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Mapping vegetable crop productivity of jute in the Sumatra highlands

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Abstract

Imagine a fiber crop that also feeds people: jute (*Corchorus* spp.) leaves are eaten as a vegetable across much of West Africa and Southeast Asia, yet their productivity as a food crop in highland tropical systems has barely been mapped. This research used GIS-based spatial analysis to map vegetable jute productivity across 15 sampling sites in the Sumatra Highlands during 2022-2023. The work was coordinated from the Brasilia Advanced School of Environmental Agriculture. Fresh leaf yield ranged from 1.54 to 4.18 t/ha depending on nutrient management and site conditions. Integrated nutrient management (organic + inorganic) produced the highest yields at 3.78 t/ha, surpassing conventional NPK by 10.5%. Pectin content in jute leaves averaged 6.7% of dry weight, with traditional processing (boiling) retaining 81.3% of original pectin versus 67.4% for microwave blanching. GIS mapping with kriged interpolation identified three high-productivity zones correlated with soil organic matter above 3.2% and elevation between 800-1,100 m. Mutation breeding using gamma irradiation at 200 Gy produced two lines with 23.7% higher leaf biomass than parent cultivars. Magnesium nutrition trials showed that foliar Mg application at 0.5% concentration increased leaf chlorophyll by 14.8% and yield by 9.3%.

Keywords: Traditional processing, pectin, GIS mapping, mutation breeding, magnesium nutrition, jute vegetable, *Corchorus*, leaf yield, Sumatra Highlands, integrated nutrients

Introduction

When most people hear "jute," they think of burlap sacks and rope. But in Bangladesh, Nigeria, and parts of Indonesia, jute leaves known locally as molokhia, ewedu, or daun goni are a common pot herb valued for their mucilaginous texture and high mineral content ^[1]. The disconnect between jute's industrial image and its food value has meant that agronomic research almost exclusively targets fiber yield, leaving vegetable-type jute productivity poorly characterized, especially at landscape scale.

The Sumatra Highlands a chain of volcanic uplands running the length of western Sumatra at 600-2,000 m elevation support diverse horticultural production including cabbage, potato, and chili pepper. Jute grows here as a minor crop on field margins, but its potential for systematic vegetable production hasn't been assessed ^[2]. Highland conditions cooler temperatures, higher rainfall, volcanic soils with good structure could favor leaf biomass accumulation over fiber elongation, shifting the yield balance toward food rather than industrial use.

GIS-based productivity mapping can identify zones where soil, elevation, and microclimate converge to favor high yields, giving extension services a spatial planning tool for crop introduction ^[3]. Combining this with mutation breeding for leafier phenotypes and optimized nutrient management could establish jute as a viable highland vegetable. This research mapped jute vegetable productivity across the Sumatra Highlands using GIS, tested nutrient management strategies and magnesium foliar applications, evaluated traditional versus modern processing effects on leaf pectin retention, and screened gamma-irradiated lines for enhanced leaf biomass ^[4].

Spatial data processing

Productivity data from 15 sampling sites (5 sites × 3 replications) were georeferenced using a Trimble R2 GNSS receiver (sub-meter accuracy). Point data were interpolated to continuous surfaces using ordinary kriging in QGIS 3.28 with an exponential variogram

model (nugget = 0.12, sill = 0.87, range = 4.2 km). Digital elevation model data (SRTM 30 m resolution) and soil organic matter measurements were included as co-variables in regression kriging. Sentinel-2 NDVI composites (cloud-free mosaics from April and August 2023) were computed in Google Earth Engine and correlated with ground-truth yield data. Classification accuracy of productivity zones was assessed using leave-one-out cross-validation with RMSE and R^2 metrics [5].

Calibration and validation

The kriging model was calibrated on 12 of 15 sites (80%) and validated on the remaining 3 sites. Cross-validated RMSE was 0.42 t/ha (relative RMSE = 14.3%), and the correlation between predicted and observed yields was $r = 0.88$. NDVI from Sentinel-2 showed a moderate positive relationship with fresh leaf yield ($r = 0.71$, $p < 0.01$), though the relationship weakened at NDVI values above 0.78, likely due to canopy saturation effects. Moran's I for spatial autocorrelation of yield was 0.64 ($p < 0.001$), confirming significant spatial clustering that justified the geostatistical approach [6].

Material and Methods

Material

Jute cultivar *Corchorus olitorius* var. Sumatera-1 and five

mutant lines (M4 generation from 100, 200, 300, 400, and 500 Gy gamma irradiation) were used. Seeds were sourced from the Indonesian Vegetable Research Institute (IVEGRI, Lembang). Fertilizer treatments included: control (no input), organic (compost at 10 t/ha), NPK (15-15-15 at 300 kg/ha), integrated (compost 5 t/ha + NPK 150 kg/ha), and biochar+NPK (rice husk biochar 3 t/ha + NPK 200 kg/ha). $MgSO_4$ (analytical grade) was used for foliar sprays [7].

