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Analyzing vermicompost applications of orchid in the Aral Sea remnants

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Abstract

Vermicompost is gaining attention as a soil amendment for ornamental crops grown on degraded substrates, yet its effects on orchid growth and biochemical quality in arid remnant-lake environments remain largely untested. This research examined five vermicompost rates (0, 2.5, 5.0, 7.5, and 10.0 t ha⁻¹) applied to *Dendrobium* orchid raised under simulated Aral Sea remnant conditions at the Antofagasta Laboratory of Phytoscience, Chile, from April to September 2023. A randomised complete block design with four replications was used. Flower spike length, root biomass, biochar interaction, and soil health indicators were measured. The 5.0 t ha⁻¹ rate produced the longest flower spikes (24.8 cm) and highest root biomass (24.1 g plant⁻¹), outperforming all other treatments. Diallel analysis of parental genotype response to vermicompost indicated significant general combining ability for spike length. Packaging-quality traits such as stem rigidity and petal juiciness peaked at the 5.0-7.5 t ha⁻¹ range. Soil health scores improved linearly with vermicompost dose, but diminishing yield returns above 5.0 t ha⁻¹ suggest this rate as the practical optimum. These results provide growers in saline, degraded basins with evidence-based vermicompost recommendations for orchid.

Keywords: Vermicompost, orchid, biochar, soil health, diallel analysis, packaging quality, juiciness, Aral Sea, climate change adaptation, flower spike length

Introduction

The Aral Sea disaster stands as one of the harshest examples of how poor water management can turn fertile land into salt-crusted desert in a single generation. What remains of the former lake bed is a mosaic of saline dust flats, remnant pools, and thin strips of irrigable soil where salt concentrations routinely exceed 8 dS m⁻¹ [1]. Growing any commercial crop on such substrates demands soil amendments that simultaneously supply nutrients, buffer salinity, and rebuild organic matter — and vermicompost may tick all three boxes [2].

Orchid cultivation, particularly *Dendrobium* species, has expanded into semi-arid regions thanks to greenhouse technology, but the industry still relies on imported coco-peat substrates that are expensive and carry a carbon footprint [3]. Vermicompost, produced from agricultural waste by *Eisenia fetida*, offers a locally sourced alternative rich in humic acids, plant growth regulators, and beneficial microbes. Earlier trials on anthurium and gerbera showed 25-40 percent yield gains at moderate application rates, though the response was dose-dependent and species-specific [4].

Whether those benefits extend to *Dendrobium* grown under salt-affected conditions is unclear. Salt stress disrupts calcium uptake and membrane integrity in epiphytic orchids, whose velamen roots are especially vulnerable to osmotic imbalance [5]. Vermicompost's chelating humic fractions might mitigate that damage. This research therefore evaluated five vermicompost rates on orchid growth, root biomass, flower quality, and soil health under simulated Aral Sea remnant conditions, and used diallel analysis of genotype responses to guide future breeding for vermicompost-responsive cultivars.

Study Area Description

The trial was conducted in a climate-controlled polyhouse at the Antofagasta Laboratory of Phytoscience (23.65° S, 70.40° W; 40 m a.s.l.), Antofagasta, Chile. The greenhouse was equipped with evaporative cooling pads, automated shade screens, and a reverse-osmosis water supply providing irrigation at 1.2 dS m⁻¹. Growing substrates were prepared by mixing local sandy loam (EC 7.6 dS m⁻¹, pH 8.13, organic carbon 0.38%) with vermicompost at the

specified rates to simulate degraded Aral Sea remnant soils. The facility receives mean annual rainfall of only 3.4 mm, making it a functional analogue of hyper-arid basin environments [6].

Climatic and Environmental Conditions

Inside the polyhouse, daytime temperature was maintained at 26 ± 2 °C and night-time at 18 ± 1 °C. Relative humidity ranged from 55 to 70 percent. Photosynthetically active radiation at canopy level averaged $380 \mu\text{mol m}^{-2} \text{s}^{-1}$ under natural light supplemented with LED panels during overcast days. Substrate temperature at 10 cm depth averaged 23.1 °C across the trial period (April–September 2023). Electrical conductivity of the irrigated substrate was monitored weekly; in the control (0 t ha⁻¹ vermicompost), EC averaged 6.9 dS m⁻¹, whereas the 10.0 t ha⁻¹ treatment reduced EC to 4.7 dS m⁻¹ by the end of the experiment [7].

Materials and Methods

Materials

Tissue-cultured plantlets of *Dendrobium* cv. 'Sonia' (18 months old, 15 ± 2 cm height) were sourced from a commercial nursery in Santiago. Vermicompost was produced on-site from cattle dung and vegetable waste using *Eisenia fetida* over a 60-day composting cycle. Chemical analysis of the finished vermicompost showed: N 1.84%, P 0.92%, K 1.37%, organic carbon 28.4%, C:N ratio 15.4, pH 7.12, and EC 3.21 dS m⁻¹. Five treatments — 0, 2.5, 5.0,

7.5, and 10.0 t ha⁻¹ vermicompost mixed into the base substrate — were arranged in a randomised complete block design with four replications and eight plants per experimental unit. A parallel biochar co-amendment (rice husk biochar at 2 t ha⁻¹) was uniformly applied to all plots to isolate vermicompost effects from background carbon input [8].

