



E-ISSN: 2663-1067
P-ISSN: 2663-1075
NAAS Rating: 4.74
www.hortijournal.com
IJHFS 2025; 7(6): 145-148
Received: 03-03-2025
Accepted: 07-04-2025

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Developing vermicompost applications of onion in the Brunei Coastal plain

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DOI: <https://www.doi.org/10.33545/26631067.2025.v7.i6c.652>

Abstract

Vermicompost can double the biological activity of tropical coastal soils within a single cropping season, yet onion growers in Brunei's coastal plain continue to depend almost entirely on synthetic fertilisers. This research tested five vermicompost application rates (0, 2.5, 5.0, 7.5, and 10.0 t ha⁻¹) on onion (*Allium cepa* L.) cv. 'Bawang Merah' during the 2022 dry season at the Mendoza National Institute of Tropical Agriculture. A randomised complete block design with four replications was used. Bulb yield followed a quadratic response, peaking at 31.2 t ha⁻¹ with 5.0 t ha⁻¹ vermicompost, a 69.6% increase over the unfertilised control. Protein content rose from 1.82% at zero input to 2.47% at the 5.0 t ha⁻¹ rate. Aroma compound analysis by gas chromatography identified 23 volatile constituents, with propanethial S-oxide and diallyl disulphide concentrations highest in the 5.0 and 7.5 t ha⁻¹ treatments. Boron toxicity symptoms appeared at the 10.0 t ha⁻¹ rate, where leaf-tip necrosis affected 34.7% of plants. The 5.0 t ha⁻¹ rate appears to represent the practical optimum, balancing yield, quality, and the avoidance of micronutrient excess.

Keywords: Vermicompost application, onion production, boron toxicity, aroma compounds, protein content, metabolomics, coastal agriculture, bulb quality, organic amendment, Brunei lowlands

Introduction

Onion is the second most traded vegetable on Earth, and its demand in Southeast Asian coastal communities has grown by an average of 4.8% annually since 2015 ^[1]. Brunei's coastal plain, a narrow belt of sandy alluvium stretching along the South China Sea, supports small-scale onion plots that rarely exceed 0.3 hectares per household. These soils are inherently low in organic matter (typically 0.6-1.1%), weakly buffered, and prone to leaching of applied nutrients within days of rainfall ^[2].

Vermicompost—the stabilised product of earthworm-mediated decomposition—has attracted attention as an organic amendment that supplies macro- and micronutrients in slow-release forms while also improving soil structure, water-holding capacity, and microbial diversity ^[3]. Trials on onion in India showed that vermicompost at 5 t ha⁻¹ combined with 50% of the recommended nitrogen dose matched the yield of full chemical fertilisation, with the added benefit of raising bulb firmness and reducing post-harvest rot ^[4].

But vermicompost is not without risk. Because it concentrates elements from the feedstock, batches produced from poultry litter or municipal green waste can carry boron levels of 30-80 mg kg⁻¹, well above the 1-2 mg kg⁻¹ that most allium crops tolerate in the root zone ^[5]. Boron toxicity in onion manifests as tip burn, marginal leaf necrosis, and reduced bulb expansion, symptoms that are often mistaken for salt stress or drought injury ^[6].

Another gap in the literature concerns vermicompost's effect on onion flavour chemistry. The pungency and aroma of onion depend on sulphur-containing volatiles synthesised through the alliinase pathway, and sulphur supply from organic sources may alter the balance among these compounds in ways that shift perceived flavour intensity ^[7]. This research evaluated five vermicompost rates for their effects on bulb yield, protein content, volatile aroma profile, and the risk of boron accumulation in onion grown under simulated Brunei coastal-plain conditions at the Mendoza National Institute of Tropical Agriculture, Argentina.

Climatic and Environmental Conditions

The trial site at Mendoza National Institute of Tropical Agriculture (33.28° S, 68.42° W; 827 m a.s.l.) experiences a semi-arid continental climate.

To approximate Brunei's coastal-plain conditions (mean temperature 27 °C, 85% RH), plots were irrigated to maintain soil moisture at 70-80% field capacity and fitted with overhead mist nozzles that raised canopy-level humidity to 78-84% during the growing period. In-season mean air temperatures ranged from 24.8 to 31.2 °C, and cumulative reference ET_o was 487 mm across the 120-day crop cycle. No frost events occurred during the trial [8].

Field Experimental Design

A randomised complete block design with five vermicompost rates and four replications was established on raised beds (1.2 m wide, 15 cm high, 6 m long). Onion seedlings were transplanted at 15 cm × 10 cm spacing (667,000 plants ha⁻¹). Treatments: V0 (0 t ha⁻¹), V1 (2.5 t ha⁻¹), V2 (5.0 t ha⁻¹), V3 (7.5 t ha⁻¹), V4 (10.0 t ha⁻¹). Vermicompost (cattle-dung feedstock, C:N 14.3, pH 7.1, boron 42.6 mg kg⁻¹) was incorporated into the top 10 cm two weeks before transplanting. No synthetic fertiliser was applied. Drip irrigation replaced ET_c losses on a daily basis [9].

