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Efficacy of vermicompost on seedling growth of *Solanum melongena* var. Mayalu and Arka Keshav

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Abstract

Production of healthy seedling is a must for successful plant production. This paper deals with the evaluation of the effects of five different vermicompost applied at four different concentrations on seed germination and seedling quality of *Solanum melongena* var. *arka keshav* and *mayalu* in laboratory and greenhouse conditions. The experiments were conducted in a complete randomized design with twenty treatments and control per variety. Germination %, seedling length, seedling biomass, and seed vigour index (SVI) were measured at the end of the experiment. Vermicompost application improved all the parameters in both environmental conditions except seed germination that decreased with increasing vermicompost concentration. Vermicompost sample V2 and control produced the highest seedling quality in var. *arka keshav* and *mayalu*, respectively. Vermicompost had an inhibitory effect on seedling quality at laboratory condition in both varieties. Conversely, in greenhouse condition, vermicompost sample V1 yielded highest SVI of 1340.15 in *arka keshav* and 1225.66 in *mayalu*. Highest vermicompost concentration yielded the best quality seedling with SVI of 1219.88 and 1153.56 in var. *arka keshav* and *mayalu*, respectively. This suggested an important role of vermicompost concentration in growing media for enhanced seedling quality. The findings also suggested that favourable pH for developing seedlings of *S. melongena* is slightly acidic. The study firmly concludes that vermicompost differentially affects seedling growth and quality according to the concentrations and seed variety.

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Introduction

Vermicompost is an organic fertilizer rich in macro- and micro- plant nutrients produced by biological processing of organic feed by earthworms. It is known to have several positive impacts in uplifting agricultural productivity through various ways like increasing soil stability (Doan *et al*., 2015; Aksaka *et al*., 2016) enhancing soil fertility (Ansari, 2008; Azarmi *et al*., 2008; Tejada *et al*., 2009; Ansari and Sukhraj, 2010; Karmakar *et al*., 2013), production of good quality seedlings, optimizing plant growth and control pathogens (Gopalakrishnan *et al*., 2011; Xiao *et al*., 2016). Vermicomposting has been gaining popularity in recent times in Nepal, owing to its sustainable approach towards organic waste management. The process utilizes organic wastes to produce vermicompost, which has been found to have several positive effects on crop production. Also, its minimal price compared to expensive chemical fertilizers and environment-friendly nature has made it an effective and efficient alternative to chemical fertilizers.

Vermicompost is found to have a positive effect on early as well as later stages of the plant life cycle. Manh *et al*. (2014) reported higher germination, plant height, leaf biomass and leaf area after application of vermicompost with rice hulls ash and coconut husk which is also supported by another finding which reported increased seedling emergence of petunias seeds grown in mixture of vermicompost (produced from cattle manure, food waste and paper waste) and MM360 compared to control (100% MM360) (Arancon *et al*., 2008). However, few research findings suggest careful application of vermicompost, due to the possible negative influence on seed germination and early seedling development. Vermicompost was found to inhibit germination and plant growth at the highest rate of vermicompost application (Ievinsh, 2011).

Production of healthy seedling at a suitable time is a must for successful plant production. This research aimed to determine the effect of vermicompost applied at different concentrations and seed variety on germination and seedling quality of *S. melongena* under laboratory and greenhouse conditions.

Materials and methods

Vermicompost and seed varieties

The experiment was conducted at Department of Biotechnology, Kathmandu University in 2017 using five different vermicomposts (Table 1) available in the Nepalese market and two most popular varieties of *S. melongena* var. *arka keshav* and *mayalu*.

pH, Electric Conductivity (EC) and Moisture of vermicompost

pH and EC were measured in 10 g of air-dried sample mixed with 20ml of Calcium Chloride and water respectively in a 50ml beaker which was stirred for 1-2 minutes (Gupta, 2009). The mixture was then allowed to set for 30 minutes and filtered with Whatman no. 1 filter paper. pH and EC probes were properly submerged in the filtrate to take the reading. The moisture content of the samples was determined by the gravimetric method. 40–50 g of a sample was weighed in a porcelain dish and placed in an oven at 105^{o}C for 24 hours (Gupta, 2009). Oven dried weight of samples was taken and moisture was calculated using the formula given below.

Gravimetric moisture (%) = ((wet weight-oven dried weight)/oven dried weight)) *100.

Seedling growth

Seedlings were grown in two conditions; laboratory and greenhouse conditions which are explained in detailed below.

Laboratory conditions

Preparation of vermicompost *extract*

Vermicompost extracts were used to germinate the seeds. They were prepared by mixing vermicompost with distilled water at 1:1 (weight /volume, w/v) ratio in capped bottles. These mixtures were kept in a mechanical shaker at high speed for 2 hours and left to stand for 24 hours. The supernatant filtered with Whatman no. 1 filter paper was used as 100% vermicompost extract and was further diluted with distil water to get 50%, 25% and 12.5% extracts (volume /volume, v/v).

Experimental setup

Seeds were soaked in respective extracts for 4 hours. Five vermicompost extracts diluted at four different ratios each and a control was used for each variety and 3 replications per treatment. 10 seeds per replication were placed on a petriplate lined with Whatman no. 1 filter paper spiked with 2 ml of extracts and left to germinate in dark at 23±2ºC. The number of seeds germinated per day was recorded until 10 days of the first germination. At the end of the experiment, Germination %, hypocotyl length, radicle length, Seedling vigourindex, wet and dry biomass was recorded. All set of experiments were repeated twice for obtaining consistency in data.

Greenhouse conditions

Preparation of seedling substrate mixture

Four treatment ratios of each vermicompost sample and a control were prepared by mixing vermicompost and cocopeat at different concentrations; Ratio 1- Vermicompost: Cocopeat, Ratio 2- Vermicompost: 2Cocopeat, Ratio 3- Vermicompost: 3Cocopeat, Ratio 4- Vermicompost: 4Cocopeat and Control- Cocopeat only.

Experimental setup

Seedlings were grown in a greenhouse under natural conditions in polystyrene plug trays containing 128 cells. Complete random block design with (2Vaietyr*5vermicompost*4 ratios) 40 treatments, one control for each variety and three replications per treatment were used for the experiment with 24 cells per replication and one seed per cell. Tap water was used for maintaining the moisture of the seedling.

No of seeds germinated were recorded for 10 days of the first germination to determine germination %. Shoot length, root length, leaf number, Seedling vigourindex, wet and dry shoot, and root biomass was measured at the end of the experiment, ninety days after sowing.

Statistical analysis

Data were analyzed statistically by two-way ANOVA using PASW Statistics 18. Duncan's Multiple Range Test was used to compare means of each parameter at $P \leq 0.05$. Each set of experiment was conducted twice. Data from sub-experiments were pooled for comparisons.

