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RESEARCH ARTICLE

Standardization of the vermicompost for organic cultivation of *Andrographis paniculata* (Burm. f.) Wallich ex Nees

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Abstract

Andrographis paniculata (Burm. f.) Wallich ex Nees is an important medicinal plant that belongs to the family Acanthaceae . It has been used to treat many human diseases since ancient times. The pharmaceutical industries accept only organically grown biomass of *A. paniculata* that is free from contamination. Vermicompost is an important organic manure that is used as an organic source for the cultivation of crops. The experiment aims to find the optimum dose of vermicompost for organic cultivation of *A. paniculata*. The different doses of the vermicompost, i.e., Control (T_1), 2.5 t/ha (T_2), 5 t/ha (T_3), 7.5 t/ha (T_4), 10 t/ha (T_5), 12.5 t/ha (T_6) and 15 t/ha (T_7) were standardized in Randomized Block Design with 4 replications. The experimental results showed that the optimum dose of vermicompost was 7.5 t/ha for *A. paniculata*. The analytical results indicated that N, P, K and Ca content increased with an increase in doses of vermicompost. Micronutrient (Fe, Zn, Cu, Mn, Ni) content varies in different amounts and increases with increasing doses of vermicompost. For quality parameters, andrographolide, neo-androgra-pholide and wogonine varied in different amounts and had no effect corresponding to increasing doses of vermicompost. Soil physico-chemical properties were improved with increasing doses of vermicompost.

Keywords

Andrographis ; organic; vermicompost

Introduction

Andrographis paniculata is a medicinal plant belonging to the family Acanthaceae. It is a traditional herbal medicine in South Asian countries (1, 2). It is also called "King of bitters" due to its highly bitter taste (3). The whole plant treats many diseases in Asia and Europe (1, 4). In the Unani and Ayurvedic medicines, andrographolide is the chief compound of *A. paniculata*, one of the most used medicinal plants (1). *A. paniculata* is used to treat many diseases like anticancer, antidiarrheal, antihepatitis, antimicrobial, antimalarial, anti-HIV, antihyperglycemic and cardiovascular (5-12). It is also an antibiotic for controlling typhoid, fever, worms, dysentery, improving the digestive system, curing the lever etc. Due to the severe exploitation of medicinal plants, cultivation is the only option for supplying raw materials to the pharmaceutical industries. Only organically grown medicinal plants are accepted by the pharmaceutical industries for drug formulation. Vermicompost is an important organic manure that is used for the cultivation of crops. So, there is a future need to standardize the dose of vermicompost for organic cultivation of *A. paniculata*. As per the information, we first time analyzed and reported the micronutrient and heavy metal concentrations in different parts (root, stem and leaf) of the *A. paniculata* using vermicompost. This research paper will help to manage the macro and micronutrients for the cultivation of *A. paniculata*.

Materials and Methods

Experimental site

The experiment was conducted at Banthra Research Station of the CSIR-NBRI, Lucknow, in 2016 and 2017. The geographical location of the experiments was 26°42′ 09″N latitude and 80°49′ 46″E longitude.

Physico-chemical properties of the experimental field and nutrient composition of vermicompost

Soil samples were collected from 4 places of the experimental site up to a depth of 15 cm by the soil sampler. The samples were shade-dried and sieved by a 2 mm sieve. The physico-chemical properties of the soils are given in Table 1 and the nutrient compositions of the vermicompost used in the experiments are given in Table 2.

Sowing of the nursery

The accession 'MRDC-650' of *A. paniculata* was raised in good soil using a fine vermicompost layer. After that, the nursery was irrigated from time to time as required. The 45 -day-old seedlings were transplanted into the field by maintaining a 30 cm × 30 cm distance.

Methods of experiment

The different doses of the vermicompost, i.e. Control (T_1), 2.5 t/ha(T_2), 5 t/ha(T_3), 7.5 t/ha(T_4), 10 t/ha(T_5), 12.5 t/ha(T_6) and 15 t/ha(T_7) was applied in July before 25 days of transplanting of the *A. paniculata* in Randomized Block Design with 4 replications. The experiment was repeated during both years in the same field with the same treatments. The treatment was applied in the field on a dry weight basis.

Andrographis paniculata was transplanted in August and harvested in December during both years. The crop management practices, like weed, irrigation etc., were managed as and when required. No pest or disease incidences were recorded in the crop during the study period.