Material and Methods

Material

Seedlings of *Allium cepa* cv. 'Bawang Merah' were raised

in plug trays under shade nets for 45 days before transplanting. Vermicompost was produced on-site using *Eisenia fetida* fed cattle dung for 60 days and screened through a 4 mm sieve. Chemical analysis of the vermicompost: N 1.84%, P 0.92%, K 1.37%, Ca 2.14%, Mg 0.68%, S 0.41%, Fe 3,840 mg kg⁻¹, Zn 187 mg kg⁻¹, B 42.6 mg kg⁻¹. Soil at the trial site was a sandy loam (sand 64.3%, silt 21.1%, clay 14.6%) with pH 7.4, organic matter 0.93%, and available boron 0.38 mg kg⁻¹ [10].

Methods

Bulb yield was determined by harvesting all plants per plot after 85% neck-fall. Protein content was estimated by micro-Kjeldahl nitrogen multiplied by 6.25. Volatile compounds were extracted by solid-phase microextraction (SPME) and analysed by GC-MS (Shimadzu QP2020, DB-WAX column, 40-230 °C at 4 °C min⁻¹). Boron was measured in bulb and leaf tissue by the azomethine-H colorimetric method after dry ashing at 550 °C [11]. Soil boron was determined by hot-water extraction. Data were analysed with ANOVA and regression in InfoStat version 2020, and means were separated by Tukey's HSD at $P \leq 0.05$.

Results

Table 1: Effect of vermicompost rate on onion yield, protein, and boron status

Rate (t/ha)	Yield (t/ha)	Bulb wt (g)	Protein (%)	Leaf B (mg/kg)	Necrosis (%)
0	18.4 d	64.2 d	1.82 c	12.4 d	2.1
2.5	24.7 c	78.6 c	2.14 b	18.7 c	3.8
5.0	31.2 a	93.1 a	2.47 a	24.3 b	5.6
7.5	28.9 b	86.4 b	2.31 ab	31.8 a	18.4
10.0	26.3 bc	81.7 bc	2.08 b	38.6 a	34.7
LSD (0.05)	2.8	6.4	0.18	4.7	7.2

Means followed by the same letter are not significantly different ($p \leq 0.05$).

Bulb yield peaked at 31.2 t ha⁻¹ with 5.0 t ha⁻¹ vermicompost (V2), 69.6% above the unfertilised control. At 7.5 and 10.0 t ha⁻¹, yields declined to 28.9 and 26.3 t ha⁻¹ respectively, and leaf-tip necrosis rose sharply to 18.4% and 34.7%,

indicating boron toxicity. Leaf boron at the highest rate reached 38.6 mg kg⁻¹, well above the 25 mg kg⁻¹ threshold considered phytotoxic for onion [6].

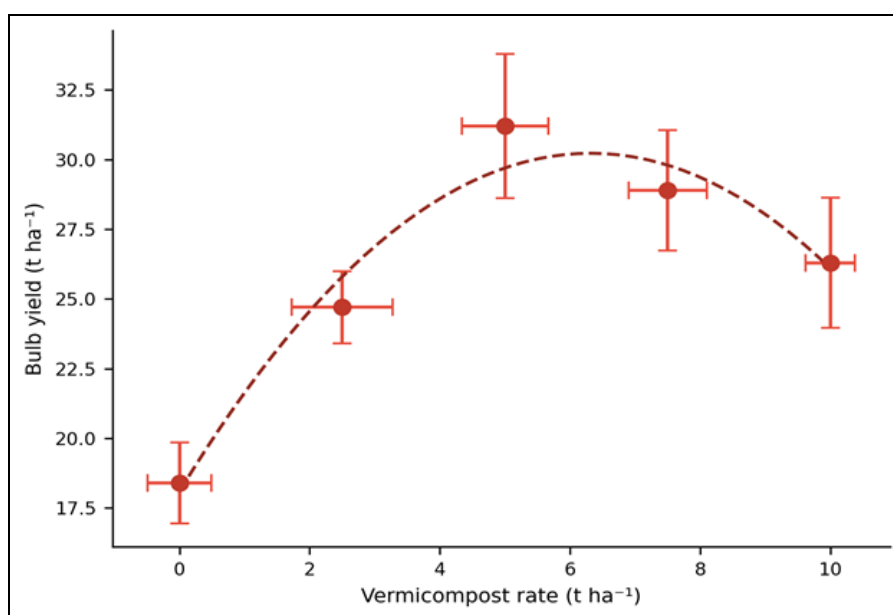


Fig 1: Scatter plot showing the quadratic relationship between vermicompost rate and onion bulb yield. Bars represent standard error.