Results

Quality of vermicompost

Table 1 shows the physical quality of the vermicompost used in this study. pH, EC, and moisture of vermicompost samples were significantly different at $P<0.001$. pH of vermicompost samples ranged from 5.80 to 8.77. V1 and V2 were found to be acidic in nature while V3 and V4 and V5 were slightly basic. EC of samples ranged from 0.77 to 2.47 $mScm^{-1}$ with highest in V5 and lowest in V1. Moisture content in all samples ranged from 44.74% to 69.99% of V1 and V5 respectively. Nitrogen and Carbon content in vermicompost samples was significantly different at $P \leq 0.05$ and $P \leq 0.001$ respectively. But the C/N ratio was found to be similar in all vermicompost samples.

Table 1. Characteristics of VC samples used in this study.

Sample ID	Manufacturer	Earthworm species	Feeding materials (FM)	Moisture (%)	EC (mS/cm)	pH	Nitrogen (%)	Carbon (%)	C/N
V1	Birat Biotech	*Eiseniafetida*	Animal manure, Garden waste	44.74 ± 0.24^{e}	0.77 ± 0.13^{c}	5.80 ± 0.19^{e}	1.48 ± 0.04^{b}	15.48 ± 0.43^{c}	10.45±0.36
V2	Divya organic fertilizer company P.L	*E. fetida*	Animal manure	53.02 ± 0.34^{d}	0.75 ± 0.17^{c}	6.53 ± 0.13^{d}	1.24 ± 0.10^{b}	12.38 ± 0.54^{c}	10.07±0.61
V3	Praramva Biotech P L.	*E. fetida*	Animal manure, Agricultural waste	47.13 ± 0.34^{c}	1.80 ± 0.05^{b}	7.92 ± 0.03^{b}	2.12 ± 0.36^{ab}	15.27 ± 0.51^{c}	7.55±1.05
V4	DipakVermicomopst Mal Company P.L	*E. fetida*	Animal manure, Banana pseudostem,	60.49 ± 0.01^{b}	1.56 ± 0.03^{b}	7.38 ± 0.05^{c}	3.65 ± 0.98^{a}	19.20 ± 2.00^{b}	6.64±2.63

			Cloth waste, Water hyacinth, Oil seed cake						
V5	Central Horticulture Centre	*E. fetida*	Vegetable waste, cowdung, sawdust, rice husk, grass cutting	69.99±0.08^{a}	2.47±0.19^{a}	8.77±0.12^{a}	2.95±0.63^{ab}	25.20±1.34^{a}	9.86±3.11
Sig				***	***	***	*	***	NS

EC: Electrical conductivity, C/N: Carbon /Nitrogen.

Sig: Statistical significance. *, ***, NS indicate statistically significant differences at $P \leq 0.05$, $P \leq 0.001$ and not significant respectively. Data presented are means ± Standard Error from three independent measurements each. Values within same column with the same letter are not significantly different from each other (Duncan test).

Table 2. Effect of different VC sample extracts (Laboratory conditions) on length of hypocotyl and radicle of seedlings of *S. melongena* var. *arka keshav* and *mayalu.*

Sample[a]	Ratio[b]	Length of hypocotyl, cm[c]		Length of radicle, cm[c]	
		Ak[d]	Ma[d]	Ak[d]	Ma[d]
Control		2.66±0.09	3.29±0.17	2.28±0.11	3.24±0.98
V1	R1	2.90±0.15^{b}	3.20±0.22	2.34±0.79	2.08±0.90^{b}
	R2	3.54±0.11^{a}	3.83±0.21	2.09±0.79	2.62±0.88^{ab}
	R3	3.57±0.10^{a}	3.42±0.22	2.16±0.71	2.58±1.24^{ab}
	R4	3.25±0.11^{a}	3.09±0.19	2.07±0.89	3.10±3.21^{a}
V2	R1	3.05±0.15^{c}	3.56±0.24	1.76±0.69^{b}	1.98±0.89^{b}
	R2	3.56±0.14^{ab}	3.52±0.23	2.17±0.74^{a}	2.45±2.05^{ab}
	R3	3.75±0.10^{a}	3.02±0.24	2.40±0.56^{a}	2.44±1.18^{ab}
	R4	3.35±0.12^{bc}	2.94±0.20	2.22±0.59^{a}	2.71±1.20^{a}
V3	R1	1.50±0.09^{c}	1.42±0.12^{c}	0.57±0.49^{c}	0.68±0.54^{d}
	R2	2.45±0.10^{b}	2.29±0.14^{b}	1.46±0.80^{b}	1.68±0.71^{c}
	R3	2.81±0.11^{a}	2.81±0.19^{a}	1.96±0.75^{a}	2.35±1.04^{b}
	R4	3.08±0.14^{a}	2.98±0.20^{a}	1.96±0.78^{a}	2.69±1.15^{a}
V4	R1	2.22±0.10^{c}	3.09±0.16^{b}	2.05±1.08	2.29±0.72^{b}
	R2	2.99±0.17^{b}	4.06±0.24^{a}	1.93±0.79	2.47±1.01^{ab}
	R3	3.30±0.14^{ab}	3.79±0.22^{a}	2.01±0.62	2.21±0.89^{b}
	R4	3.55±0.13^{a}	3.54±0.23^{ab}	2.00±0.59	2.70±1.15^{a}
V5	R1	2.22±0.09^{c}	1.69±0.13^{c}	1.81±0.87^{c}	1.57±0.75^{c}
	R2	2.42±0.11^{c}	2.46±0.18^{b}	2.16±0.82^{b}	2.56±1.09^{b}
	R3	2.90±0.12^{b}	3.65±0.23^{ab}	2.58±0.79^{a}	2.72±1.07^{a}
	R4	3.42±0.12^{a}	3.44±0.19^{a}	2.49±0.80^{a}	3.04±1.30^{a}
Main Effects					
Sample	Control	2.66±0.70^{CD}	3.29±1.32^{A}	2.28±0.80^{A}	3.24±0.98^{A}
	V1	3.32±0.06^{A}	3.38±0.11^{A}	2.16±0.06^{AB}	2.59±0.12^{B}
	V2	3.42±0.07^{A}	3.27±0.12^{A}	2.14±0.05^{AB}	2.39±0.09^{B}
	V3	2.49±0.07^{D}	2.39±0.09^{C}	1.52±0.06^{C}	1.87±0.08^{C}
	V4	3.02±0.08^{B}	3.63±0.11^{A}	2.00±0.05^{B}	2.42±0.06^{B}
	V5	2.74±0.06^{C}	2.81±0.11^{B}	2.26±0.06^{A}	2.47±0.08^{B}
Ratio	Control	2.66±0.09^{C}	3.29±0.17^{A}	2.28±0.11^{A}	3.24±0.13^{A}
	R1	2.40±0.06^{D}	2.60±0.09^{B}	1.72±0.06^{C}	1.73±0.06^{D}
	R2	3.00±0.06^{B}	3.23±0.10^{A}	1.96±0.05^{B}	2.36±0.07^{C}
	R3	3.27±0.06^{A}	3.33±0.10^{A}	2.22±0.04^{A}	2.46±0.06^{C}
	R4	3.33±0.06^{A}	3.20±0.09^{A}	2.15±0.04^{A}	2.85±0.11^{B}
Sig.					
Sample		***	***	***	***
Ratio		***	***	***	***
Sample × Ratio		***	***	***	***

a: Abbreviations of sample names as in Table 1; b: Dilution of VC extracts (w/v); R1 = 100%; R2 = 50%; R3 = 25%; R4 = 12.5%; c: Data are means ± Standard Error from six independent measurements with 10 seedlings each.; d: Two varieties of *S. melongena* var. *arka keshav* (Ak) and *mayalu* (Ma)