Observations recorded

Four plants from each plot were randomly selected at harvesting time (full bloom stage) and observations were recorded. After shed drying, the samples were dried in a hot air oven at 40 °C and kept for further digestion and analysis.

Sample preparation and analysis of vermicompost and A. paniculata

The total organic carbon in vermicompost was analyzed using analyticjena multi N/C, 2100S. The 20 mg vermicompost was analyzed and the result was converted into g/kg. The dried and ground 0.5 g vermicompost and plant (root, stem and leaf) samples were used for digestion by using a di-acid mixture containing sulphuric and perchloric acid (3:1) (13). After digestion, the volume was made up of distilled water up to 100 mL.

Table 1. Physico-chemical properties of the experimental soil

Sl. No.	Physico-chemical properties of the soil	Values (±SD)
1	pH (1:2)	8.57 ± 0.05
2	EC (1:2) (dS/m^3)	0.11 ± 0.01
3	Organic Carbon (g/kg)	4.1 ± 0.05
4	Bulk Density (Mg/m^3)	1.38 ± 0.06
5	Particle Density (Mg/m^3)	2.63 ± 0.07
6	Porosity (%)	47.53 ± 1.42
7	Soil Texture	Silt loam
8	Sand (%)	27.65 ± 1.14
9	Silt (%)	57.50 ± 1.33
10	Clay (%)	14.85 ± 1.55
11	Water holding capacity (%)	37.24 ± 1.38
12	CEC (c mol/kg)	21.74 ± 1.44
13	Available N (mg/kg)	42.91 ± 3.43
14	Available P (mg/kg)	11.3 ± 1.24
15	Available K (mg/kg)	141 ± 5.55
16	Exchangeable Ca (C mol/kg)	5.82 ± 0.06
17	Exchangeable Mg (C mol/kg)	2.64 ± 0.08
18	Available S (mg/kg)	7.61 ± 0.17
19	DTPA Extractable Fe (mg/kg)	24.16 ± 1.08
20	DTPA Extractable Zn (mg/kg)	0.62 ± 0.09
21	DTPA Extractable Cu (mg/kg)	0.66 ± 0.07
22	DTPA Extractable Mn (mg/kg)	6.81 ± 0.76
23	DTPA Extractable Mo (mg/kg)	0.063 ± 0.01
24	DTPA Extractable Ni (mg/kg)	0.245 ± 0.02
25	DTPA Extractable Co (mg/kg)	0.001 ± 0.00
26	DTPA Extractable As (mg/kg)	0.018 ± 0.01
27	DTPA Extractable Se (mg/kg)	0.002 ± 0.00
28	DTPA Extractable Cd (mg/kg)	0.001 ± 0.00
29	DTPA Extractable Cr (mg/kg)	0.61 ± 0.03
30	DTPA Extractable Pb (mg/kg)	0.002 ± 0.00

For analysis of total N, a 25 mL digested sample was taken in a tube and run with N analyzer Kel Plus Classic DX with 25 mL 40% NaOH. Collected the ammonia gas in 4% boric acid in a 250 mL conical flask, titrated against N/50 H_2SO_4 and calculated the result in g/kg (14). For P analysis, 5 mL of the digested sample was taken, 10 mL of vanade-molybdate solution was added and diluted to 50 mL and yellow appeared. Taken reading using Shimadzu, UV-1800 spectrophotometer and calculated in g/kg according to the standard reading and dilution factor (15). The digested samples were directly used for Potassium (K), Calcium (Ca) and Sodium (Na) analysis by EI microprocessor-based Flame Photometer, model - 1382 corresponding to the used standards and calculated in g/kg multiplying the dilution factor (16). Magnesium (Mg) was analysed directly by the digested samples by AAS. Micronutrients and metals were also directly analyzed by ICP-MS, Model - Agilent 7500CX.