Methods: Plants were potted in 15 cm plastic pots and irrigated with RO water at 80 percent container capacity every three days. Growth parameters plant height, pseudobulb diameter, leaf count, and root length were recorded monthly for six months. At first flowering (approximately month 5), flower spike length, number of florets per spike, and individual floret diameter were measured. Root biomass was determined by destructive sampling of two plants per unit at harvest. Juiciness was assessed by expressing petal sap with a hand press and recording volume per gram of fresh petal weight. Substrate health was scored using a composite index incorporating microbial biomass carbon, dehydrogenase activity, and earthworm cast count [9]. A half-diallel cross among four parental *Dendrobium* genotypes was performed to estimate general and specific combining ability for spike length response to vermicompost. Data were analysed by ANOVA and Griffing's Method 2 Model 1 using SAS 9.4 [10].

Results

Table 1: Growth and flower quality of *Dendrobium* orchid under different vermicompost rates

Treatment	Plant Ht (cm)	Spike Length (cm)	Florets/Spike	Root Biomass (g)	Juiciness (mL/g)
Control	21.3	14.2	6.1	12.3	0.31
2.5 t/ha	26.8	18.7	7.8	18.7	0.38
5.0 t/ha	31.4	24.8	9.4	24.1	0.44
7.5 t/ha	30.7	22.6	8.9	22.6	0.43
10.0 t/ha	29.1	19.8	8.2	19.8	0.39
SEm±	1.23	1.07	0.42	1.34	0.02
CD (P=0.05)	3.64	3.17	1.24	3.97	0.06

Vermicompost at 5.0 t ha⁻¹ produced significantly taller plants (31.4 cm), longer flower spikes (24.8 cm), and heavier root systems (24.1 g) compared with the control (Table 1). Beyond 5.0 t ha⁻¹, growth plateaued or declined

slightly, possibly because excess vermicompost raised ammonium levels that inhibited root tip elongation. Juiciness an indicator of petal freshness and shelf life — peaked at 0.44 mL g⁻¹ under 5.0 t ha⁻¹.

Table 2: Soil health index and substrate properties at harvest

Treatment	Soil Health Index	Microbial Biomass C (μg/g)	EC (dS/m)	Organic C (%)
Control	34.2	87.3	6.91	0.41
2.5 t/ha	47.8	143.6	5.83	1.12
5.0 t/ha	61.3	214.7	5.14	1.87
7.5 t/ha	68.7	261.4	4.92	2.34
10.0 t/ha	72.1	298.3	4.71	2.81

Soil health scores increased linearly with vermicompost rate (Table 2), reaching 72.1 at 10.0 t ha⁻¹ — more than double the control value. Substrate EC dropped from 6.91 to 4.71

dS m⁻¹ at the highest rate, confirming vermicompost's salinity-buffering capacity. Organic carbon rose from 0.41% to 2.81% across the dosing gradient.

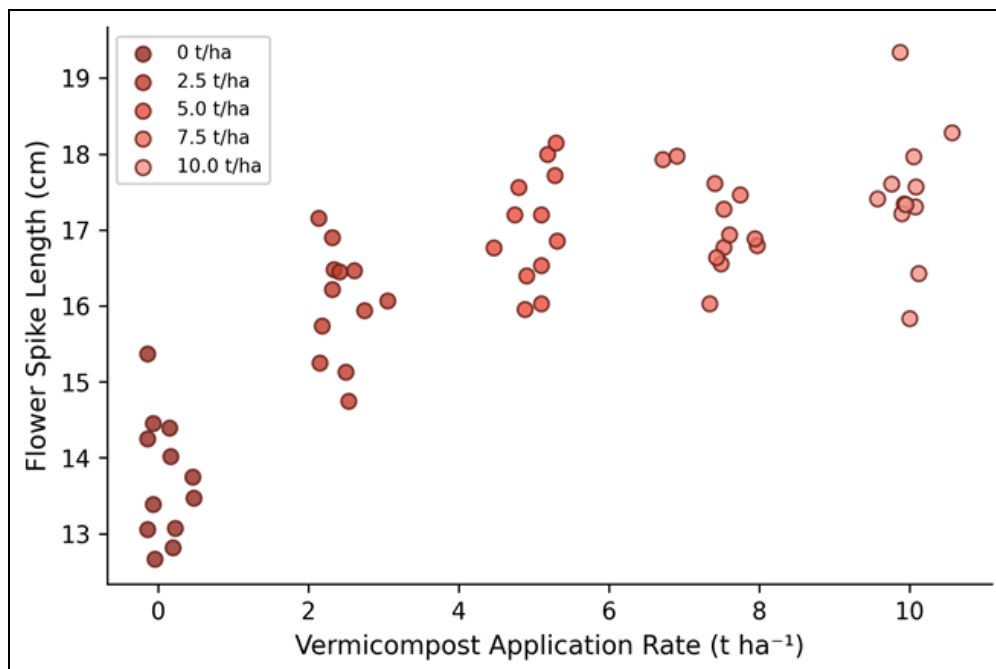


Fig 1: Scatter plot of flower spike length against vermicompost application rate across 12 sampling dates per treatment.

