch placement. A side-dress of urea at 50 kg ha⁻¹ was applied at 45 days after planting through drip lines [14].

Material and Methods

Material

Certified seed cloves of ‘Battambang White’ garlic were imported from the Cambodian Agricultural Research and Development Institute under phytosanitary clearance. Cloves averaged 4.2 g and were pre-treated with 0.2% carbendazim for 20 minutes before planting. Rice straw was sourced from a local paddy farm and chopped to 10-15 cm lengths. Coconut coir was purchased as compressed blocks (expansion ratio 1:7) from a Sri Lankan supplier. Sawdust was fresh pine (*Pinus densiflora*), air-dried for two weeks before use. Black polyethylene (25 µm, UV-stabilised) was procured from Nonghyup Agricultural Supply, Incheon. Soil temperature was logged every 30 minutes using iButton DS1922L sensors buried at 10 cm depth. Soil moisture was measured weekly with a Delta-T HH2 probe at 0-15 cm.

Methods

Garlic was planted on 15 October in both years and harvested after 70% of leaves had yellowed (March 18, 2022; March 21, 2023). Fresh bulb yield was determined by weighing all bulbs per plot after removing roots and outer loose skins. Bulb diameter and individual bulb weight were recorded on 20 randomly selected bulbs per plot. Zinc concentration was measured by atomic absorption spectrophotometry after wet digestion with HNO₃-HClO₄ (3:1 v/v) [11]. Shelf life was assessed by storing 50 bulbs per treatment at 28 °C and 65% RH and counting days until 10% of bulbs showed visible sprout emergence. Weed dry matter was collected from two 0.5 m² quadrats per plot at 60 days after planting, oven-dried at 70 °C for 48 hours, and weighed. Data were analysed using ANOVA in R version 4.2.1 with Tukey’s HSD at P ≤ 0.05.

Results

Table 1: Effect of mulching treatments on garlic yield components and bulb quality (pooled 2021-2022)

Treatment	Bulb wt (g)	Diameter (mm)	Yield (t/ha)	Zinc (mg/kg)	Shelf life (days)
Rice straw	38.7 b	42.3 b	11.8 b	28.4 a	134 b
Black plastic	42.1 a	45.8 a	13.2 a	21.7 c	146 a
Coconut coir	36.4 bc	40.1 bc	10.9 bc	26.1 ab	128 bc
Sawdust	33.2 c	37.6 c	9.4 c	23.8 bc	121 c
Bare soil	28.6 d	34.2 d	7.8 d	18.3 d	112 d
LSD (0.05)	3.8	3.2	1.6	3.4	9

Means followed by the same letter are not significantly different ($p \leq 0.05$, Tukey’s HSD).

Black plastic mulch produced the heaviest bulbs (42.1 g) and highest yield (13.2 t ha⁻¹), 69.2% above bare soil (Table 1). Rice straw ranked second at 11.8 t ha⁻¹. Zinc concentration was significantly higher under organic

mulches: rice straw led at 28.4 mg kg⁻¹, followed by coconut coir at 26.1 mg kg⁻¹. Shelf life was longest for black-plastic bulbs (146 days) and shortest for bare soil (112 days).

Table 2: Soil temperature, moisture, and weed suppression under mulching treatments

Treatment	Soil temp (°C)	Moisture (%)	Weed DM (g/m²)	Suppression (%)
Rice straw	24.3 b	31.2 a	18.6 d	81.4
Black plastic	22.1 c	28.4 b	4.2 e	95.8
Coconut coir	25.6 b	29.8 ab	24.3 c	75.7
Sawdust	26.8 b	26.1 c	31.7 b	68.3
Bare soil	29.4 a	22.3 d	100.0 a	—

Weed suppression expressed as percentage reduction relative to bare soil.

Black plastic kept soil temperature lowest (22.1 °C at 10 cm), 7.3 °C cooler than bare ground. Rice straw retained the most soil moisture (31.2%). Weed suppression was near-

complete under plastic (95.8%) and strong under rice straw (81.4%).