Table 2. Nutrient composition of vermicompost used in the experiment

S. No.	Parameters	Values (±SD)
1	Total Organic Carbon (g/kg)	117 ± 1.62
2	Total N (g/kg)	11.4 ± 0.76
3	Total P (g/kg)	2.76 ± 0.27
4	Total K (g/kg)	98.16 ± 4.21
5	Total Ca (g/kg)	52.4 ± 0.86
6	Total Mg (g/kg)	5.47 ± 0.44
7	Total S (g/kg)	3.22 ± 0.17
8	Total Na (g/kg)	2.75 ± 0.14
9	Total Fe (mg/kg)	1812 ± 58
10	Total Zn (mg/kg)	68.3 ± 5.32
11	Total Cu (mg/kg)	8.80 ± 1.21
12	Total Mn (mg/kg)	151 ± 7.11
13	Total Al (mg/kg)	1017 ± 93
14	Total Cr (mg/kg)	25.2 ± 3.68
15	Total As (mg/kg)	3.28 ± 0.41
16	Total Se (mg/kg)	1.26±0.09
17	Total Cd (mg/kg)	0.47 ± 0.02
18	Total Pb (mg/kg)	2.96 ± 0.23
19	DTPA Extractable Fe (mg/kg)	5.64 ± 0.86
20	DTPA Extractable Zn (mg/kg)	11.12 ± 0.29
21	DTPA Extractable Cu (mg/kg)	2.38 ± 0.17
22	DTPA Extractable Mn (mg/kg)	6.28 ± 0.89
23	C/N Ratio	10.26 ± 2.13:1

To analyze the secondary metabolites, 10 g of dried biomass was extracted with methanol and evaporated and 1 mg dried sample was dissolved in 1 mL 100% methanol filtered and analyzed by HPLC (Table 5).

Statistical analyses

The SPSS software 16.0 package was used for the analysis of data of the experiment and presented as mean ± standard deviation (SD).

Results

Yield and yield attributing characters

The results revealed that yield attributing characters of the *A. paniculata* increased with an increase in doses of vermicompost between 7.5-10 t/ha (Table 3).

Nutrient and heavy metal content

N, P, K, Ca, Mg, Na content: N content in the root decreased with increased doses of vermicompost but increased in the stem and leaf. P content in root, stem and leaf increased with increased doses of vermicompost. K and mg content was not affected due to the increased dose of vermicompost. Ca content increased in the root and leaf but was not affected in the stem with a higher dose of vermicompost. No trend was observed in either root, stem, or leaf for the Na content in *A. paniculata* (Table 4).

Micronutrients : There was a decreasing trend of Zinc (Zn) content in the root and stem and no trend recorded in the stem with increasing doses of vermicompost. An increasing trend was recorded for Iron (Fe) content in the root and stem and a decreasing trend in the leaf corresponding to increasing doses of vermicompost. There were no trends recorded for Copper (Cu), Manganese (Mn) and Molybdenum (Mo) content in *A. paniculata* with different doses of vermicompost. However, an increasing trend of Nickel (Ni) was observed in the root and stem but decreased in the stem with increasing doses of vermicompost in *A. paniculata* (Table 4).

Heavy metals : The Chromium (Cr) content increased in the root and stem. However, no trend was observed with increasing doses of vermicompost. A decreasing trend was observed for Selenium (Se) content with increasing doses of vermicompost. No trend was noted for Arsenic (As) in the root, but a decreasing trend was recorded with stem and leaf corresponding to increased doses of vermicompost. No trends were noted for Lead (Pb), Cobalt (Co) and Cadmium (Cd) in *A. paniculata* with increased doses of vermicompost (Table 5).

Bio-active compounds (diterpenoids) in the biomass of *A. paniculata*

The extraction yield of the biomass increased from 14.56% to 17.03%, corresponding to an increase in doses of the vermicompost. No trends were recorded for the andrographolide, neo-andrographolide and wogonin content, however, total yield was increased with higher doses of vermicompost due to the high biomass yield of

Table 3. Effect of different doses of vermicompost on biomass yield and attributing characteristics of *A. paniculata* (mean of 2 years)

Treatments	Plant height (cm)	Number of branches	Stem diameter (mm)	Plant spread (cm^2)	Biomass (kg/ha)		Ratio
					Fresh	Dry	
T_1- Control	37.4^{d}	8.68^{d}	4.46^{d}	408^{e}	2974^{e}	1047^{e}	2.84^{b}
T_2- VC at 2.5 t/ha	42.8^{c}	10.35^{c}	5.44^{c}	615^{d}	4378^{d}	1412^{d}	3.10^{ab}
T_3- VC at 5.0 t/ha	44.5^{bc}	11.51^{b}	5.84^{b}	718^{c}	5672^{c}	1755^{c}	3.23^{ab}
T_4- VC at 7.5 t/ha	46.1^{ab}	12.51^{a}	6.03^{ab}	798^{b}	6479^{b}	2003^{b}	3.23^{ab}
T_5- VC at 10.0 t/ha	47.4^{ab}	12.81^{a}	6.11^{ab}	858^{a}	6959^{a}	2102^{ab}	3.31^{ab}
T_6- VC at 12.5 t/ha	48.2^{a}	13.21^{a}	6.17^{a}	886^{a}	7171^{a}	2145^{a}	3.34^{a}
T_7- VC at 15.0 t/ha	48.6^{a*}	13.45^{a}	6.21^{a}	906^{a}	7211^{a}	2165^{a}	3.33^{a}

