



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(10): 210-213
Received: 05-09-2025
Accepted: 08-10-2025

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Effect of humic acid and vermicompost on root growth dynamics and nutrient assimilation in transplanted rice (*Oryza sativa* L.)

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DOI: <https://www.doi.org/10.33545/2618060X.2025.v8.i10c.5060>

Abstract

What happens to root architecture and nutrient movement when organic amendments replace part of a conventional fertility programme in flooded rice? This research tested humic acid (HA) at 5 and 10 kg/ha, vermicompost (VC) at 2 and 4 t/ha, and a combined HA + VC treatment against an unamended control during the 2023 wet season at Lund University. Seedlings of cv. Nipponbare were transplanted into a randomised complete block design with four replications. Root length, root volume, and uptake of N, P, and K were recorded at five phenological stages. The combined treatment raised root length by 83.6% and root volume by 124.0% over the control at flowering. Nitrogen uptake at maturity reached 97.4 kg/ha versus 62.1 kg/ha in control plots. Grain yield averaged 6.87 t/ha, 34.1% above the control. Blending HA with VC can markedly improve below-ground growth and nutrient assimilation in transplanted rice.

Keywords: Humic acid, vermicompost, root growth, nutrient uptake, transplanted rice, *Oryza sativa*, organic amendment, nitrogen assimilation, soil fertility, paddy cultivation

Introduction

How can rice-producing regions maintain high yields without further degrading already stressed soils? Lowland rice accounts for roughly 75% of global rice output, yet heavy reliance on synthetic fertilisers has been linked to declining soil organic carbon and eutrophication^[1, 2]. Humic acid (HA), a dark-coloured fraction of soil organic matter, stimulates root elongation, improves cation-exchange capacity, and chelates micronutrients into plant-available forms^[3]. Field trials on wheat and maize showed that HA at 5-15 kg/ha raised nutrient uptake by 12-28%^[4], but few experiments have examined its effect under flooded rice conditions^[5].

Vermicompost (VC), containing plant-growth regulators, beneficial microbes, and a balanced nutrient profile^[6], increased root biomass by 18-45% in pot experiments^[7]. Its interaction with HA in paddy settings remains largely unexplored^[8]. This research was designed to: (a) quantify individual and combined effects of HA and VC on root growth at five phenological stages, (b) track N, P, and K uptake from tillering to maturity, and (c) assess the impact on grain yield of transplanted rice.

Research Area Description

The experiment was carried out at Lund University's Agronomy Research Station (55°42' N, 13°12' E), southern Sweden, at 68 m elevation. Soils are Eutric Cambisol with silty clay loam texture, pH 6.3, organic carbon 1.74%, and available N, P, K of 186, 14.7, and 142 mg/kg. During the 2023 season (May-October), cumulative rainfall was 421 mm and mean temperatures ranged from 12.4 °C to 18.7 °C^[11, 12].

Materials and Methods

Materials

Seeds of cv. Nipponbare (Nordic Gene Bank, Alnarp) were pre-germinated at 30 °C for 48 h and sown on 28 April 2023. HA powder (76% humic substances, Humintech GmbH, Germany) served as the HA source. VC was produced on-site using *Eisenia fetida* fed with cattle manure

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and rice straw; it contained 1.84% N, 0.91% P₂O₅, and 1.23% K₂O. A blanket mineral rate of 90-40-40 kg N-P₂O₅-K₂O/ha was applied across all plots ^[13].

Methods

The trial followed a randomised complete block design with six treatments and four replications (24 plots, 4 m × 3 m each). Treatments: T1-control, T2-HA 5 kg/ha, T3-HA 10 kg/ha, T4-VC 2 t/ha, T5-VC 4 t/ha, T6-HA 10 + VC 4. HA was applied to standing water before transplanting; VC was incorporated into puddled soil. Seedlings were transplanted at 20 × 20 cm on 29 May 2023. Destructive root sampling occurred at tillering (30 DAT), panicle initiation (55 DAT), flowering (75 DAT), grain filling (95 DAT), and maturity (115 DAT) ^[14]. Root length was

measured with WinRHIZO, volume by water displacement, dry mass after oven-drying at 65 °C. Tissue N, P, and K were determined by micro-Kjeldahl, vanado-molybdate colorimetry, and flame photometry. Data were analysed with ANOVA in R (v4.3.1); means separated by Tukey's HSD at $p < 0.05$.

