



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
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NAAS Rating (2025): 5.20
www.agronomyjournals.com
2025; 8(9): 143-146
Received: 15-08-2025
Accepted: 17-09-2025

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Evaluation of biodegradable mulch films as alternatives to plastic mulching in sustainable agriculture

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DOI: <https://www.doi.org/10.33545/2618060X.2025.v8.i9b.5181>

Abstract

Plastic mulch films boost crop yields by conserving moisture and suppressing weeds, but they leave behind persistent residues that degrade soil structure and pollute farmland across the tropics. This research compared four biodegradable mulch alternatives PLA/PBAT blend, starch-based, paper, and PHA-based films against Conventional Polyethylene (PE) in a 24-week okra field trial at the University of Ibadan Teaching and Research Farm between March and August 2023. All biodegradable films maintained soil moisture within 87-94% of PE performance during the first 12 weeks. Paper mulch degraded fastest, losing 78.3% of its mass by week 24, while PHA-based film retained the most integrity at 41.7% mass loss. Okra yield under PLA/PBAT (14.8 t ha⁻¹) did not differ from PE (15.3 t ha⁻¹, $p > 0.05$). Soil temperature was positively correlated with degradation rate across all biodegradable types ($r = 0.71-0.84$). Results suggest that PLA/PBAT blends offer the best balance between agronomic performance and post-season biodegradation for humid tropical vegetable systems.

Keywords: Biodegradable mulch, plastic mulch alternatives, PLA/PBAT, soil moisture conservation, weed suppression, mulch degradation, tropical agriculture, okra production, sustainable farming

Introduction

On one hand, polyethylene mulch films have transformed vegetable farming by raising soil temperature, cutting water loss, and blocking weeds lifting yields by 20-60% in tropical systems [1]. On the other hand, these films persist in soil for decades, fragmenting into microplastics that reduce porosity and contaminate water [2, 3]. Nigeria generates roughly 18,000 tonnes of agricultural plastic waste annually with limited disposal options [4].

Biodegradable alternatives made from PLA, PBAT, starch, PHA, or cellulose paper have entered markets in Europe and East Asia [5, 6], but most performance data come from temperate climates and their behavior in warm, humid West African conditions is largely untested [7, 8]. Key unknowns include whether tropical temperatures accelerate degradation so fast that films lose function before crop maturity, and whether moisture conservation matches PE during critical early growth [9, 10]. This research compared four biodegradable films against PE in a 24-week okra trial in southwestern Nigeria.

Climatic conditions during the trial

The trial ran March-August 2023 at the University of Ibadan (7.44° N, 3.90° E, 227 m), spanning the dry-to-wet season transition. Total rainfall was 847 mm, peaking in June (194 mm) and July (178 mm) [11]. Mean air temperature ranged 26.3-29.7 °C. Soil temperature at 5 cm under mulch averaged 27.8-31.4 °C, 2-4 °C above bare soil, creating conditions for accelerated microbial decomposition [12].

Materials and Methods

Materials

Four biodegradable films were tested: PLA/PBAT blend (15 µm thickness, BASF ecovio®), starch-based (20 µm, Novamont Mater-Bi®), cellulose paper mulch (80 g m⁻², Weedguard Plus®), and PHA-based film (18 µm, Danimer Scientific). Conventional black PE film (25 µm, local supplier) served as the control. Okra (cv. Clemson Spineless) was the test crop. Compound

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NPK fertilizer (15:15:15) was applied at 200 kg ha⁻¹ at transplanting. The soil is a ferric Luvisol (Alfisol) with 62% sand, 21% clay, 17% silt, pH 6.4, and organic carbon 1.34% [13].