Table 4. Nutrient content in the biomass of *A. paniculata* (mean of 2 years)

Treatments	N	P	K	Ca	Mg	Na	Zn	Fe	Cu	Mn	Mo	Ni
	g/kg	g/kg	g/kg	g/kg	g/kg	g/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Root												
T_1- Control	18.31^{a}	1.87^{d}	38.65^{a}	2.41^{c}	1.69^{b}	0.31^{bc}	90.19^{a}	2532^{e}	4.64^{b}	5.48^{c}	2.91^{d}	33.8^{c}
T_2- VC at 2.5 t/ha	18.08^{a}	2.71^{bc}	38.69^{a}	2.93^{b}	1.73^{b}	0.36^{ab}	47.70^{c}	3248^{d}	3.91^{c}	6.14^{b}	6.94^{a}	110.6^{a}
T_3- VC at 5.0 t/ha	19.48^{a}	2.49^{c}	32.16^{d}	3.58^{a}	1.79^{ab}	0.33^{abc}	53.28^{b}	3079^{e}	5.02^{b}	5.51^{c}	3.75^{c}	69.1^{b}
T_4- VC at 7.5 t/ha	10.52^{b}	3.44^{a}	37.12^{ab}	3.43^{a}	1.88^{a}	0.37^{a}	48.20^{c}	4145^{a}	3.41^{d}	5.07^{c}	3.52^{cd}	28.4^{c}
T_5- VC at 10.0 t/ha	8.66^{bc}	3.56^{a}	37.31^{ab}	3.66^{a}	1.66^{b}	0.32^{abc}	49.89^{c}	2105^{g}	5.59^{a}	5.06^{c}	4.46^{b}	62.5^{b}
T_6- VC at 12.5 t/ha	8.96^{bc}	3.72^{a}	35.06^{bc}	3.51^{a}	1.74^{b}	0.29^{c}	44.81^{d}	3458^{c}	2.63^{e}	5.48^{c}	3.77^{c}	70.8^{b}
T_7- VC at 15.0 t/ha	7.95^{c}	2.92^{b}	32.73^{cd}	3.29^{ab}	1.71^{b}	0.32^{abc}	40.78^{e}	3843^{b}	3.51^{cd}	6.65^{a}	4.53^{b}	118.6^{a}
Stem												
T_1- Control	6.59^{f}	2.66^{ab}	25.37^{a}	3.41^{ab}	1.63^{a}	0.54^{a}	72.75^{a}	1161^{d}	2.23^{f}	3.81^{d}	2.36^{c}	47.2^{d}
T_2- VC at 2.5 t/ha	7.46^{e}	2.84^{ab}	26.03^{a}	3.56^{a}	1.69^{a}	0.61^{a}	35.04^{c}	583^{f}	3.94^{e}	4.61^{d}	2.05^{c}	19.8^{e}
T_3- VC at 5.0 t/ha	8.73^{d}	2.95^{a}	26.14^{a}	2.95^{cd}	1.74^{a}	0.58^{a}	41.16^{b}	955^{e}	23.41^{a}	32.53^{c}	5.32^{a}	48.9^{d}
T_4- VC at 7.5 t/ha	10.39^{c}	3.13^{a}	25.84^{a}	2.99^{cd}	1.78^{a}	0.53^{a}	29.94^{d}	1566^{c}	15.21^{c}	30.82^{c}	3.91^{b}	98.9^{a}
T_5- VC at 10.0 t/ha	11.64^{b}	2.72^{ab}	25.05^{a}	2.65^{d}	1.77^{a}	0.62^{a}	21.23^{e}	1879^{b}	18.71^{b}	50.40^{a}	4.09^{b}	91.1^{b}
T_6- VC at 12.5 t/ha	12.29^{a}	2.39^{b}	25.16^{a}	3.13^{bc}	1.72^{a}	0.38^{b}	16.01^{f}	1990^{a}	11.31^{d}	46.06^{b}	1.57^{c}	87.3^{bc}
T_7- VC at 15.0 t/ha	10.38^{c}	1.45^{c}	27.19^{a}	3.24^{abc}	1.59^{a}	0.33^{b}	7.59^{g}	1850^{b}	3.69^{e}	47.76^{ab}	2.36^{c}	83.1^{c}
Leaves												
T_1- Control	9.55^{c}	1.39^{ab}	28.51^{a}	2.60^{c}	1.41^{a}	0.23^{a}	25.53^{bc}	1270^{b}	13.02^{a}	46.64^{b}	2.16^{a}	126.7^{a}
T_2- VC at 2.5 t/ha	9.69^{c}	1.41^{ab}	25.41^{a}	2.59^{c}	1.59^{a}	0.20^{a}	27.92^{ab}	1448^{a}	12.33^{ab}	70.21^{a}	1.95^{a}	120.0^{a}
T_3- VC at 5.0 t/ha	11.51^{b}	1.53^{ab}	26.31^{a}	3.27^{b}	1.54^{a}	0.21^{a}	15.03^{d}	1087^{c}	8.97^{c}	27.91^{c}	1.29^{b}	96.6^{d}
T_4- VC at 7.5 t/ha	12.51^{b}	1.53^{ab}	28.02^{a}	3.72^{a}	1.41^{a}	0.20^{a}	22.99^{c}	1013^{c}	10.65^{bc}	47.31^{b}	0.57^{c}	65.1^{c}
T_5- VC at 10.0 t/ha	14.47^{a}	1.65^{a}	28.53^{a}	3.71^{a}	1.47^{a}	0.19^{a}	12.07^{de}	365^{d}	4.45^{e}	24.16^{cd}	0.55^{c}	40.8^{d}
T_6- VC at 12.5 t/ha	15.07^{a}	1.39^{ab}	30.06^{a}	3.81^{a}	1.45^{a}	0.29^{a}	30.53^{a}	306^{d}	6.61^{d}	15.04^{d}	0.35^{c}	50.5^{d}
T_7- VC at 15.0 t/ha	15.04^{a}	1.18^{b}	30.24^{a}	3.77^{a}	1.51^{a}	0.32^{a}	8.91^{a}	474^{d}	4.71^{e}	15.08^{d}	1.09^{b}	40.6^{d}