Sig: Statistical significance. *** indicate statistically significant difference at $P \leq 0.001$. Values within same column with the same lower case letter are not significantly different from each other within a VC sample (Duncan test). Values within same column with the same uppercase letter are not significantly different from each other (Duncan test).

Phase 1: Laboratory experiment

Table 2, 3 and 4 show results of germination, seed vigourindex, length and biomass of seedlings of *S. melongena* var. *arka keshav* and *mayalu* in laboratory conditions at 25±5°C.

Table 3. Effect of different VC sample extracts (Laboratory conditions) on germination and Seedling vigour index of seedlings of *S. melongena* var. *arka keshav* and *mayalu*.

Sample[a]	Ratio[b]	Germination, %[c]		Seedling Vigour Index, SVI[c]	
		Ak[d]	Ma[d]	Ak[d]	Ma[d]
Control		86.67±5.58	98.33±1.67	443.33±16.66^{b}	638.59±34.88
V1	R1	93.33±2.11^{b}	93.33±3.33	457.67±15.53^{ab}	496.97±45.71
	R2	93.33±2.11^{b}	93.33±4.94	505.17±20.31^{a}	600..37±39.60
	R3	100.00±0.00^{a}	98.33±1.67	547.33±8.02^{ab}	588.57±69.63
	R4	100.00±0.00^{a}	98.33±1.67	501.00±18.36	618.90±60.52
V2	R1	90.00±4.47^{ab}	96.67±2.11	455.57±17.91	559.39±57.79
	R2	98.33±1.67^{a}	98.33±1.67	531.19±42.30	585.68±52.47
	R3	83.33±5.58^{b}	95.00±3.42	509.00±32.03	539.19±58.66
	R4	100.00±0.00^{a}	91.67±8.33	557.33±10.60	515.69±72.37
V3	R1	96.67±2.11	98.33±1.67	163.33±11.87^{d}	213.41±20.52^{c}
	R2	85.00±6.71	98.33±1.67	282.87±25.03^{c}	393.17±31.46^{b}
	R3	93.33±3.33	98.33±1.67	377.29±20.45^{b}	507.14±44.74^{ab}
	R4	100.00±0.00	98.33±1.67	447.00±24.98^{a}	563.17±65.17^{a}
V4	R1	88.33±1.67	96.67±3.33	320.57±12.51^{c}	515.8±15.14
	R2	91.67±1.67	95.00±3.42	374.91±20.76^{b}	617.86±49.94
	R3	93.33±2.11	98.33±1.67	413.67±15.34^{b}	591.09±20.79
	R4	93.33±2.11	96.67±2.11	49.00±13.88^{a}	604.67±39.64
V5	R1	86.67±4.22^{b}	98.33±1.67	280.33±12.23^{b}	328.35±29.55^{b}
	R2	83.33±7.60^{b}	100.00±0.00	357.67±31.20^{b}	502.95±52.33^{a}
	R3	88.33±3.07^{a}	96.67±3.33	477.95±36.40^{a}	616.40±56.07^{a}
	R4	88.33±4.77^{a}	96.67±3.33	488.00±35.24^{a}	626.50±74.49^{a}
Main Effects					
Sample	Control	86.67±5.58^{B}	98.33±1.67	443.33±16.66^{B}	638.59±34.88^{A}
	V1	96.67±0.98^{A}	95.83±1.58	502.79±10.06^{A}	576.20±27.52^{AB}
	V2	92.92±2.21^{AB}	95.42±2.25	513.27±15.41^{A}	549.99±28.84^{AB}
	V3	93.75±2.15^{A}	98.33±0.78	317.62±24.31^{D}	419.22±34.54^{C}
	V4	91.67±0.98^{AB}	96.67±1.30	400.49±15.12^{C}	582.27±18.04^{AB}
	V5	86.67±2.46^{B}	97.92±1.20	400.99±22.93^{C}	518.55±35.99^{B}
Ratio	Control	86.67±5.58^{B}	98.33±1.67	443.33±16.66^{BC}	638.59±34.88^{A}
	R1	91.00±1.47^{AB}	96.67±1.11	335.50±21.54^{D}	157.75±28.80^{C}
	R2	90.33±2.22^{AB}	97.00±1.28	410.36±21.18^{C}	540.01±24.56^{B}
	R3	91.67±1.73^{AB}	97.33±1.06	465.05±15.44^{AB}	568.48±23.07^{AB}
	R4	96.33±1.31^{A}	96.33±1.82	497.47±11.38^{A}	585.78±27.53^{AB}
Sig.					
Sample		**	Ns	***	***
Ratio		*	Ns	***	***
Sample × Ratio		Ns	Ns	***	*

a:Abbreviations of sample names as in Table 1.; b: Dilution of VC extracts (w/v); R1 = 100%; R2 = 50%; R3 = 25%; R4 = 12.5%; c: Data are means ± Standard Error from six independent measurements with 10 seedlings each. d: Two varieties of *S. melongena* var. *arka keshav* (Ak) and *mayalu* (Ma)

Sig: Statistical significance. Ns, *, **, *** indicate not significant, statistically significant differences at P ≤ 0.05, P ≤ 0.01, P ≤ 0.001, respectively. Values within same variety with the same letter are not significantly different from each other (Duncan test). Values within same column with the same uppercase letter are not significantly different from each other (Duncan test).

