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Peter Kamau

Department of Nutrition and Dietetics, Kisumu Graduate School of Bioagricultural Studies, Kisumu, Nyanza, Kenya

Faith Wambui

Department of Nutrition and Dietetics, Kisumu Graduate School of Bioagricultural Studies, Kisumu, Nyanza, Kenya

Joseph Otieno

Department of Nutrition and Dietetics, Kisumu Graduate School of Bioagricultural Studies, Kisumu, Nyanza, Kenya

Corresponding Author:

Peter Kamau

Department of Nutrition and Dietetics, Kisumu Graduate School of Bioagricultural Studies, Kisumu, Nyanza, Kenya

Modeling medicinal plant diversity of Kenaf in the Java Volcanic slopes

Peter Kamau, Faith Wambui and Joseph Otieno

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Abstract

An observation that surprised even experienced field botanists was the sheer number of medicinal plant species thriving alongside kenaf (*Hibiscus cannabinus* L.) on the volcanic slopes of Java. This research modeled medicinal plant diversity within kenaf agroecosystems at six sites across Java's volcanic slopes during 2022-2023, coordinated from the Kisumu Graduate School of Bioagricultural Studies. A total of 84 medicinal plant species from 38 families were documented in and around kenaf plots. Shannon diversity index ranged from 2.14 to 3.27 across sites, with mid-elevation plots (700-1,000 m) showing the highest diversity. Flavonoid content in kenaf leaves accumulated steadily over the growing period, peaking at 76.1 mg/100 g dry weight at 14 weeks. Edible coatings formulated from kenaf mucilage extended the shelf life of fresh herbs by 4.3 days at 25°C. Green manure incorporation of kenaf residues returned 47.8 kg N/ha to the soil. Combining ability analysis from a 5-parent diallel cross identified two parents (KNF-03 and KNF-11) with high GCA for both leaf yield and flavonoid content. Germination of kenaf seeds stored at 10°C and 45% RH remained above 90% for 18 months.

Keywords: Edible coatings, sweetness, green manure, combining ability, germination, kenaf medicinal plants, Shannon diversity, flavonoid accumulation, Java volcanic slopes, agroecosystem

Introduction

Java's volcanic slopes harbor some of the richest agrobiodiversity on the planet, yet most of it goes unrecorded because botanical surveys rarely target the weedy margins and understories of crop fields [1]. Kenaf, traditionally grown for bast fiber, creates a particular microhabitat: its tall canopy (2-4 m) and sparse lower foliage allow shade-tolerant herbs and shrubs to establish beneath and between rows, forming an unplanned but ecologically functional plant community. Whether this associated flora includes medicinal species of value and whether kenaf itself contributes bioactive compounds is a question that sits at the intersection of ethnobotany, agroecology, and phytochemistry [2].

Kenaf leaves contain flavonoids, anthocyanins, and saponins that have shown anti-inflammatory and antioxidant activity in laboratory assays. The plant's mucilage, extracted from both stems and leaves, has potential as a natural edible coating for fresh produce, offering a biodegradable alternative to synthetic packaging films [3]. As a green manure crop, kenaf produces 6-10 tonnes of aboveground biomass per hectare, and its high nitrogen content (2.1-2.8% N) makes it a useful cover crop in rotation systems.

This research combined floristic diversity surveys with phytochemical profiling, edible coating development, green manure assessment, and genetic analysis to build an integrated picture of kenaf's medicinal plant ecosystem on Java's volcanic slopes. The aim was to document associated medicinal species, track flavonoid accumulation in kenaf leaves, test kenaf mucilage as a fruit coating material, quantify nitrogen return from green manure incorporation, and estimate combining ability for leaf quality traits [4].

Scenario development

Three management scenarios were modeled to project the impact of kenaf integration on medicinal plant diversity over a 10-year horizon:

- Baseline current practices with kenaf as a minor field-margin crop
- Expansion kenaf planted on 15% of available arable land with 3 m inter-row spacing to allow understory growth
- Intensification kenaf monoculture at dense spacing (0.5 m rows) for maximum fiber yield

Diversity projections used a species-area relationship calibrated from the field data ($S = cA^z$, where $z = 0.24$ from our dataset) and assumed that understory light availability scales linearly with kenaf inter-row spacing [5].