Table 5. Heavy metal content in the biomass of *A. paniculata* (mean of 2 years)

Treatments	Cr	Se	As	Pb	Co	Cd
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Root						
T_1- Control	88.8^{c}	3.57^{a}	1.94^{b}	0.87^{c}	0.11^{d}	0.26^{b}
T_2- VC at 2.5 t/ha	484.0^{a}	3.12^{bc}	2.18^{ab}	0.97^{c}	0.53^{a}	0.23^{b}
T_3- VC at 5.0 t/ha	196.4^{b}	2.74^{c}	1.85^{b}	1.69^{b}	0.18^{cd}	0.24^{b}
T_4- VC at 7.5 t/ha	214.0^{b}	3.38^{ab}	2.58^{a}	0.88^{c}	0.44^{b}	0.28^{b}
T_5- VC at 10.0 t/ha	155.9^{b}	2.33^{d}	2.57^{a}	1.69^{b}	0.19^{cd}	0.22^{b}
T_6- VC at 12.5 t/ha	173.1^{b}	2.25^{d}	2.01^{b}	0.75^{c}	0.21^{c}	0.24^{b}
T_7- VC at 15.0 t/ha	190.2^{b}	3.14^{abc}	2.08^{ab}	2.22^{a}	0.39^{b}	0.35^{a}
Stem						
T_1- Control	116.9^{c}	2.44^{a}	0.98^{a}	1.19^{c}	0.12^{c}	0.25^{a}
T_2- VC at 2.5 t/ha	74.3^{d}	1.01^{b}	0.53^{c}	0.72^{d}	0.22^{c}	0.07^{b}
T_3- VC at 5.0 t/ha	138.8^{b}	0.92^{b}	1.03^{a}	1.73^{b}	1.34^{bc}	0.05^{b}
T_4- VC at 7.5 t/ha	233.9^{a}	0.71^{c}	0.83^{b}	2.58^{a}	3.53^{a}	0.03^{b}
T_5- VC at10.0 t/ha	139.1^{b}	0.51^{d}	0.81^{b}	0.34^{e}	1.74^{b}	0.01^{b}
T_6- VC at12.5 t/ha	142.4^{b}	0.23^{e}	0.52^{c}	1.25^{c}	2.14^{b}	0.03^{b}
T_7- VC at15.0 t/ha	26.56^{e}	0.26^{e}	0.22^{d}	0.53^{de}	3.81^{a}	0.02^{b}
Leaf						
T_1- Control	190.4^{c}	0.91^{ab}	0.96^{b}	3.05^{bc}	3.21^{a}	0.01^{a}
T_2- VC at 2.5 t/ha	292.7^{a}	1.04^{ab}	0.92^{bc}	5.12^{a}	2.95^{ab}	0.03^{a}
T_3- VC at 5.0 t/ha	35.35^{e}	0.72^{ab}	0.49^{de}	1.38^{d}	2.44^{ab}	0.04^{a}
T_4- VC at 7.5 t/ha	237.5^{b}	1.15^{a}	1.47^{a}	2.73^{bcd}	1.87^{bc}	0.02^{a}
T_5- VC at 10.0 t/ha	14.22^{e}	0.81^{ab}	0.63^{cd}	3.24^{b}	0.21^{d}	0.04^{a}
T_6- VC at 12.5 t/ha	15.34^{e}	0.61^{b}	0.38^{de}	4.73^{a}	0.20^{d}	0.08^{a}
T_7- VC at 15.0 t/ha	96.01^{d}	0.59^{b}	0.26^{e}	1.71^{cd}	1.01^{cd}	0.03^{a}