Table 4. Effect of different VC sample extracts (Laboratory conditions) on wet and dry biomass of seedlings of *S. melongena* var. *arka keshav* and *mayalu.*

Sample[a]	Ratio[b]	Wet biomass, mg[c]		Dry biomass, mg[c]	
		Ak[d]	Ma[d]	Ak[d]	Ma[d]
Control		18.04±0.70	22.98±1.04	1.09±0.04	1.51±0.09
V1	R1	19.24±1.30	24.40±1.30	1.31±0.03[a]	1.82±0.19
	R2	22.56±0.84	29.46±0.93	1.23±0.05[ab]	1.63±0.13
	R3	23.73±0.76	26.20±2.40	1.15±0.02[b]	1.67±0.17
	R4	18.30±3.31	24.14±1.89	1.16±0.04[b]	1.67±0.16
V2	R1	20.34±0.53	28.43±2.97	1.23±0.05	1.72±0.17
	R2	23.62±1.65	23.88±2.49	1.21±0.09	1.58±0.12
	R3	23.40±0.78	26.38±2.35	1.12±0.03	1.76±0.21
	R4	21.45±1.06	24.92±2.12	1.07±0.06	1.62±0.19
V3	R1	9.34±1.92	12.68±0.89[c]	0.96±0.07	1.46±0.14
	R2	10.05±3.91	17.73±1.47[bc]	1.05±0.07	1.70±0.21
	R3	17.74±1.24	22.77±2.21[ab]	1.10±0.03	1.71±0.20
	R4	16.85±3.25	25.32±3.00[a]	1.12±0.04	1.73±0.26
V4	R1	14.41±0.98[b]	25.09±1.36[b]	1.18±0.03	1.51±0.10
	R2	20.79±2.75[a]	33.81±3.13[a]	1.18±0.05	1.79±0.19
	R3	23.11±2.45[a]	28.63±1.86[ab]	1.16±0.04	1.52±0.11
	R4	23.55±0.34[a]	27.81±1.35[ab]	1.18±0.03	1.71±0.15
V5	R1	14.05±0.83[b]	13.66±1.16[c]	1.05±0.04	1.84±0.22
	R2	15.71±1.12[b]	19.30±1.79[b]	1.12±0.04	1.59±0.08
	R3	18.97±0.94[a]	28.42±2.19[a]	1.12±0.06	1.63±0.10
	R4	20.90±0.57[a]	27.36±1.85[a]	1.05±0.03	1.70±0.20
Main Effects					
Sample	Control	18.04±0.70[BC]	22.98±1.04[BC]	1.09±0.04[BC]	1.51±0.09
	V1	20.96±0.99[AB]	26.05±0.92[AB]	1.21±0.02[A]	1.70±0.08
	V2	22.20±0.58[A]	27.15±1.21[A]	1.16±0.03[AB]	1.67±0.08
	V3	13.50±1.52[D]	19.63±1.39[C]	1.05±0.03[C]	1.65±0.10
	V4	20.46±1.17[ABC]	28.83±1.16[A]	1.18±0.02[AB]	1.63±0.07
	V5	17.41±0.70[C]	22.18±1.51[C]	1.09±0.02[BC]	1.69±0.08
Ratio	Control	18.04±0.70[BC]	22.98±1.04[AB]	1.09±0.04	1.51±0.09
	R1	15.48±0.89[C]	20.85±1.39[B]	1.14±0.03	1.67±0.08
	R2	18.54±1.35[ABC]	25.84±1.45[A]	1.16±0.03	1.66±0.06
	R3	21.39±0.74[A]	26.48±1.00[A]	1.13±0.02	1.66±0.07
	R4	20.21±0.99[AB]	25.91±0.92[A]	1.12±0.02	1.69±0.08
Sig.					
Sample		***	***	***	Ns
Ratio		***	***	Ns	Ns
Sample × Ratio		Ns	***	Ns	Ns

a: Abbreviations of sample names as in Table 1.; b: Dilution of VC extracts (w/v); R1 = 100%; R2 = 50%; R3 = 25%; R4 = 12.5%c: Data are means ± Standard Error from six independent measurements with 10 seedlings each. d: Two varieties of *S. melongena* var. *arka keshav* (Ak) and *mayalu* (Ma)

Sig: Statistical significance. Ns, *** indicate not significant, statistically significant differences at P ≤ 0.001, respectively. Values within same variety with the same letter are not significantly different from each other (Duncan test). Values within same column with the same uppercase letter are not significantly different from each other (Duncan test).

Seed germination

Seed germination percentage between varieties was found to be significantly different but no significant difference was found within treatments of var. *mayalu*. In var. *arka keshav*, highest germination was seen in V1 (96.67%) and R4 (96.33%) whereas lowest in V4 (91.67%) and control (86.67%) (Table 3). Highest seed germination was seen in the lowest treatment ratios of vermicompost extracts but it differed with vermicompost types used. Nevertheless, in var. *mayalu*, seedling germination percentage was found to be similar to control, regardless of different vermicompost extracts used.

Seedling length

Differences between the means of hypocotyl and radicle lengths of seedlings of both varieties were highly significant due to both vermicompost type and treatment ratios (Table 2). In var. *arka keshav*, the maximum value for the length of hypocotyl was at V2R3 (3.75 cm) which was 1.5 and 2.5 times greater than control (2.66 cm) and the minimum value at V3R1 (1.50 cm) respectively (Fig.1a). But in var. *mayalu*, maximum and minimum values were observed at V4R2 (4.06 cm) and V3R1 (1.42 cm) respectively and all of the ratios of V3 yield seedlings with smaller hypocotyl length than control (3.29 cm) (Fig. 1b). Maximum hypocotyl growth was seen in treatments with lower ratios of vermicompost extracts in both varieties.

Table 5. Effect of different VC (Greenhouse conditions) on germination and Seedling vigour index of seedlings of *S. melongena* var. *arka keshav* and *mayalu*.