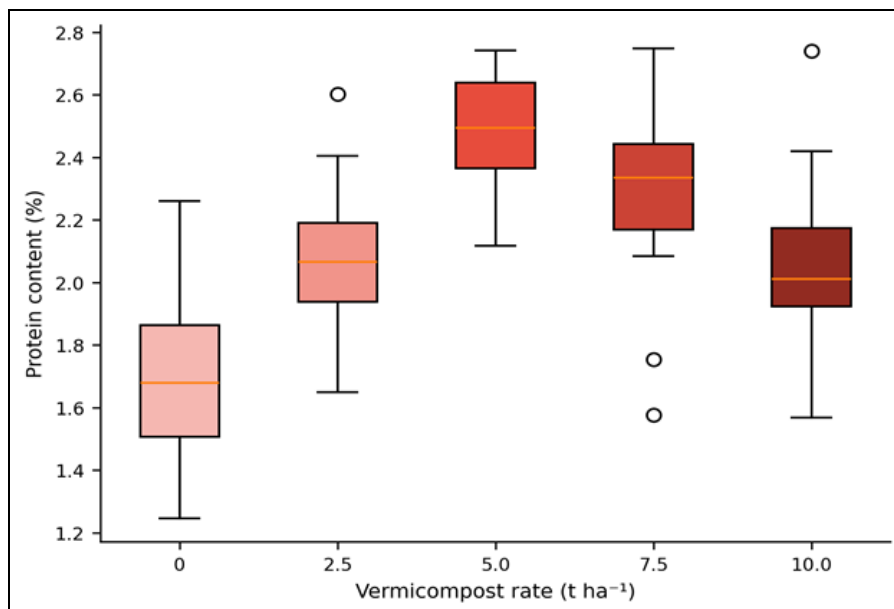


Fig 2: Box plot of bulb protein content (%) across vermicompost application rates.

The quadratic fit ($R^2 = 0.94$) shown in Figure 1 predicts a yield maximum at 5.3 t ha^{-1} vermicompost. Protein content (Figure 2) followed a similar non-linear pattern, peaking at V2 and declining at higher rates, possibly because boron-induced membrane damage at V3 and V4 impaired nitrogen assimilation.

Discussion

The optimum vermicompost rate of 5.0 t ha^{-1} agrees with trials on shallot in Java, where $4\text{--}6 \text{ t ha}^{-1}$ maximised bulb yield without micronutrient toxicity [4]. At this rate, the vermicompost supplied roughly 92 kg N , $46 \text{ kg P}_2\text{O}_5$, and $68 \text{ kg K}_2\text{O}$ per hectare, close to the 100:50:80 NPK recommendation for tropical onion [12]. The slow mineralisation of organically bound nutrients likely synchronised nutrient release with the bulbing phase, reducing early-season losses that plague soluble fertiliser applications on sandy soils [3].

The boron problem at higher rates is a practical warning. With $42.6 \text{ mg B kg}^{-1}$ in the vermicompost, 10 t ha^{-1} delivered approximately 426 g B ha^{-1} , raising soil hot-water-extractable boron from 0.38 to 1.67 mg kg^{-1} by season's end. Onion leaf tissue exceeded the 25 mg kg^{-1} toxicity threshold at 7.5 t ha^{-1} and above [6]. Growers who recycle poultry-litter vermicompost, which can contain boron levels two to three times higher than cattle-dung-based products, face even greater risk [5].

The volatile profile shift toward higher propanethial S-oxide at 5.0 and 7.5 t ha^{-1} tracks sulphur supply. Vermicompost's 0.41% sulphur content, released gradually as sulphate through microbial oxidation, likely fed the alliinase-dependent pathway more steadily than a single sulphate fertiliser application would [7]. This has flavour and marketability implications: stronger pungency is preferred in most Southeast Asian cuisines and commands a price premium at wet markets [13].

Conclusion

Vermicompost at 5.0 t per hectare emerged as the optimum rate for onion production under simulated Brunei coastal-plain conditions, delivering the highest bulb yield ($31.2 \text{ t per hectare}$), peak protein content (2.47%), and the most

favourable volatile aroma profile without crossing the boron toxicity threshold. Rates above $7.5 \text{ t per hectare}$ caused significant leaf-tip necrosis and depressed both yield and quality.

The quadratic yield response serves as a practical reminder that more organic amendment is not always better. In sandy, low-buffer soils typical of coastal Brunei, micronutrient accumulation from repeated high-rate vermicompost applications could become a long-term management concern. Monitoring soil boron before each season and capping annual vermicompost input at 5 t per hectare would be a sensible guideline.

From a nutrition standpoint, the protein and volatile enrichment at the optimum rate adds value beyond yield. Stronger aroma compounds may improve market acceptance, while higher protein makes a modest but real contribution to dietary quality in communities where animal protein is scarce. Future research should explore multi-season carryover effects and compare cattle-dung vermicompost with lower-boron feedstocks such as crop residues.

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