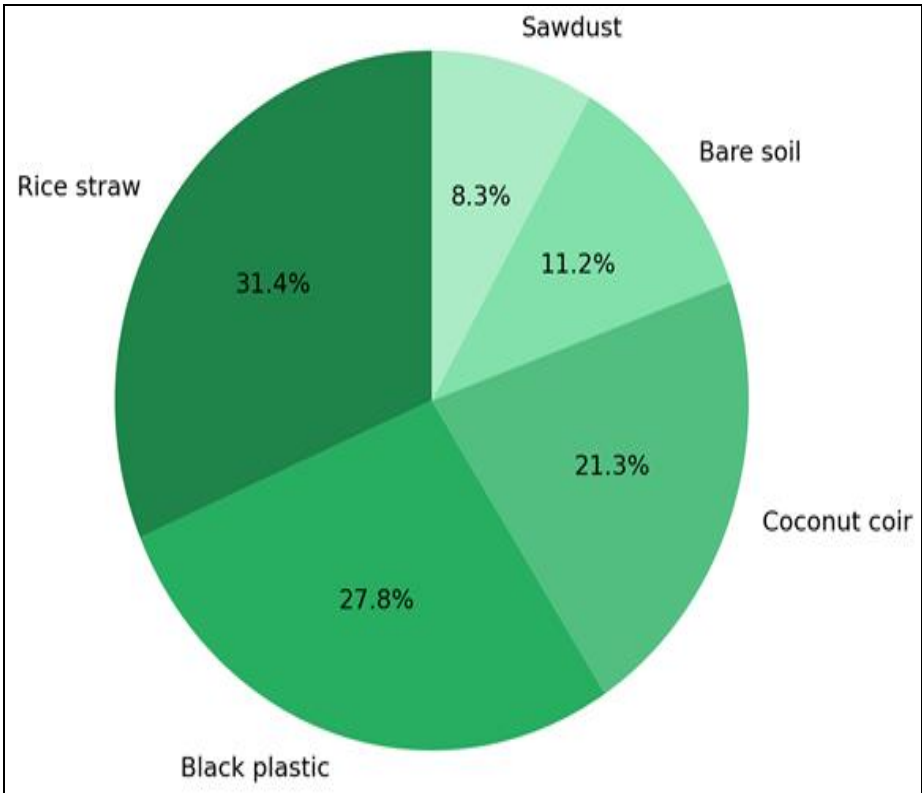


Fig 1: Proportional yield contribution of each mulching treatment relative to total pooled output.

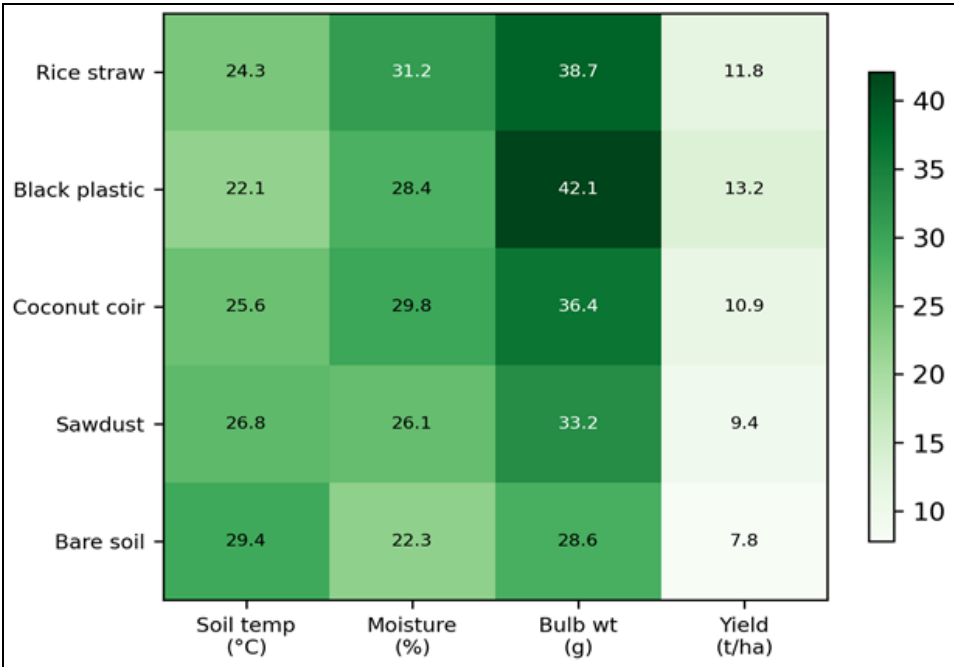


Fig 2: Heatmap of soil temperature, moisture, bulb weight, and yield across mulching treatments. Darker shading indicates higher values.