Sample[a]	Ratio[b]	Germination, %[c]		Seedling Vigour Index, SVI[c]	
		Ak[d]	Ma[d]	Ak[d]	Ma[d]
Control		94.79±1.99	91.67±5.89	959.93±46.28	970.58±127.10
V1	R1	93.75±0.93	86.81±4.41	1436.85±169.84	1172.46±62.91
	R2	95.14±1.99	93.75±2.43	1369.34±98.64	1310.47±57.56
	R3	92.71±1.04	92.61±5.31	1329.65±136.12	1318.35±171.50
	R4	93.75±1.78	87.78±3.02	1221.26±113.69	1101.35±100.34
V2	R1	92.50±3.33	91.11±4.63	1364.30±173.80	1279.50±114.62
	R2	90.56±2.22	91.25±3.99	1195.42±116.07	1161.87±137.35
	R3	90.83±3.33	94.39±1.95	1165.99±159.79	1203.14±97.69
	R4	94.17±1.02	95.58±2.27	1161.65±79.72	1108.93±70.67
V3	R1	83.33±1.52	96.50±1.59[a]	1080.33±120.76	1222.89±102.56
	R2	97.50±4.68	93.67±2.07[a]	1208.21±128.54	1039.63±50.55
	R3	88.54±3.13	83.47±4.71[b]	1122.37±91.56	963.32±72.10
	R4	83.33±5.10	96.80±2.33[a]	929.65±75.93	1160.13±130.48
V4	R1	87.50±3.23	95.14±3.47	1098.78±124.76	1157.62±91.84
	R2	88.33±3.82	93.95±3.23	1112.85±66.02	1141.64±92.09
	R3	79.86±4.74	97.28±1.72	924.08±113.84	1142.15±85.61
	R4	86.67±4.25	90.58±5.82	1041.57±106.89	1106.07±96.03
V5	R1	93.75±2.69	85.92±4.92	1104.90±67.77	946.88±121.98
	R2	93.06±3.34	87.67±5.67	941.76±80.21	1089.94±147.65
	R3	90.00±2.12	93.75±2.43	937.51±47.16	1037.05±101.92
	R4	79.86±3.30	94.75±2.10	813.55±75.33	1137.84±53.49
Main Effects					
Sample	Control	94.79±1.99[A]	91.67±5.89	959.93±46.28[C]	970.58±127.10
	V1	93.94±0.76[AB]	90.24±1.95	1340.15±67.36[A]	1225.66±53.95
	V2	91.94±1.25[AB]	93.08±1.64	1220.58±65.20[AB]	1188.36±51.95
	V3	87.92±2.20[BC]	92.24±1.87	1083.04±55.87[BC]	1087.85±46.71
	V4	85.42±2.03[C]	94.24±1.87	1041.33±53.03[BC]	1136.87±42.83
	V5	88.69±1.91[ABC]	90.64±2.00	935.19±39.85[C]	1051.32±52.58
Ratio	Control	94.79±1.99[A]	91.67±5.89	959.93±46.28	970.58±127.10
	R1	89.81±1.30[AB]	90.91±1.88	1219.88±66.17	1153.56±47.09
	R2	92.92±1.46[AB]	92.21±1.53	1165.87±49.93	1150.74±45.48
	R3	87.85±1.74[B]	92.30±1.71	1077..92±57.23	1132.80±51.64
	R4	87.50±1.78[B]	92.97±1.58	1032.34±49.73	1121.58±37.94
Sig.					
Sample		*	Ns	***	Ns
Ratio		*	Ns	Ns	Ns
Sample × Ratio		*	Ns	Ns	Ns

a: Abbreviations of sample names as in Table 1.; b: VC and cocopeat ratio (w/w); R1 = 1:1, R2 = 1:2, R3 = 1:3; R4 = 1:4; c: Data are means ± Standard Error from six independent measurements with 10 seedlings each.; d: Two varieties of *S. melongena*; Ak: *arka keshav* and Ma: *mayalu*

Sig: Statistical significance. Ns, *, *** indicate not significant, statistically significant differences at P ≤ 0.05, P ≤ 0.001, respectively. Values within same variety with the same letter are not significantly different from each other (Duncan test).

Radicle length of seedling in var. *arka keshav* was found maximum in V5R3 (2.58 cm) and minimum at V3R1 (0.57 cm) but in var. *mayalu*, control (3.24 cm) treatment yielded the longest radicle than all the treatments except V5R4 (3.04 cm) and V1R4 (3.10 cm) (Table 2). Similar to hypocotyl length, V3 produced seedlings with minimum radicle length and radicle length increased significantly with decreasing ratio of treatment.

Table 6. Effect of different VC (Greenhouse conditions) on length of hypocotyl and radicle of seedlings of *S. melongena* var. *arka keshav* and *mayalu*.

Sample[a]	Ratio[b]	Length of hypocotyl, cm[c]		Length of radicle, cm[c]		Leaf No	
		Ak[d]	Ma[d]	Ak[d]	Ma[d]	Ak[d]	Ma[d]
Control		2.35±0.10	1.45±0.06	7.77±0.35	3.61±0.50	2.34±0.11	1.83±0.10
V1	R1	6.93±0.37^{a}	4.40±0.30^{a}	8.32±0.24	7.09±0.35	4.66±0.10^{a}	4.53±0.11^{a}
	R2	6.17±0.30^{a}	3.31±0.16^{b}	8.38±0.23	7.86±0.54	4.69±0.10^{a}	4.17±0.09^{b}
	R3	6.02±0.34^{a}	3.01±0.24^{b}	8.32±0.24	6.48±0.40	4.45±0.10^{a}	3.77±0.08^{c}
	R4	4.78±0.22^{b}	2.88±0.16^{b}	8.24±0.23	6.15±0.36	3.72±0.10^{b}	3.75±0.10^{c}
V2	R1	7.05±0.48^{a}	5.07±0.37^{a}	7.70±0.19	7.12±0.29	4.72±0.14^{a}	4.52±0.14^{a}
	R2	5.42±0.31^{b}	3.99±0.24^{b}	7.79±0.21	6.23±0.24	4.44±0.09^{a}	4.36±0.15^{a}
	R3	5.35±0.34^{bc}	3.50±0.20^{b}	7.78±0.27	6.54±0.33	4.09±0.14^{b}	3.98±0.11^{b}
	R4	4.38±0.23^{d}	2.72±0.11^{c}	7.93±0.24	5.96±0.33	4.06±0.12^{b}	3.61±0.10^{c}
V3	R1	5.68±0.39^{a}	4.30±0.29^{a}	7.46±0.16	6.17±0.26	4.29±0.14^{a}	4.35±0.12^{a}
	R2	5.08±0.28^{a}	2.98±0.14^{b}	7.31±0.19	6.10±0.33	4.16±0.11^{a}	3.74±0.11^{bc}
	R3	5.08±0.33^{a}	2.72±0.12^{b}	7.74±0.24	6.18±0.34	3.97±0.14^{a}	3.83±0.08^{c}
	R4	3.89±0.22^{b}	2.50±0.11^{b}	7.40±0.27	5.23±0.29	3.56±0.11^{b}	3.50±0.10^{c}
V4	R1	5.24±0.27^{a}	3.72±0.19^{a}	7.17±0.26	6.45±0.27	4.34±0.11^{a}	4.31±0.08^{a}
	R2	5.32±0.23^{a}	3.28±0.14^{b}	7.28±0.21	6.27±0.31	4.18±0.10^{a}	3.72±0.10^{b}
	R3	4.18±0.21^{b}	2.82±0.11^{c}	7.44±0.25	5.92±0.34	3.72±0.14^{b}	3.66±0.10^{b}
	R4	4.52±0.20^{b}	2.76±0.11^{c}	7.49±0.20	6.14±0.46	3.58±0.11^{b}	3.49±0.08^{b}
V5	R1	3.52±0.11^{a}	1.96±0.06^{c}	8.13±0.31^{a}	5.33±0.53	2.97±0.12^{a}	2.31±0.12^{b}
	R2	3.17±0.11^{b}	2.47±0.10^{a}	7.00±0.27^{b}	5.27±0.52	2.96±0.11^{a}	2.85±0.12^{a}
	R3	2.95±0.09^{bc}	2.16±0.08^{b}	7.49±0.27^{ab}	5.31±0.37	2.44±0.09^{b}	2.66±0.09^{a}
	R4	2.76±0.11^{c}	1.93±0.07^{c}	7.37±0.22^{ab}	5.74±0.59	2.34±0.11^{b}	2.26±0.09^{b}
Main Effects							
Sample	Control	2.35±0.10^{D}	1.45±0.06^{D}	7.77±0.35^{B}	9.01±0.51^{B}	2.34±0.11^{D}	1.83±0.10^{D}
	V1	5.97±0.17^{A}	3.41±0.12^{B}	8.31±0.12^{A}	9.90±0.19^{A}	4.37±0.06^{A}	4.06±0.05^{A}
	V2	5.54±0.19^{A}	3.82±0.14^{A}	7.80±0.11^{B}	9.02±0.16^{B}	4.34±0.06^{A}	4.12±0.07^{A}
	V3	4.96±0.16^{B}	3.11±0.10^{B}	7..46±0.11^{B}	8.70±0.18^{B}	4.01±0.07^{B}	3.85±0.06^{B}
	V4	4.81±0.12^{B}	3.16±0.07^{B}	7.34±0.12^{B}	8.89±0.18^{B}	3.97±0.06^{B}	3.80±0.05^{C}
	V5	3.06±0.06^{C}	2.12±0.04^{C}	7.73±0.14^{B}	9.45±0.24^{A}	2.66±0.06^{C}	2.51±0.05^{C}
Ratio	Control	2.35±0.10^{D}	1.45±0.06	7.77±0.35	9.01±0.51^{B}	2.34±0.11^{D}	1.83±0.10^{E}
	R1	5.83±0.18^{A}	3.93±0.13	7.73±0.11	8.87±0.16^{BC}	4.29±0.06^{A}	4.04±0.07^{A}
	R2	5.03±0.13^{B}	3.24±0.08	7.57±0.10	9.23±0.17^{B}	4.09±0.06^{A}	3.81±0.06^{B}
	R3	4.62±0.14^{B}	2.84±0.08	7.72±0.12	9.13±0.17^{B}	3.69±0.07^{B}	3.58±0.05^{C}
	R4	4.05±0.10^{C}	2.57±0.05	7.70±0.11	9.55±0.18^{AB}	3.42±0.06^{C}	3.33±0.05^{D}
Sig.							
Sample		***	***	***	***	***	***
Ratio		***	***	Ns	*	***	***
Sample × Ratio		*	***	Ns	Ns	Ns	***