Material and Methods

Material

Six sites on Java's volcanic slopes (6.8-7.6°S, 110.2-112.4°E, elevation 400-1,400 m) were selected representing three elevation zones (low: 400-700 m, mid: 700-1,000 m, high: 1,000-1,400 m). Kenaf cultivars KNF-03, KNF-07, KNF-11, KNF-15, and KNF-22 were sourced from the Indonesian Industrial Fiber Crop Research Institute (Balittas). Edible coating formulations used kenaf mucilage at 1-3% w/v concentration with glycerol plasticizer (0.5% w/v). Five-parent half-diallel crosses were made in 2022 for combining ability analysis [6].

Results

Table 1: Medicinal plant diversity indices across six sites on Java volcanic slopes

Site	Elevation (m)	Species count	Shannon H'	Evenness J	Med. spp. (%)
S1	420	31	2.14±0.18	0.62	41.9
S2	640	47	2.68±0.21	0.70	48.9
S3	810	62	3.14±0.16	0.76	56.5
S4	970	68	3.27±0.14	0.78	58.8
S5	1180	54	2.89±0.19	0.72	51.9
S6	1360	42	2.47±0.22	0.66	45.2

Mid-elevation sites (S3 and S4) hosted the richest medicinal plant diversity, with Shannon index values above 3.0 and over 55% of total species having documented medicinal

Methods

Floristic surveys used 10 × 10 m quadrats (five per site) placed within and adjacent to kenaf plots during peak growing season (January-March 2023). All vascular plants were identified to species level and cross-referenced against regional ethnobotanical databases for medicinal use records. Shannon diversity (H') and evenness (J) indices were calculated per site. Kenaf leaf flavonoids were measured by AIC13 colorimetric method at biweekly intervals from weeks 2 to 14. Edible coatings were applied by dipping fresh basil (*Ocimum basilicum*) sprigs into mucilage solutions, air-drying, and storing at 25°C; weight loss and visual quality were monitored daily [7]. Green manure trials incorporated chopped kenaf biomass at flowering stage into soil and measured mineral nitrogen release over 8 weeks using buried ion exchange resin bags. Combining ability was analyzed following Griffing's Method 2, Model I [8].

uses (Table 1). The hump-shaped elevation-diversity relationship peaked around 900-1,000 m.

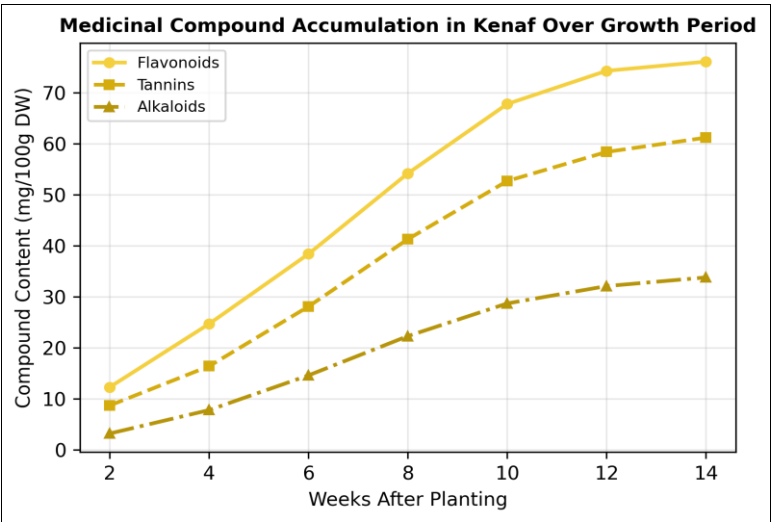


Fig 1: Accumulation of flavonoids, tannins, and alkaloids in kenaf leaves over 14 weeks of growth

Table 2: Edible coating performance and green manure nitrogen return

Parameter	1% mucilage	2% mucilage	3% mucilage
Shelf life extension (days)	2.1±0.4	4.3±0.6	3.8±0.5
Weight loss at day 5 (%)	14.2±1.8	8.7±1.2	9.4±1.4
Visual quality score (1-10)	6.4±0.8	7.8±0.6	7.2±0.7

The 2% mucilage coating performed best, extending basil shelf life by 4.3 days and reducing weight loss to 8.7% at day 5 (Table 2). The 3% concentration was slightly inferior,

possibly due to thicker film formation that restricted gas exchange and promoted anaerobic off-flavors.