Table 6. Plant extract and bio-active compounds (Diterpenoid - Andrographolide) in biomass of *A. paniculata* (mean of 2 years)

Treatments	Plant extract by Methanol (%)	Andrographolide in plant extract (mg/g)	Neo-andrographolide in plant extract (mg/g)	Wogonine in plant extract (mg/g)	Plant extract yield (kg/ha)	Andrographolide in plant extract (kg/ha)	Neo-andrographolide in plant extract (kg/ha)	Wogonine in plant extract (kg/ha)
T_1- Control	15.56^{a}	96.48^{bc}	58.32^{bc}	0.002^{a}	162.63^{c}	15.69^{c}	9.55^{d}	0.32^{c}
T_2- VC at 2.5 t/ha	14.56^{a}	97.22^{bc}	67.56^{ab}	0.003^{a}	205.22^{c}	19.95^{c}	13.83^{cd}	0.61^{b}
T_3- VC at 5.0 t/ha	16.47^{a}	102.87^{b}	72.45^{a}	0.002^{a}	289.14^{b}	29.65^{b}	20.88^{ab}	0.57^{b}
T_4- VC at 7.5 t/ha	15.74^{a}	93.68^{c}	67.17^{ab}	0.001^{a}	316.52^{ab}	29.57^{b}	21.63^{ab}	0.31^{c}
T_5- VC at 10.0 t/ha	17.03^{a}	109.52^{a}	46.98^{c}	0.003^{a}	358.38^{a}	39.35^{a}	16.92^{bc}	0.87^{a}
T_6- VC at 12.5 t/ha	16.37^{a}	98.32^{bc}	74.22^{a}	0.002^{a}	351.24^{a}	34.51^{ab}	26.04^{a}	0.71^{a}
T_7- VC at 15.0 t/ha	15.49^{a}	95.77^{c}	66.97^{ab}	0.001^{a}	335.76^{ab}	32.13^{b}	22.48^{ab}	0.33^{c}

the plant (Table 6).

Physico-chemical properties of the soil

The application of vermicompost significantly decreased the soil pH and bulk density; however, no effect was recorded for the soil's EC. Organic carbon, N, P, K, Ca, Mg and S significantly increased, corresponding to an increase in doses of vermicompost. In the case of micronutrients, an increasing trend was recorded in Fe, Zn, Mn and Mo due to increasing doses of vermicompost. However, no trend was recorded in Cu and Ni content corresponding to an increase in doses of vermicompost (Table 7).

In the case of heavy metal, no trend was recorded in Co, As, Se, Cd, Cr and Pb, corresponding to an increase in doses of vermicompost (Table 8).

