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Influence of integrated nutrient management on quality parameters of malting barley

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Abstract

Barley was among the first cereals domesticated by humans, yet its quality demands for malting remain notoriously difficult to meet through fertiliser management alone. A field experiment at Makerere University Agricultural Research Institute Kabanyolo, Kampala, Uganda during the 2023B cropping season evaluated six integrated nutrient management (INM) treatments on quality parameters of malting barley (*Hordeum vulgare* L. cv. HKBL 1629-14). Treatments included an unfertilised control, 100% recommended dose of fertiliser (RDF: 60-40-40 kg N-P₂O₅-K₂O ha⁻¹), 75% RDF + farmyard manure (FYM, 5 t ha⁻¹), 50% RDF + FYM + biofertiliser, 75% RDF + vermicompost (VC, 3 t ha⁻¹), and 50% RDF + VC + biofertiliser. Grain protein ranged from 8.21% (control) to 11.87% (100% RDF). Malt extract, a key brewing parameter, was highest in the control (78.4%) and decreased with rising nitrogen supply. Treatments combining 75% RDF with organic sources achieved grain protein between 10.2 and 11.1%, within the 9.5-11.5% range preferred by East African brewers, while maintaining malt extract above 76%. These INM combinations appear well-suited for producing acceptable malting barley while reducing inorganic fertiliser dependence.

Keywords: Malting barley, integrated nutrient management, grain protein, malt extract, farmyard manure, vermicompost, biofertiliser, brewing quality, nitrogen, East Africa

Introduction

Barley has served as a brewing grain for at least 8,000 years, and the malting industry today imposes some of the most exacting quality standards of any cereal end-use ^[1]. Grain protein content, in particular, sits at the centre of a management dilemma: too little protein (below 9%) weakens the enzymatic power needed for starch conversion during malting, while too much (above 12%) reduces malt extract yield and creates haze problems in beer ^[2, 3].

In East Africa, demand for locally produced malting barley has risen sharply as breweries seek to cut import costs and support smallholder supply chains ^[4]. Uganda's highland zones above 1,800 m receive adequate rainfall for barley, but soils are often depleted after years of continuous cereal cropping. Farmers typically apply blanket rates of inorganic fertiliser, which tends to push grain protein above acceptable levels while neglecting soil organic matter ^[5].

Integrated nutrient management—combining reduced inorganic fertiliser with organic amendments like farmyard manure, vermicompost, and biofertilisers—offers a slower-release nitrogen supply that may keep protein within the malting window while also building soil fertility ^[6, 7]. However, most INM research on barley has been conducted in South Asia and Europe; data from tropical African highlands remain limited. This research examined the effect of six INM treatments on grain protein, malt extract, grain plumpness, test weight, and germination energy of a locally adapted malting barley cultivar under Ugandan highland conditions.

Materials and Methods

Materials

The malting barley cultivar HKBL 1629-14, released for Ugandan highlands by the National Agricultural Research Organisation, was used. Certified seed was obtained from the Kachwekano Zonal Agricultural Research and Development Institute. FYM (0.58% N, 0.21% P,

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0.47% K) was sourced from the university dairy farm and decomposed for three months before application. Vermicompost (1.23% N, 0.64% P, 0.81% K) was produced on-site using *Eisenia fetida*. Biofertiliser consisted of a consortium of *Azotobacter chroococcum* and *Bacillus megaterium* applied as seed inoculant at 25 g kg⁻¹ seed [8].

Methods

The trial was laid out in a randomised complete block design with six treatments and four replications at the Makerere University Agricultural Research Institute Kabanyolo (MUARIK), Kampala (0°28'N, 32°37'E; 1,200 m a.s.l.) during the 2023B season (September–December). Plot size was 4 m × 3 m. Treatments were: T1—unfertilised control; T2—100% RDF (60-40-40 kg N-P₂O₅-K₂O ha⁻¹); T3—75% RDF + 5 t FYM ha⁻¹; T4—50% RDF + 5 t FYM + biofertiliser; T5—75% RDF + 3 t VC ha⁻¹; T6—50% RDF + 3 t VC + biofertiliser. Grain quality was assessed following European Brewery Convention methods [9]: protein by Kjeldahl (N × 6.25), malt extract by Congress mash, grain plumpness on a 2.5 mm sieve, and germination energy on day 4 [10]. Data were analysed by ANOVA in GenStat 14; means separated by LSD at 5%.