a: Abbreviations of sample names as in Table 1.; b: VC and cocopeat ratio (w/w); R1 = 1:1, R2 = 1:2, R3 = 1:3; R4 = 1:4; c: Data are means ± Standard Error from six independent measurements with 10 seedlings each.; d: Two varieties of *S. melongena*; Ak: *arka keshav* and Ma: *mayalu*.

Sig: Statistical significance. Ns, *, *** indicate not significant, statistically significant differences at P ≤ 0.05, P ≤ 0.001, respectively. Values within same variety with the same letter are not significantly different from each other (Duncan test).

Seedling vigour *index (SVI)*

A highly significant difference was observed between the means of SVI according to variety, treatment, and ratio (Table 3). Highest SVI in var. *arka keshav* was at V2R4 (557.33) and lowest at V3R1 (163.33) whereas in var. *mayalu* they were at Control (638.59) and V3R1 (213.41) respectively. In both varieties, SVI values were highest at lower ratios except in var. *mayalu*- Treatment V2, where the lowest value was observed at the lowest ratio. In var. *arka keshav*, all higher ratios of each treatment had SVI smaller than Control and it increased with decreasing ratio but in var. *mayalu* all of the treatments yielded SVI lower than Control.

Table 7. Effect of different VC (Greenhouse conditions) on wet and dry biomass of seedlings of *S. melongena* var. *arka keshav* and *mayalu*.

Sample[a]	Ratio[b]	Shoot wet wt, mg[c]		Shoot dry wt, mg[c]	
		Ak[d]	Ma[d]	Ak[d]	Ma[d]
Control		65.80±21.20	5.85±1.87	10.25±4.10	1.18±0.23
V1	R1	933.65±413.19	131.29±31.23[a]	23.22±8.83	22.24±6.01
	R2	673.32±264.59	86.27±15.98[ab]	73.17±37.12	17.04±3.13
	R3	844.07±292.60	56.33±10.97[b]	75.31±47.56	10.68±2.23
	R4	342.27±165.42	56.34±10.89[b]	34.66±19.7	11.04±2.07
V2	R1	1216.69±476.27	156.74±44.21	93.79±50.62	22.45±5.95
	R2	640.83±268.60	108.85±25.38	22.76±7.24	16.69±3.67
	R3	445.85±198.15	87.15±19.96	51.17±29.62	14.00±3.01
	R4	318.87±133.38	56.67±4.87	85.17±52.13	10.38±1.25
V3	R1	628.79±324.19	138.62±39.29[a]	73.48±38.29	17.73±4.87
	R2	448.82±211.62	69.18±12.82[b]	86.37±32.94	10.61±2.01
	R3	533.43±179.68	58.45±9.81[b]	107.47±58.27	9.78±1.92
	R4	266.18±116.58	45.41±9.53[b]	52.14±21.68	7.79±1.74
V4	R1	721.71±303..55	107.25±24.13[a]	95.64±39.84	17.11±3.98
	R2	487.60±248.67	65.72±15.86[ab]	45.65±27.50	11.28±2.60
	R3	320.09±134.66	47.36±9.10b	16.22±5.71	9.71±1.32
	R4	396.97±159.42	48.39±8.82b	31.19±13.97	9.21±1.59
V5	R1	121.38±45.13	12.12±1.75	14.10±5.03	2.19±0.37
	R2	109.75±51.75	30.03±6.19	24.75±11.77	5.15±1.31
	R3	122.97±46.95	24.08±4.99	5.20±1.46	4.12±0.83
	R4	121.67±59.82	14.81±2.91	5.25±1.94	2.65±0.38
Main Effects					
Sample	Control	65.80±21.20[B]	5.85±1.87[B]	10.25±4.10[B]	1.18±0.23[B]
	V1	685.08±148.94[A]	82.56±10.99[A]	49.43±14.26[AB]	15.25±2.00[A]
	V2	654.86±155.87[A]	102.35±14.90[A]	61.29±18.41[AB]	15.88±2.02[A]
	V3	474.08±115.68[AB]	76.63±12.04[A]	78.17±18.00[A]	11.36±1.51[A]
	V4	485.17±110.01[AB]	67.18±8.92[A]	47.97±13.86[AB]	11.83±1.37[A]
	V5	118.52±24.73[B]	19.84±2.78[B]	12.50±3.81[B]	3.46±0.43[B]
Ratio	Control	65.80±21.20[B]	5.85±1.87[C]	10.25±4.10	1.18±0.23[C]
	R1	750.89±162.62[A]	108.19±16.22[A]	62.20±15.85	46.29±2.42[A]
	R2	472.34±100.81[AB]	73.46±8.56[AB]	49.44±11.62	42.40±1.40[AB]
	R3	428.11±85.78[AB]	54.67±6.26[B]	46.26±14.67	9.66±1.02[B]
	R4	284.95±57.41[AB]	44.28±4.41[B]	40.07±11.83	8.23±0.85[B]
Sig.					
Sample		*	***	*	***
Ratio		*	***	Ns	***
Sample × Ratio		Ns	*	Ns	Ns