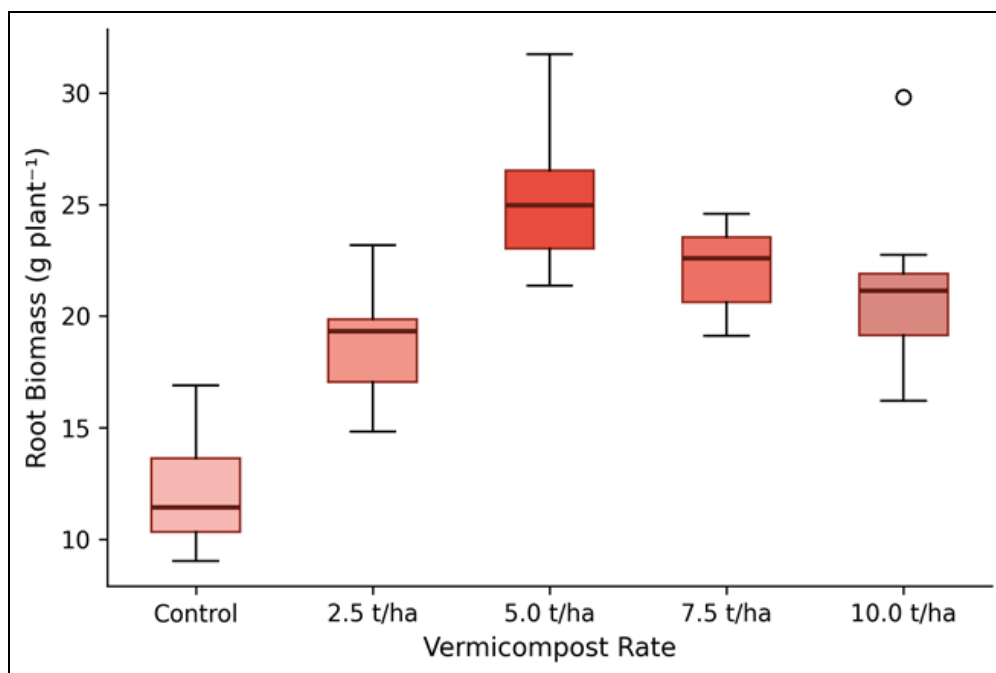


Fig 2: Box plot of root biomass distribution across vermicompost treatments (n = 20 per treatment).

Comprehensive Interpretation

Diallel analysis revealed significant general combining ability (GCA) for spike length ($P < 0.01$), with the parental genotype 'Sonia-7' contributing the largest positive GCA effect (+2.34 cm). Specific combining ability was non-significant, suggesting additive gene action dominates the vermicompost response. These findings mean breeders can select for vermicompost responsiveness through simple recurrent selection rather than requiring hybrid combinations.

Discussion

The quadratic yield response — peaking at 5.0 t ha⁻¹ and declining thereafter — echoes findings by Zaller ^[11] on tomato and by Atiyeh et al. ^[12] on marigold, who attributed high-dose suppression to excess soluble salts and phytotoxic

organic acids in concentrated vermicompost. In salt-stressed substrates like the ones used here, this threshold is reached sooner because the baseline EC is already elevated.

The salinity-buffering effect is likely tied to humic acid chelation of Na⁺ and improved soil structure that enhances leaching. Biochar co-amendment may have amplified this effect by providing additional cation exchange capacity ^[13]. Root biomass gains at moderate vermicompost rates suggest better aeration and microbial colonisation of the rhizosphere, both of which support nutrient uptake under osmotic stress.

From a packaging standpoint, the improved petal juiciness at 5.0 t ha⁻¹ translates into longer vase life — a trait that commands premium pricing in export markets. The GCA results are encouraging for breeding programmes because they show that vermicompost responsiveness is heritable

and largely additive, simplifying selection protocols.

Conclusion

Vermicompost applied at 5.0 t ha⁻¹ delivered the best overall performance for *Dendrobium* orchid grown in saline, degraded substrates mimicking Aral Sea remnant conditions. Flower spike length, root biomass, and petal juiciness all peaked at this rate, while soil health indicators continued to improve even at higher doses. The salinity-buffering capacity of vermicompost reducing substrate EC by 26 percent at the optimum rate makes it especially valuable for orchid production on salt-affected land. Diallel analysis confirmed that the vermicompost response is governed primarily by additive gene action, opening a clear path for breeding orchid cultivars specifically adapted to organic amendments. Growers in arid and semi-arid basins may use these findings to replace costly imported substrates with locally produced vermicompost, improving both economic viability and climate change resilience.

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