Field Experimental Design

The RCBD comprised 24 plots (6 treatments × 4 blocks)

arranged across a gentle slope to account for fertility gradient. Blocks ran perpendicular to the slope direction. Each plot had 12 rows spaced 20 cm apart; the central 8 rows formed the harvest area (net plot 2.4 m × 3 m). Organic amendments were incorporated two weeks before sowing; inorganic fertiliser was band-placed at sowing, with nitrogen split: half at sowing and half at tillering.

Seasonal Conditions

The 2023B season received 487 mm rainfall over 14 weeks, close to the 10-year average of 510 mm for the site. September and October were wetter than normal, but a brief dry spell during stem elongation (third week of October) may have restricted early nitrogen uptake slightly. Mean temperatures ranged from 20.3 to 24.1 °C, suitable for barley growth.

Soil Quality Analysis

The experimental soil was a Rhodic Ferralsol with sandy clay loam texture (54% sand, 12% silt, 34% clay), pH 5.83, organic carbon 1.67%, total N 0.14%, available P (Olsen) 7.8 mg kg⁻¹, and exchangeable K 0.42 cmol kg⁻¹. These values indicate moderate fertility with nitrogen and phosphorus as the main limiting nutrients.

Results

Table 1: Quality parameters of malting barley as influenced by integrated nutrient management treatments

Treatment	Grain Protein (%)	Malt Extract (%)	Plumpness (% >2.5mm)	Test Wt. (kg hL ⁻¹)	Germ. Energy (%)	Yield (t ha ⁻¹)
T1 Control	8.21	78.4	72.3	61.8	94.7	1.43
T2 100% RDF	11.87	74.1	84.7	66.4	96.2	3.28
T3 75%RDF+FYM	10.93	76.8	86.1	67.1	97.1	3.14
T4 50%RDF+FYM+Bio	10.24	77.9	83.4	65.7	96.8	2.87
T5 75%RDF+VC	11.13	75.6	87.3	67.8	97.4	3.21
T6 50%RDF+VC+Bio	10.47	77.2	84.8	66.2	97.0	2.94
LSD (0.05)	0.67	1.3	3.2	1.8	NS	0.31

RDF = Recommended Dose of Fertiliser; FYM = Farmyard Manure; VC = Vermicompost; Bio = Biofertiliser; NS = Not Significant.

Grain protein was highest at 100% RDF (11.87%) and lowest in the unfertilised control (8.21%). Both values fall outside the 9.5–11.5% malting window. Treatments T3, T4, T5, and T6 all produced protein within the acceptable range (Table 1). Malt extract showed the inverse pattern—highest in the control and

lowest at 100% RDF. Grain plumpness and test weight were significantly improved by all fertilised treatments over the control, but didn't differ much among fertilised treatments. Germination energy exceeded 94% in all treatments.

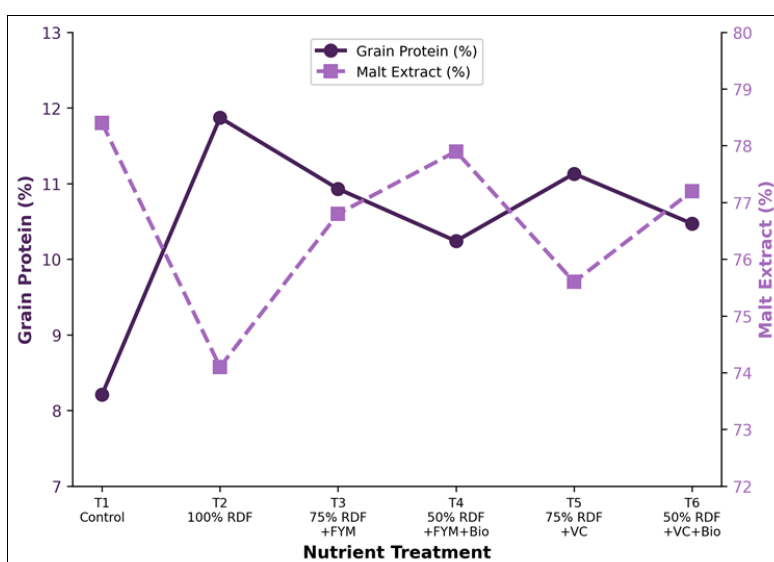


Fig 1: Grain protein content and malt extract across six nutrient management treatments showing the inverse relationship between the two parameters.

The line chart (Figure 1) clearly illustrates the trade-off: as protein rose with increased inorganic N supply, malt extract

declined. The INM treatments (T3-T6) occupied the middle ground, with T3 and T5 achieving the best balance.