a: Abbreviations of sample names as in Table 1.; b: VC and cocopeat ratio (w/w); R1 = 1:1, R2 = 1:2, R3 = 1:3; R4 = 1:4; c: Data are means ± Standard Error from six independent measurements with 10 seedlings each.; d: Two varieties of *S. melongena*; Ak: *arka keshav* and Ma: *mayalu*.

Sig: Statistical significance. Ns, *, *** indicate not significant, statistically significant differences at P ≤ 0.05, P ≤ 0.001, respectively. Values within same variety with the same letter are not significantly different from each other (Duncan test).

Seedling biomass

Wet and dry biomass was significantly different according to variety type but only wet biomass varied due to the application of various treatments and ratios (Table 4). In var. *arka keshav*, maximum wet and dry biomass were observed in V2R2 (23.62 h) and V1R1 (1.31 g) respectively whereas, both were minimum in V3R1. Similarly, in var. *mayalu*, maximum wet and dry biomass was observed in V1R2 (29.46 g) and V5R1 (1.84 g) whereas both parameters were minimum at V3R1. In general, maximum wet biomass was observed in V2 and R3 in var. *arka keshav* and V1 and R2 in var. *mayalu*. Minimum wet biomass in both varieties was shown by V3 and R1. Conversely, maximum dry biomass was observed in V1 and R2 and V1 and R4 in var. *arka keshav* and var. *mayalu* respectively. Minimum dry biomass in both varieties was shown by control.

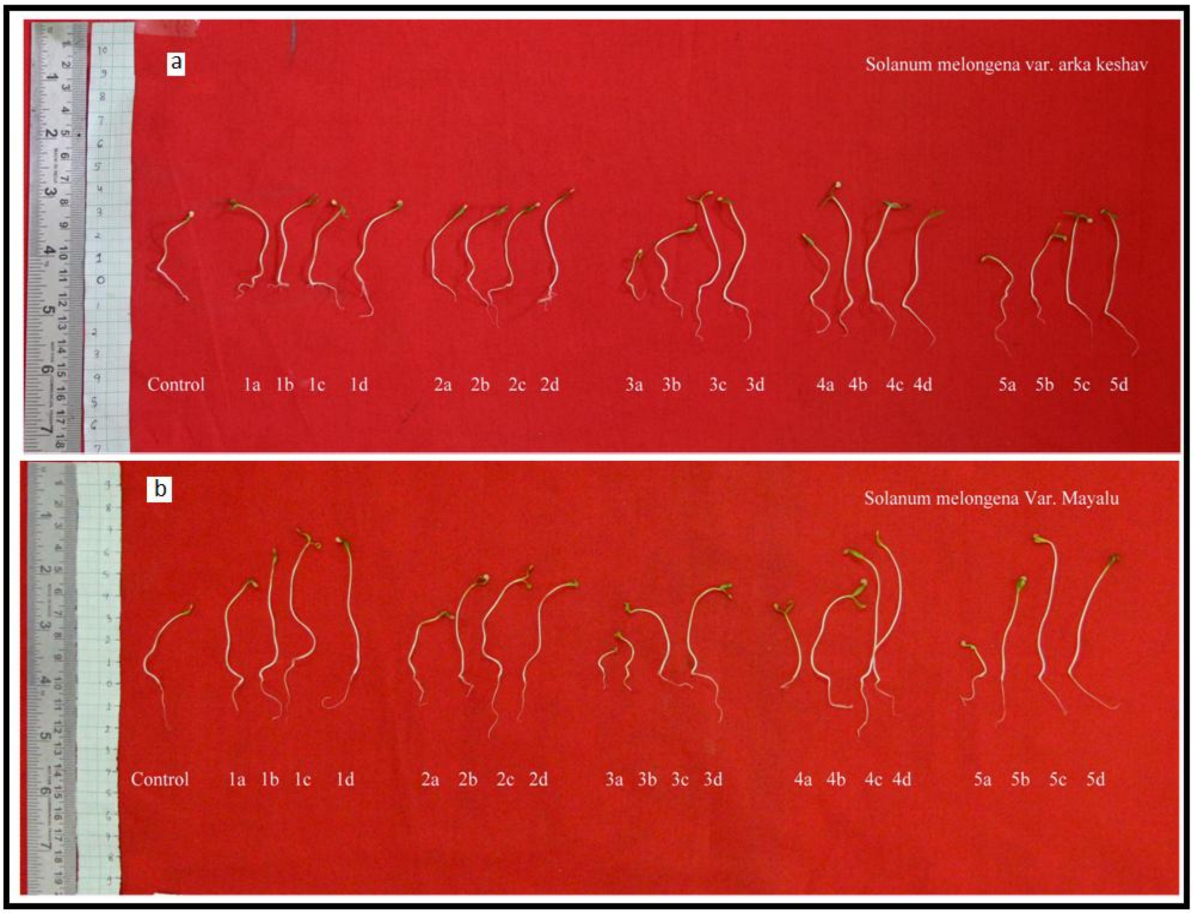

Fig. 1. Representative seedlings grown in VC extract at different dilutions in laboratory after 10 days of first germination. Vermicompost samples: 1 – V1, 2 – V2, 3 – V3, 4- V4, 5 - V5. Ratios: a - 100%, b - 50%, c - 25% and d - 12.5% of var. *arka keshav* (a) and *mayalu* (b).

Phase 2: Greenhouse condition

Table 5, 6, 7 and 8 show results of germination, SVI, length, and biomass of seedlings of *S. melongena* var. *arka keshav* and *mayalu* in greenhouse condition. All the parameters were significantly different between varieties except Seedling vigourindex. Differential patterns were observed on all parameters with regards to using different vermicomposts and their ratios.

Seed germination

Comparing the means between treatment and vermicompost application ratio, highest germination was found in Control (94.79%) whereas lowest in V4 (85.42%) and R4 (87.50%) in var. *arka keshav* (Table 5).

However, in var. *mayalu*, seedling germination percentage was similar in all treatments ($P \leq 0.05$).