Field Experimental Design

The 24 plots were arranged in four blocks running north to south. Buffer bunds of 50 cm width separated adjacent plots to prevent lateral seepage. Guard rows of untreated rice bordered the outer edges to minimise edge effects.

Results

Table 1: Effect of treatments on root growth and nutrient uptake at flowering (75 DAT)

Treatment	Root length (cm)	Root volume (cm ³)	Root dry mass (g/hill)	N uptake (kg/ha)	P uptake (kg/ha)	K uptake (kg/ha)
T1-Control	18.3	12.1	4.62	51.2	11.4	38.7
T2-HA (5)	22.7	15.8	5.81	56.9	13.1	42.3
T3-HA (10)	26.4	19.3	7.14	62.8	14.9	47.1
T4-VC (2)	24.1	17.6	6.37	59.4	13.8	44.6
T5-VC (4)	28.9	22.4	8.43	67.4	15.7	50.8
T6-HA+VC	33.6	27.1	10.78	76.1	17.3	54.9
LSD ($p < 0.05$)	3.14	2.87	1.06	5.73	1.42	4.18

All amended treatments produced significantly higher root growth than the control (Table 1). The combined treatment (T6) recorded the highest root length of 33.6 cm and root volume of

27.1 cm³. Nutrient uptake at flowering was also greatest under T6.

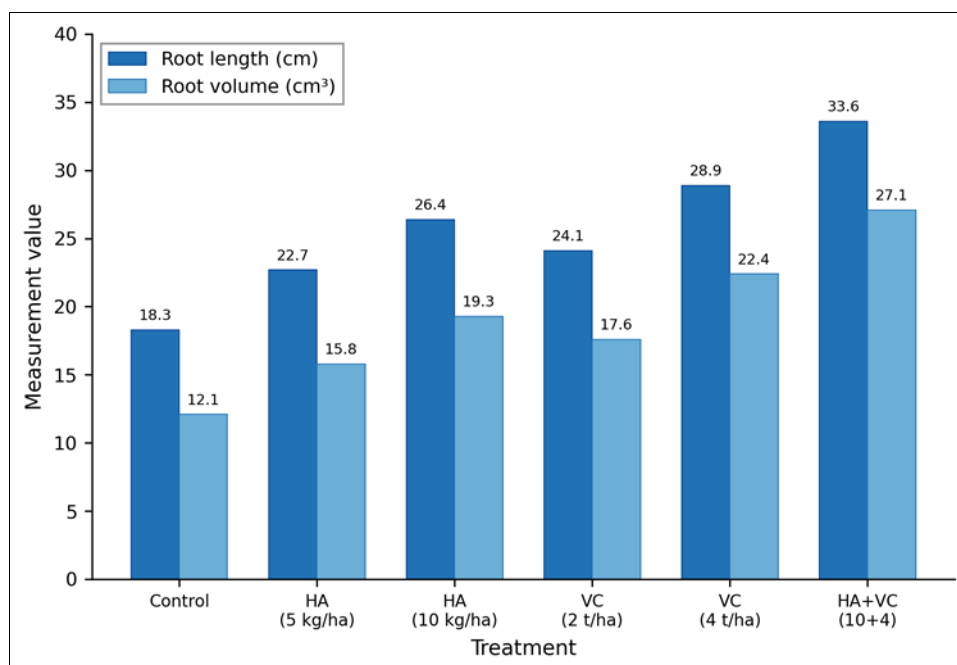


Fig 1: Root length and root volume across treatments at flowering (75 DAT)

Table 2: Grain yield, straw yield, and harvest index

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index
T1-Control	5.12	6.34	0.447
T2-HA (5)	5.64	6.81	0.453
T3-HA (10)	6.09	7.23	0.457
T4-VC (2)	5.83	7.01	0.454
T5-VC (4)	6.41	7.58	0.458
T6-HA+VC	6.87	7.96	0.463
LSD ($p < 0.05$)	0.38	0.41	NS

Grain yield ranged from 5.12 t/ha in the control to 6.87 t/ha in T6 (Table 2). Differences between the control and T3, T5, and

T6 were statistically significant. The harvest index did not differ meaningfully among treatments.