Discussion

Yield attributing characters and biomass yield

Increases in plant height, number of branches, stem diameter, plant spread and plant biomass were recorded with an increase in doses of vermicompost because after mineralization of added vermicompost, increased available nutrients in the plant root zone, which induced favourable effects on *A. paniculata*. It is a short-duration and low nutrient-demanding crop that was not given a significant response due to high doses of vermicompost

Table 7. Changes in physico-chemical properties of soil after harvest of *A. paniculata* (after 2 years of experiments)

Treatments	pH	EC	OC	BD	N	P	K	Ca	Mg	S	Fe	Zn	Cu	Mn	Mo	Ni
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
T_1- Control	8.53^{a}	0.11^{a}	4.1^{c}	1.38^{a}	41.2^{e}	10.6^{d}	137^{e}	5.53^{f}	2.51^{b}	6.32^{e}	22.48^{c}	0.58^{c}	0.62^{c}	6.51^{c}	0.058^{c}	0.242^{a}
T_2- VC at 2.5 t/ha	8.52^{ab}	0.10^{a}	4.2^{c}	1.37^{a}	43.1^{de}	11.7^{cd}	144^{e}	5.88^{e}	2.56^{b}	7.38^{d}	27.82^{b}	0.65^{bc}	0.63^{c}	7.23^{b}	0.042^{cd}	0.182^{b}
T_3- VC at 5.0 t/ha	8.49^{ab}	0.10^{a}	4.4^{b}	1.36^{a}	44.35^{de}	12.7^{cd}	156^{d}	5.95^{de}	2.68^{ab}	7.74^{d}	28.12^{b}	0.68^{b}	0.53^{c}	6.39^{c}	0.083^{b}	0.224^{a}
T_4- VC at 7.5 t/ha	8.45^{ab}	0.10^{a}	4.5^{abc}	1.34^{a}	47.1^{cd}	13.6^{bc}	162^{cd}	6.13^{cd}	2.74^{ab}	8.21^{d}	29.71^{b}	0.69^{b}	0.63^{b}	5.19^{d}	0.032^{d}	0.068^{c}
T_5- VC at10.0 t/ha	8.43^{ab}	0.09^{a}	4.7^{abc}	1.32^{a}	50.6^{bc}	14.9^{ab}	171^{bc}	6.24^{c}	2.85^{ab}	9.30^{c}	28.19^{b}	0.78^{a}	0.52^{b}	7.48^{ab}	0.044^{cd}	0.248^{a}
T_6- VC at 12.5 t/ha	8.39^{b}	0.09^{a}	4.9^{ab}	1.31^{a}	54.1^{ab}	16.25^{a}	179^{ab}	6.56^{b}	2.92^{a}	10.64^{b}	31.28^{ab}	0.82^{a}	0.71^{b}	7.54^{ab}	0.054^{c}	0.063^{c}
T_7- VC at 15.0 t/ha	8.36^{b}	0.09^{a}	5.2^{a}	1.30^{a}	57.9^{a}	16.75^{a}	187^{a}	6.92^{a}	2.94^{a}	11.75^{a}	34.18^{a}	0.85^{a}	0.53^{a}	8.15^{a}	0.194^{a}	0.147^{b}
Initial	8.57	0.11	4.1	1.38	42.9	11.3	141	5.82	2.64	7.61	24.16	0.62	0.66	6.81	0.063	0.245

1- pH (1:2), 2- EC (1:2) dS/m^1, 3- OC (g/kg), 4- BD (Mg/m^3), 5- Available N (mg/kg), 6- Available P (mg/kg), 7- Available K (mg/kg), 8- Exchangeable Ca (C. mol./kg), 09- Exchangeable Mg (C. mol./kg), 10- Available S (mg/kg), 11- DTPA Extractable Fe (mg/kg), 12- DTPA Extractable Zn (mg/kg), 13- DTPA Extractable Cu (mg/kg), 14- DTPA Extractable Mn (mg/kg), 15- DTPA Extractable Mo (mg/kg), 16- DTPA Extractable Ni (mg/kg)

Table 8. DTPA extractable heavy metal in the soil after harvest of *A. paniculata* (after 2 years of experiments)