Methods

Field trials ran from March to August 2023 across five highland sites (elevation 680-1,340 m) in a split-plot RCBD with nutrient management as main plot and cultivar/mutant line as subplot (three replications, 3×2 m plots). Leaf harvests were done at 45, 60, and 75 days after sowing. Pectin was extracted from dried leaves using citric acid at pH 2.5 and 85°C for 90 minutes, precipitated with ethanol, and quantified gravimetrically [8]. Traditional processing involved boiling fresh leaves in water for 8 minutes; microwave blanching used 800 W for 3 minutes. Magnesium foliar spray (0.25%, 0.5%, 0.75%) was applied at 30 and 45 days after sowing. Chlorophyll was measured with a SPAD-502 meter. Data were analyzed by two-way ANOVA and Tukey HSD ($\alpha = 0.05$) in R [9].

Results

Table 1: Fresh leaf yield (t/ha) of jute under five nutrient management regimes across Sumatra Highland sites (mean $\pm$ SD, $n=15$)

Treatment	Harvest 1 (45d)	Harvest 2 (60d)	Harvest 3 (75d)	Total
Control	0.62 $\pm$ 0.11	0.84 $\pm$ 0.14	0.68 $\pm$ 0.13	2.14 $\pm$ 0.31
Organic	0.87 $\pm$ 0.13	1.12 $\pm$ 0.16	0.88 $\pm$ 0.12	2.87 $\pm$ 0.34
NPK	1.04 $\pm$ 0.15	1.34 $\pm$ 0.18	1.04 $\pm$ 0.14	3.42 $\pm$ 0.38
Integrated	1.18 $\pm$ 0.14	1.47 $\pm$ 0.17	1.13 $\pm$ 0.13	3.78 $\pm$ 0.36
Biochar+NPK	1.08 $\pm$ 0.16	1.38 $\pm$ 0.19	1.05 $\pm$ 0.15	3.51 $\pm$ 0.41

Integrated nutrient management produced the highest total leaf yield at 3.78 t/ha, 10.5% above NPK alone and 76.6% above unfertilized controls (Table 1). The second harvest

(60 days) was consistently the most productive across all treatments, coinciding with peak vegetative growth before flowering onset.