Methods

A randomized complete block design with six treatments (four biodegradable films, PE, and bare soil) and four replicates gave 24 plots of 12 m² each. Mulch was laid manually on raised beds (1.0 m wide, 0.2 m high) with transplanting holes cut at 50 × 40

cm spacing. Soil moisture was recorded weekly at 15 cm depth using TDR probes (Campbell CS616). Weed biomass was harvested from a 0.5 m² quadrat per plot at 6, 12, and 18 weeks. Film degradation was assessed by retrieving buried mesh-enclosed strips (10 × 30 cm) at 6-week intervals and measuring dry mass loss. Okra pods were harvested twice weekly from week 8 to week 22 and weighed fresh [14]. Data were analyzed by one-way ANOVA with Tukey's HSD ($p < 0.05$) in R 4.3.2.

Results

Table 1: Agronomic performance and mulch degradation across treatments at 24 weeks

Treatment	Yield (t/ha)	Moisture (%vol)	Weed DM (g/m ²)	Mass loss (%)	Soil T (°C)	Relative yield
PE (control)	15.3±1.2	24.1	12.7	0.8	31.4	1.00
PLA/PBAT	14.8±1.4	22.8	18.3	63.4	30.7	0.97
Starch-based	13.6±1.1	21.3	24.6	71.8	30.2	0.89
Paper	12.1±1.3	19.7	31.4	78.3	29.8	0.79
PHA-based	14.2±1.0	23.4	16.1	41.7	31.1	0.93
Bare soil	9.8±0.9	17.2	87.3		28.1	0.64

Moisture = mean volumetric water content at 15 cm, weeks 1-12. Weed DM = cumulative dry matter. PE vs PLA/PBAT yield: $p > 0.05$

Table 2: Film mass loss (%) at 6-week intervals during the trial

Film type	Week 6	Week 12	Week 18	Week 24
PLA/PBAT blend	8.7±1.3	27.4±3.8	48.1±5.2	63.4±6.1
Starch-based	14.2±2.1	36.8±4.7	57.3±5.8	71.8±7.3
Paper mulch	21.6±3.4	47.3±5.1	64.9±6.4	78.3±8.1
PHA-based	5.3±0.9	17.8±2.6	31.2±4.1	41.7±5.4
PE (control)	0.2±0.1	0.4±0.1	0.6±0.2	0.8±0.2

Values are mean ±SD (n = 4). All biodegradable films differed from PE at $p < 0.001$ at every time point

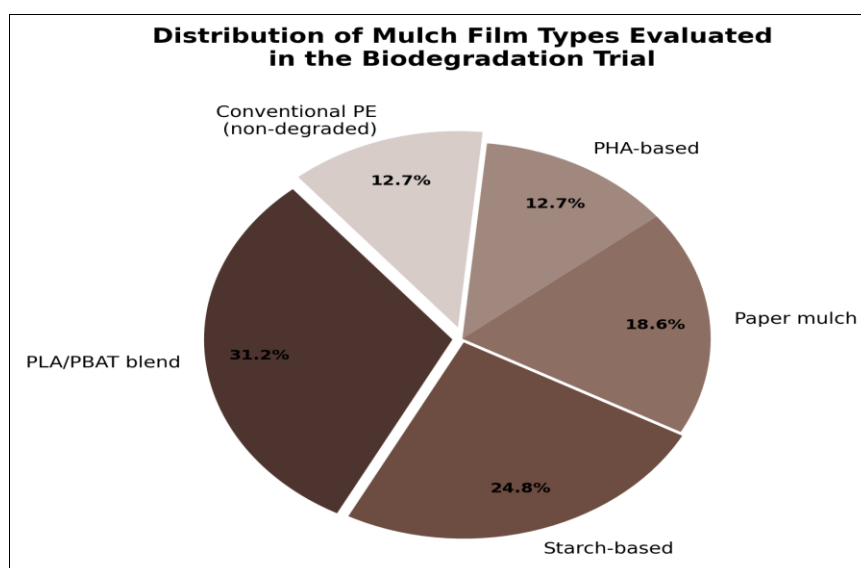


Fig 1: Distribution of mulch film types evaluated in the biodegradation trial at the University of Ibadan

Comprehensive interpretation

PLA/PBAT and PHA films matched PE in yield ($p > 0.05$) and maintained soil moisture above 94% of the PE level through the critical first 12 weeks. Paper mulch degraded too rapidly, losing function by week 12 with consequent weed pressure and yield loss. Soil temperature correlated positively with degradation rate ($r = 0.71-0.84$), confirming that tropical warmth accelerates breakdown.