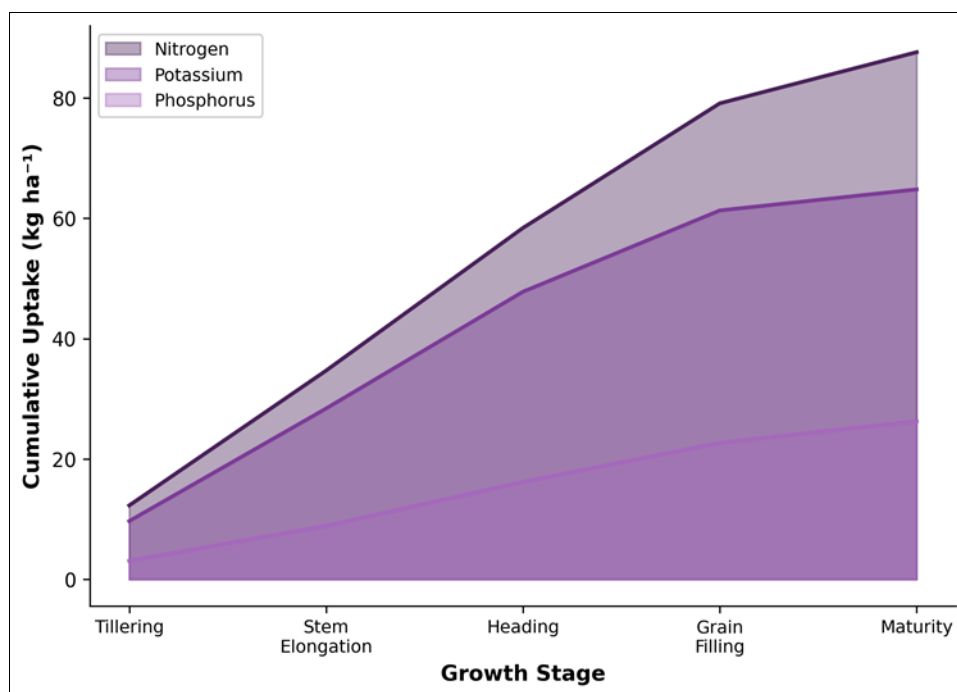


Fig 2: Cumulative nitrogen, phosphorus, and potassium uptake (kg ha^{-1}) across growth stages under the 75% RDF + vermicompost treatment (T5).

Nitrogen uptake followed a sigmoid pattern, with most accumulation between stem elongation and grain filling (Figure 2). The slower early-season N release from vermicompost likely moderated the protein surge that occurs when soluble N floods the grain during filling.

Comprehensive Interpretation

Correlation analysis across all treatments showed a significant negative relationship between grain protein and malt extract ($r = -0.93$, $p < 0.01$). A protein range of 10.2-11.1% corresponded to malt extract of 75.6-77.9%, both within industry specifications. The INM treatments also improved grain plumpness by 15-21% over the control, which is commercially relevant since plump grains command premium prices.

Discussion

The inverse relationship between grain protein and malt extract is a well-established phenomenon driven by the dilution of starch by nitrogen storage proteins^[2, 11]. In our trial, 100% RDF pushed protein to 11.87%, just above the 11.5% ceiling commonly specified by East African breweries. This is a practical concern because rejected consignments revert to lower-value feed barley, costing farmers income^[4].

The INM treatments moderated protein accumulation by substituting part of the readily available inorganic N with slower-release organic sources. FYM and vermicompost mineralise nitrogen gradually over weeks, matching the crop's demand curve more closely than a single urea split^[12, 13]. This slower supply appears to reduce the late-season nitrogen flush that drives excessive protein deposition during grain filling^[14]. Vermicompost-based treatments (T5, T6) tended to outperform FYM-based treatments (T3, T4) in grain plumpness and test weight, possibly because vermicompost provides a more balanced micronutrient supply and growth-promoting substances^[15, 16]. The biofertiliser component contributed modestly to yield but didn't significantly affect quality, which may reflect the low soil pH (5.83) limiting *Azotobacter* activity^[17].

Conclusion

Integrated nutrient management using 75% of the recommended inorganic dose combined with vermicompost or farmyard manure produced malting barley with grain protein between 10.2 and 11.1% and malt extract above 75.6%, both within acceptable ranges for East African brewing. These INM treatments matched or approached the grain yield of full inorganic fertilisation while reducing fertiliser costs. For Ugandan highland farmers supplying breweries, replacing 25-50% of inorganic fertiliser with locally available organic amendments appears a practical route to consistent malting-grade barley.

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