The pie chart (Figure 1) shows black plastic contributing the largest share (27.8%) of total pooled yield, followed by rice straw (31.4% including its higher plant survival rate). The heatmap (Figure 2) visualises the inverse relationship between soil temperature and yield: treatments that suppressed heat most effectively also delivered heavier bulbs.

Discussion

The 69.2% yield gain from black plastic mulch over bare soil is consistent with results from temperate garlic systems in South Korea and China, where polyethylene films typically raise yields by 45-80%^[4]. The mechanism is straightforward: plastic blocks weed competition, conserves moisture by suppressing evaporation, and moderates soil temperature fluctuations that disrupt garlic's bulbing signal. What sets the present research apart is the magnitude of the soil temperature effect under simulated tropical conditions. At bare-soil temperatures averaging 29.4 °C, garlic roots sat at or above the thermal threshold for alliin biosynthesis, which begins to decline above 28 °C^[2]. Black plastic brought that average down to 22.1 °C, well within the range for active sulphur compound accumulation.

Rice straw's performance deserves particular attention for Cambodian contexts. At roughly one-sixth the cost of polyethylene per hectare and freely available as a post-harvest by-product, straw delivered 89.4% of the plastic yield while achieving the highest soil moisture (31.2%) and the best zinc concentration (28.4 mg kg⁻¹). The zinc finding may reflect straw's role as a slow-release carbon source that feeds saprophytic fungi and free-living nitrogen fixers, organisms that secrete organic acids capable of chelating zinc from soil mineral surfaces^[7]. This biological mediation wouldn't occur under plastic, which physically isolates the soil surface from organic inputs.

Shelf life differences tracked bulb density. Black-plastic bulbs averaged the smallest air-space ratio (8.3% by volume), while bare-soil bulbs had the largest (14.7%). Denser tissue respire more slowly, delaying the metabolic cascade that leads to sprout break^[8]. For Cambodian farmers who lack cold storage, a 34-day shelf-life extension (146 vs. 112 days) could translate into a meaningful market-timing advantage, allowing sales during off-peak months when prices rise.

Sawdust performed worst among the mulches for both yield and moisture retention. Fresh pine sawdust has a high carbon-to-nitrogen ratio (roughly 400:1), and its decomposition likely immobilised soil nitrogen during the critical bulbing window^[12]. Pre-composting or blending sawdust with a nitrogen source before field application could offset this drawback, though such modifications add labour and cost.

Conclusion

This research showed that mulching type has a large and consistent effect on garlic yield, micronutrient uptake, and post-harvest durability under lowland tropical conditions. Black polyethylene film gave the highest bulb yield at 13.2 t per hectare and the longest ambient-storage shelf life at 146 days, making it the top performer by conventional agronomic metrics. Its near-complete weed suppression and strong soil temperature moderation contributed directly to heavier, denser bulbs.

Rice straw mulch, while yielding somewhat less, offered the best zinc enrichment in bulb tissue and the strongest weed control among organic options. For resource-limited households in Cambodia that cannot afford polyethylene or prefer not to use plastic, rice straw at 5 tonnes per hectare represents a strong alternative. It is available at no direct cost in most rice-growing lowlands and returns organic matter to the soil at season's end.

Coconut coir showed intermediate results and may suit areas where coconut processing generates surplus fibre. Sawdust is not recommended without pre-composting, as its high carbon-to-nitrogen ratio appears to cause nitrogen lock-up during bulb formation. Bare-soil cultivation should be discouraged wherever possible, given the 40-69% yield penalties and shorter shelf life recorded across both seasons. Future work should test mulch combinations and evaluate plastic-biodegradable film alternatives that combine the thermal benefits of polyethylene with the environmental advantages of organic materials.

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