Treatments	Co (mg/kg)	As (mg/kg)	Se (mg/kg)	Cd (mg/kg)	Cr (mg/kg)	Pb (mg/kg)
T_1- Control	0.001^{a}	0.015^{b}	0.001^{c}	0.001^{b}	0.568^{b}	0.002^{a}
T_2- VC at 2.5 t/ha	0.001^{a}	0.016^{b}	0.001^{c}	0.001^{b}	0.677^{a}	0.004^{a}
T_3- VC at 5.0 t/ha	0.001^{a}	0.019^{b}	0.018^{b}	0.004^{a}	0.686^{a}	0.002^{a}
T_4- VC at 7.5 t/ha	0.001^{a}	0.090^{a}	0.001^{c}	0.001^{b}	0.254^{c}	0.009^{a}
T_5- VC at 10.0 t/ha	0.001^{a}	0.019^{b}	0.015^{b}	0.001^{b}	0.733^{a}	0.002^{a}
T_6- VC at 12.5 t/ha	0.001^{a}	0.015^{b}	0.015^{b}	0.001^{b}	0.132^{d}	0.004^{a}
T_7- VC at 15.0 t/ha	0.001^{a}	0.025^{b}	0.026^{a}	0.002^{b}	0.691^{a}	0.003^{a}
Initial	0.001^{a}	0.018	0.002	0.001	0.611	0.002^{a}

above 10 t/ha (17-22).

Nutrient and heavy metal content

N, P, K, Ca, Mg and Na content : Overall, N, P and Ca content increased due to the uptake of optimum nutrient availability by adding vermicompost doses in *A. paniculata*. K and Mg content was not affected by increased doses of vermicompost because K and Mg contents because the experimental soil was already rich in K and Mg (17-21). Na content in the experimental soil was already low and added vermicompost also had low content, so the Na content was not affected in *A. paniculata* with increased doses of vermicompost.

Micronutrients (Zn, Fe, Cu, Mn, Mo, Ni): The *A. paniculata* is a short-duration and low-nutrient-demanding crop. After decomposition and mineralization, a sufficient quantity of micronutrient was available in the plant root zone. The translocation of nutrients in different parts of the plant may affect the plants physico-chemical behaviour and environmental factors. Overall, adding vermicompost recorded an increasing trend for Fe and Ni content in *A. paniculata* due to the sufficient availability of micronutrients in the plant's root zone (23, 24). The Zn, Cu, Mn and Mo content were sufficiently available in the experimental soil, so their contents in the plant were not affected by an increase in doses of vermicompost.

Heavy metals (Cr, Se, As, Pb, Co, Cd): The Cr content increased in *A. paniculata* because Cr content was also higher in the added vermicompost (25). A decreasing trend was observed for Se content due to fixation and chelation with the vermicompost used. No trend was noted for As, Pb, Co and Cd with increased doses of vermicompost because the contents of these heavy metals were already low in soil and the added vermicompost in the experiment.

Bio-active compounds (diterpenoids) in the biomass of A. paniculata

Diterpenes are a class of chemical compounds composed of 2 terpene units. They may also be thought of as consisting of 4 isoprene units. Andrographolide and neo-andrographolide are labdane diterpenoids and wogonin is an O-methylated flavone compound isolated from *A. paniculata*. No trends were noted for secondary metabolite (andrographolide, neo-andrographolide and wogonine). Total secondary metabolites yield was increased due to increased biomass corresponding to the doses of vermicompost (17, 19-21, 26). The flavonoid and phenol content significantly increased with vermicompost application compared to control (27). The wogonin concentration was not affected in the biomass of the *A. paniculata* (28).

Physico-chemical properties of the soil

Decreased pH and bulk density is a positive indicator of soil physico-chemical properties. EC of the soil was already low and it was not affected by the application of vermicompost. The increase in organic carbon, N, P, K, Ca, Mg and S was recorded by the application of an increase in doses of vermicompost because after mineralization of added vermicompost increased nutrient concentration in soil (17, 21, 26, 29).

The micronutrients (Fe, Zn, Cu, Mn and Mo) also increased, corresponding to increased doses of vermicompost. However, Cu and Ni content was not affected, corresponding to the increase in doses of vermicompost due to their low content in added vermicompost. Heavy metal (Co, As, Se, Cd, Cr, Pb) was not affected, corresponding to an increase in doses of vermicompost because the heavy metal content in added vermicompost was very low.

Conclusion

The biomass is the main component of the *A. paniculata*. The result revealed that vermicompost was a suitable source for their organic cultivation. The optimum dose of the vermicompost was found to be 7.5-10.0 t/ha for obtaining the secondary metabolite yield of *A. paniculata*. The higher dose of vermicompost was not found suitable for increasing either biomass yield or secondary metabolites of *A. paniculata*.

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Authors' contributions

RKY and SS conducted field experiments and observations. P made observations. GGS did micronutrients, heavy metal and data analysis. LB made investigation of the experiments, conceptualization, drafting, nutrients and data analysis. All the authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

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