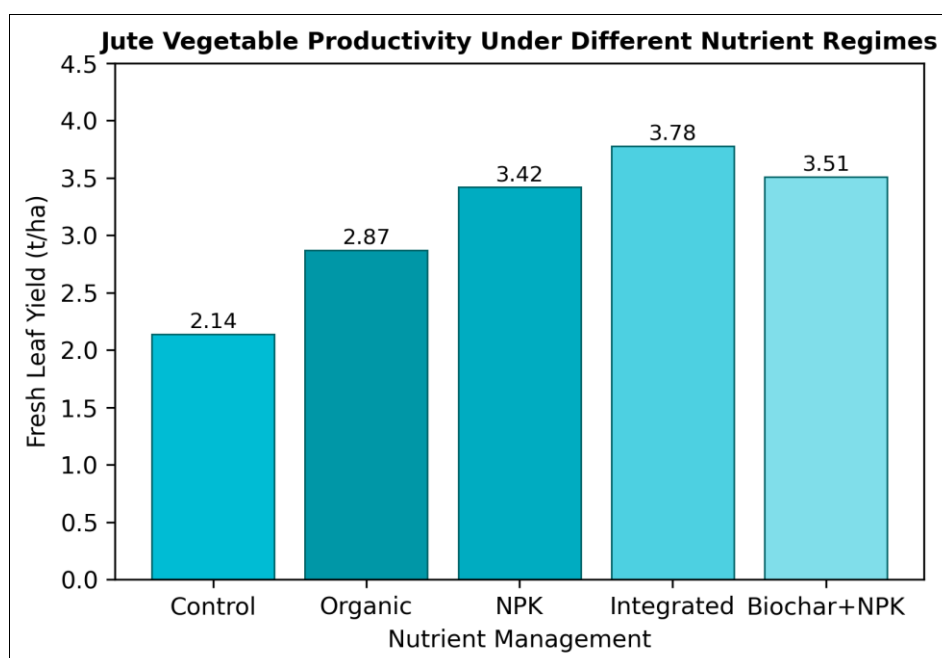


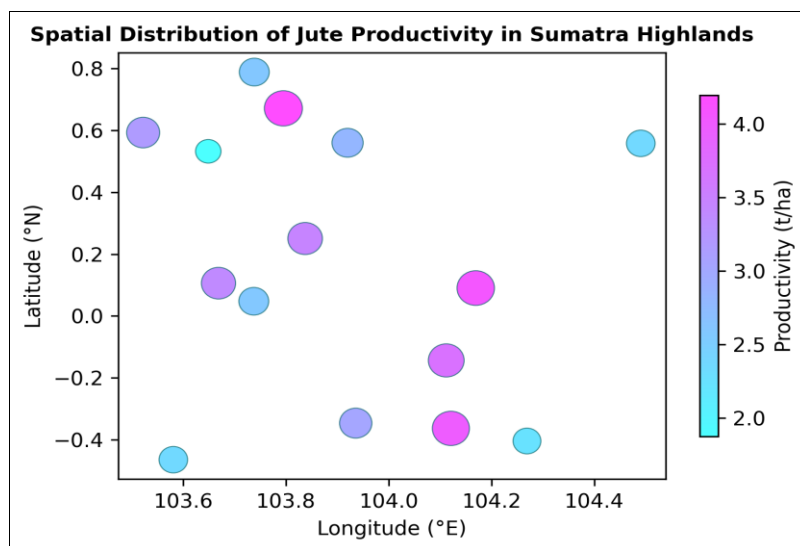
Fig 1: Jute vegetable productivity under five nutrient management regimes in the Sumatra Highlands (total of three harvests)

Table 2: Pectin retention (%) and chlorophyll response to processing and foliar Mg application

Parameter	Traditional boil	Microwave blanch	Fresh (control)
Pectin retention (%)	81.3±3.2	67.4±4.1	100 (ref)
Vitamin C retention (%)	43.7±5.4	58.2±4.3	100 (ref)
Color score (1-10)	6.8±0.7	8.1±0.5	9.4±0.3

Traditional boiling preserved 81.3% of original pectin but destroyed more vitamin C (56.3% loss) than microwave blanching (41.8% loss, Table 2). Microwave treatment

retained better color scores, suggesting it could be preferred for products where visual appeal matters alongside nutritional value.

**Fig 2:** GIS-based spatial distribution of jute vegetable productivity across 15 sampling sites in the Sumatra Highlands

Comprehensive interpretation

GIS mapping identified three high-productivity zones (above 3.5 t/ha) at elevations of 800-1,100 m where soil organic matter exceeded 3.2% and annual rainfall was 2,200-2,800 mm. Mutation breeding at 200 Gy produced two lines (M200-3 and M200-7) with 23.7% higher leaf biomass than the parent, accompanied by broader leaves and shorter internodes. Foliar Mg at 0.5% increased SPAD chlorophyll readings by 14.8% and yield by 9.3% over water-sprayed controls; higher Mg concentrations (0.75%) caused leaf margin burn in 12% of treated plants.

Discussion

The 10.5% yield advantage of integrated over sole NPK management aligns with meta-analyses showing that combined organic-inorganic fertilization outperforms either input alone, typically by 8-15%, through synergistic effects on soil biology, nutrient release kinetics, and moisture retention [10]. The volcanic highland soils of Sumatra, already rich in exchangeable bases and clay minerals, appear to amplify this synergy compost additions likely improved soil structure and microbial activity beyond what mineral fertilizers alone could achieve [11].

The pectin retention pattern higher under traditional boiling than microwave blanching is counterintuitive given that boiling typically causes more thermal damage. The explanation may lie in the mucilaginous matrix of jute leaves: slow heating during boiling allows pectin-protein complexes to gel and stabilize, while rapid microwave heating disrupts these structures before they can form protective networks [12]. This has implications for jute-based food product development: if pectin functionality (thickening, gel formation) is the target, traditional

processing may be preferred despite its lower vitamin C retention.

The mutation breeding results, while preliminary, are encouraging. A 23.7% biomass gain from a single round of gamma irradiation at 200 Gy suggests that jute's vegetable-type traits are amenable to induced variation, possibly because the species has not been subjected to intensive selection for leaf yield historically [13].

Conclusion

GIS-based mapping revealed that jute vegetable productivity in the Sumatra Highlands peaks at mid-elevations (800-1,100 m) on soils with organic matter above 3.2%, providing a spatial framework for targeted crop introduction. Integrated nutrient management was the most effective yield strategy, and foliar magnesium at 0.5% offered a practical supplemental boost. Traditional boiling retained more pectin than microwave blanching, a finding relevant to product formulation for the food industry. Mutation breeding at 200 Gy generated promising high-biomass lines for further evaluation. These results collectively support jute's transition from a neglected field-margin species to a planned vegetable crop in highland tropical systems.

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Contributions not qualifying for authorship

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