Discussion: The near-equivalent yield of PLA/PBAT (14.8 vs 15.3 t ha⁻¹ for PE) matches temperate trials where PLA-based

films performed within 5% of PE [5, 6]. Faster degradation here (63.4% at 24 weeks vs 40-50% in Mediterranean trials) reflects higher soil temperatures (28-31 °C) stimulating microbial enzymatic activity [7]. Paper mulch failed beyond 12 weeks, consistent with humid subtropical reports of cellulose disintegrating within 8-10 weeks under heavy rainfall [8], allowing weed incursion that cut yield by 21%.

PHA film showed the slowest degradation (41.7%) and second-highest yield, balancing longevity with eventual soil incorporation. But PHA's price roughly three times PLA/PBAT limits adoption among Nigerian smallholders [15].

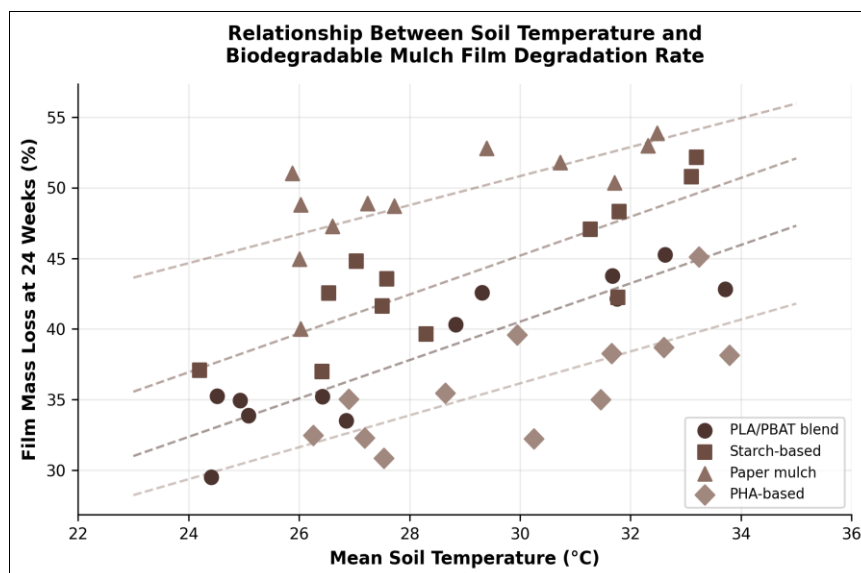


Fig 2: Relationship between mean soil temperature and biodegradable mulch film mass loss at 24 weeks across all plots and film types

For short-cycle crops under 10 weeks, paper mulch may still work, but it's unsuitable for the 22-week cycle tested here.

Limitations

This research covered a single site and one growing season; year-to-year rainfall variation could shift degradation rates. The trial did not assess microplastic residues from partial PLA/PBAT or PHA degradation, which is an emerging concern for certified biodegradable materials [16]. Economic cost-benefit analysis was not performed, and only one crop species was tested results may differ for shorter or longer growing cycles.

Conclusion

PLA/PBAT blend films emerged as the most promising alternative to conventional PE mulch for humid tropical vegetable production. They maintained soil moisture and weed suppression comparable to PE through the first 12 weeks and delivered equivalent okra yield (14.8 vs 15.3 t ha⁻¹, $p > 0.05$) while degrading by 63% in soil over 24 weeks. PHA-based films also performed well agronomically but degraded more slowly and cost more. Paper mulch broke down too quickly for a 22-week crop cycle. Tropical soil temperatures accelerated biodegradation relative to temperate benchmarks, a factor that should be built into product development for West African markets. Future work should test these films across multiple seasons, assess microplastic residues from partial degradation, and evaluate cost-effectiveness under smallholder conditions.