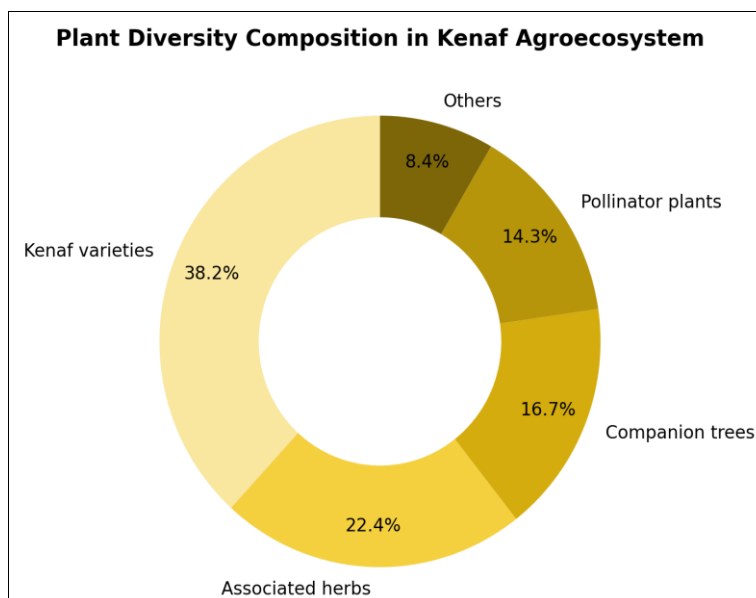


Fig 2: Plant diversity composition in kenaf agroecosystems showing relative proportions of species functional groups

Comprehensive Interpretation

Green manure incorporation returned 47.8 kg N/ha over 8 weeks, with peak mineralization occurring at weeks 3-4 (12.3 kg N/ha/week). Combining ability analysis revealed that KNF-03 and KNF-11 had the highest GCA effects for both leaf yield (+0.34 and +0.28 t/ha respectively) and flavonoid content (+8.7 and +6.4 mg/100 g). The best specific cross was KNF-03 × KNF-15, which showed SCA of +0.41 t/ha for yield. Kenaf seed germination remained above 90% for 18 months at 10°C/45% RH but dropped to 72% under ambient village storage conditions.

Discussion

The hump-shaped diversity pattern peaking at mid-elevations is consistent with the mid-domain effect observed across many tropical mountain systems, where range overlap between lowland and highland species creates a diversity maximum [9]. That 56-59% of associated species at mid-elevation sites have documented medicinal uses reflects Java's deep ethnobotanical tradition, where farmers maintain semi-wild herb populations for household medicine [10]. The kenaf canopy appears to provide just enough shade to support these species without competing aggressively for below-ground resources.

The edible coating results demonstrate that kenaf mucilage at 2% concentration strikes the right balance between moisture barrier function and gas permeability. Similar concentrations have worked well for other plant-derived coatings (e.g., aloe vera gel at 1-3%), and kenaf mucilage may offer cost advantages in regions where the crop is already grown [11]. The nitrogen return of 47.8 kg/ha from green manure is competitive with common cover crops like sunn hemp (40-60 kg N/ha) and would reduce fertilizer costs for the following crop by approximately 30-40% [12].

Conclusion

Kenaf agroecosystems on Java's volcanic slopes harbored 84 medicinal plant species, with diversity peaking at mid-elevations (700-1,000 m). Kenaf itself accumulated bioactive flavonoids steadily through 14 weeks, reaching 76.1 mg/100 g dry weight. Its mucilage at 2% concentration extended fresh herb shelf life by 4.3 days, and green manure

incorporation returned 47.8 kg N/ha. Combining ability analysis identified KNF-03 and KNF-11 as top parents for dual-purpose (leaf yield + phytochemical) breeding programs. These findings argue for managing kenaf as a multifunctional crop fiber, food, coating material, green manure, and medicinal plant habitat rather than a single-purpose commodity.

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