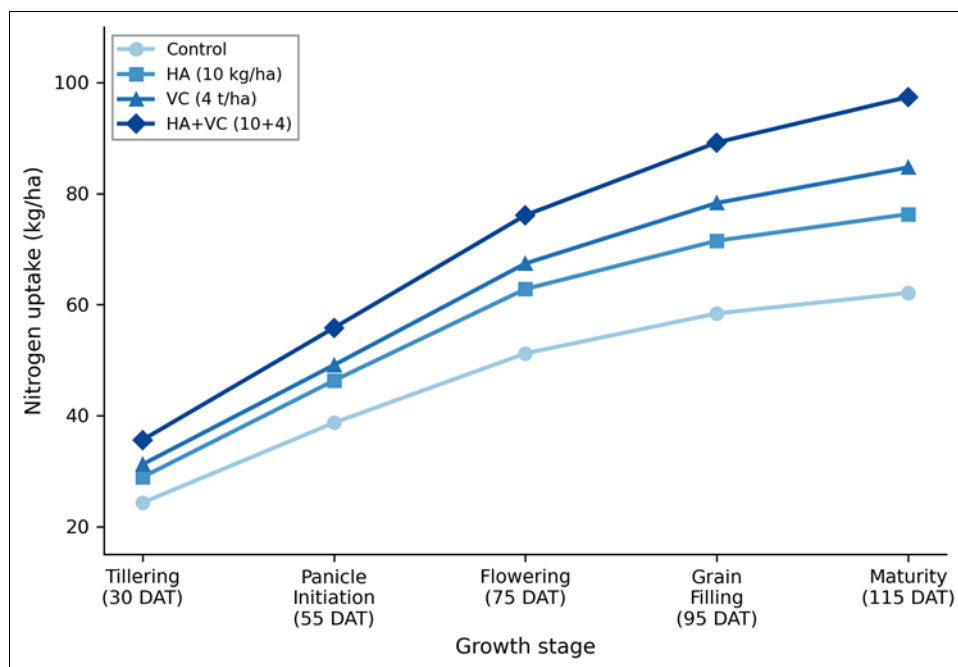


Fig 2: Nitrogen uptake (kg/ha) from tillering to maturity under selected treatments

Nitrogen uptake accelerated most between tillering and panicle initiation, but the HA + VC combination maintained a steeper trajectory through maturity. By 115 DAT, T6 exceeded the control by 35.3 kg/ha of nitrogen (Figure 2).

Discussion

The present research confirmed that combining humic acid with vermicompost produced a synergistic response in transplanted rice. This aligns with reports on wheat where HA-compost blends outperformed each component by 15-22% for nitrogen-use efficiency [3]. HA acts as a chelating agent and root stimulant while VC supplies a slow-release nutrient package in a microbially active matrix [6]. Root length values up to 33.6 cm are comparable to irrigated indica varieties in the tropics despite cooler Swedish conditions [5]. Nitrogen uptake continued rising between grain filling and maturity in VC-containing treatments, likely linked to decomposition kinetics in waterlogged soil [8]. The research was limited to a single season, so residual effects remain unknown, and the temperate setting limits extrapolation to tropical lowland rice [15].

Conclusion

Blending humic acid at 10 kg/ha with vermicompost at 4 t/ha produced the strongest root growth and nutrient uptake across all five phenological stages. Root length at flowering was 83.6% greater than the control, nitrogen uptake at maturity reached 97.4 versus 62.1 kg/ha, and grain yield averaged 6.87 t/ha—a 34.1% improvement. HA enhances nutrient solubility and root elongation while VC provides slow-release nutrients and improves soil biological activity. Multi-year trials are recommended before broad extension advice.

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