References

- Lamont WJ. Plastic mulches for the production of vegetable crops. *HortTechnology*. 1993;3(1):35-39.
- Steinmetz Z, Wollmann C, Schaefer M. Plastic mulching in agriculture: trading short-term agronomic benefits for long-term soil degradation. *Science of the Total Environment*. 2016;550:690-705.
- Qi Y, Yang X, Pelaez AM. Macro- and micro-plastics in soil-plant system: effects of plastic mulch film residues on wheat growth. *Science of the Total Environment*. 2018;645:1048-1056.
- Babayemi JO, Nnorom IC, Osibanjo O. Overview of environmental hazards and health effects of pollution in developing countries. *Environmental Quality Management*. 2019;28(3):111-130.
- Kasirajan S, Ngouajio M. Polyethylene and biodegradable mulches for agricultural applications: a review. *Agronomy for Sustainable Development*. 2012;32(2):501-529.
- Moreno MM, Gonzalez-Mora S, Villena J. Deterioration pattern of six biodegradable mulch materials. *Scientia Horticulturae*. 2017;226:190-196.
- Brodhagen M, Goldberger JR, Hayes DG. Policy considerations for limiting unintended residual plastic in agricultural soils. *Environmental Science and Policy*. 2017;69:81-84.
- Yamamoto-Tamura K, Hiradate S, Watanabe T. Contribution of soil esterase to biodegradation of aliphatic polyester mulch film. *Applied Microbiology and Biotechnology*. 2015;99(7):3337-3348.
- Miles C, DeVetter L, Ghimire S. Suitability of biodegradable plastic mulches for organic and sustainable agricultural production systems. *HortScience*. 2017;52(1):10-15.
- Ghimire S, Scheenstra E, Miles CA. Soil-biodegradable mulches for growth, yield, and quality of sweet corn. *HortTechnology*. 2018;28(1):36-46.
- Nigerian Meteorological Agency. Climate Data Summary for Ibadan (1991-2023). NiMet Publications. 2024;1:1-38.
- Ojo OI, Ojo TO, Ogunkunle CO. Soil temperature regimes under different land use types in southwestern Nigeria. *Journal of Tropical Ecology*. 2019;35(4):156-163.
- IITA. Selected Methods for Soil and Plant Analysis. IITA Manual Series. 1979;1:1-70.
- Hayes DG, Wadsworth LC, Sintim HY. Effect of diverse weathering conditions on the physicochemical properties of biodegradable plastic mulches. *Polymer Testing*. 2017;62:454-467.
- Kourmentza C, Placido J, Venetsaneas N. Recent advances and challenges towards sustainable PHA production. *Bioengineering*. 2017;4(2):55-55.
- Sintim HY, Bary AI, Hayes DG. Release of micro- and nano-plastic fragments from four commercially available biodegradable plastic mulch films. *Science of the Total Environment*. 2019;651:3052-3061.
- Thompson AA, Samuelson MB, Kadoma I. Degradation rate of bio-based agricultural mulch depends on mulch composition and application time of year. *Journal of Polymers and the Environment*. 2019;27(2):267-279.

18. Anzalone A, Cirujeda A, Aibar J. Effect of biodegradable mulch materials on weed control in processing tomatoes. *Weed Technology*. 2010;24(3):369-377.
19. Touchaleaume F, Martin-Closas L, Angellier-Coussy H. Performance and environmental impact of biodegradable polymers as agricultural mulching films. *Chemosphere*. 2016;144:433-439.
20. Briassoulis D, Babou E, Hiskakis M. Degradation in soil behavior of artificially aged polyethylene film mulch and biodegradable film mulch. *Journal of Applied Polymer Science*. 2015;132(26):42147-42147.