Seedling length

All parameters were found to be significantly higher compared to control except for germination percentage and length of radicle in both varieties. Differences between the means of hypocotyl and radicle lengths of seedlings of both varieties were highly significant due to both vermicompost type and treatment ratios except radicle lengths of seedlings in var. *mayalu* (Table 6). Hypocotyl length in var. *arka keshav* was highest in V1 (5.97 cm) and R1 (5.83 cm) whereas, in var. *mayalu*, V2 (3.82 cm) produced larger hypocotyls (Fig. 2a and 3b). Both varieties produced significantly largest hypocotyls in R1 compared to other ratios. A similar result was observed in the number of leaves in both varieties which are shown in Table 6.

Fig. 2. Seedling of *S. melangona* var. *arka keshav* after 45 days of sowing in GH in VC samples: a: V1, b: V2, c: V3, d: V4 and e: V5. R1, R2, R3 and R4 represent different concentrations of VC application i.e. 1:1, 1:2, 1:3 and 1:4 respectively.

Seedling vigour index (SVI)

Maximum SVI was observed in V1 and R1 in both varieties whereas minimum in control. In both varieties, SVI values increased with increasing ratio of vermicompost substitution, indicating its positive effect on the quality of seedling produced due to vermicompost application.

Seedling biomass

Shoot wet and dry biomass of seedlings were significantly similar in all vermicompost expect V5 which produced minimum weights in both varieties whereas R1 produced seedlings maximum shoot wet and dry wet with control producing minimum weights for all treatments (Table 7). Similarly, results were observed in root wet and dry biomass.

Discussion

All the parameters (Germination %, SVI, Wet biomass, Dry biomass, Hypocotyl length, and radicle length) were significantly different according to varieties of plants used showing the significance of plant variety in seedling growth. Ievnish (2011) and Zallar (2007) also reported that the germination response of seeds of various crops is significantly different (Zaller, 2007a; Ievinsh, 2011).

Most importantly, the two varieties of plant responded similarly to different concentrations of vermicompost extracts; the negative effect was observed on seedling growth with treatments applied at higher concentrations in laboratory condition.

Conversely, in the greenhouse experiment highest vermicompost substitution produced best quality seedlings. These discrepancies in seedling growth may be due to the use of vermicompost of different origins which are known to have different qualities (Loh*et al.*, 2005; Ferreras *et al.*, 2006).

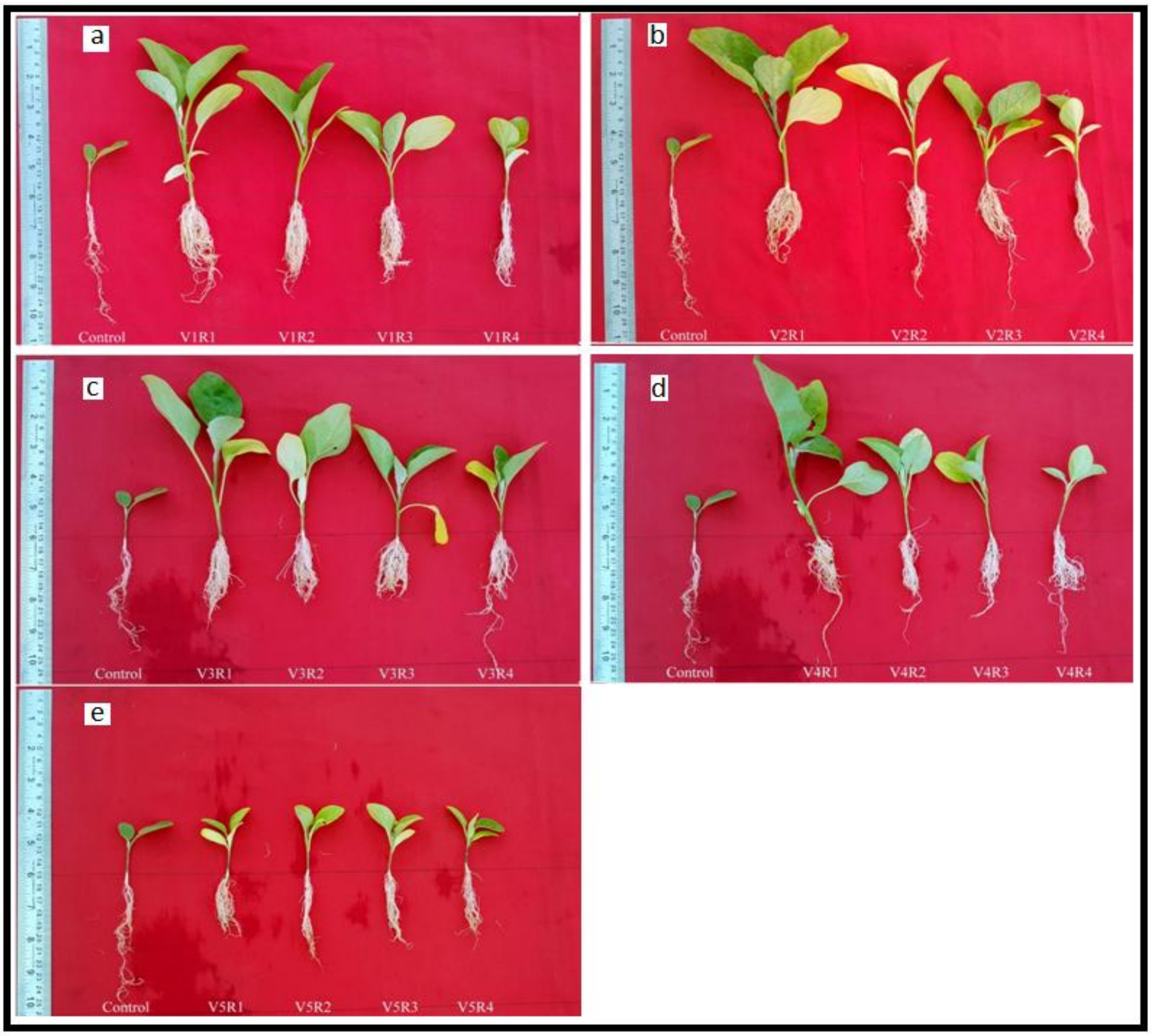

Fig. 3. Seedling of *S. melangona* var. *mayalu* after 45 days of sowing in GH in VC samples: a: V1, b: V2, c: V3, d: V4 and e: V5. R1, R2, R3 and R4 represent different concentrations of VC application i.e. 1:1, 1:2, 1:3 and 1:4 respectively.

Seed germination

In laboratory condition var. *arka keshav* produced a higher number of germinated seeds in the most diluted extract. Similarly, in greenhouse conditions too higher number of seeds germinated in control and decreased with vermicompost application. But no significant differences were observed in germination % due to the application of different treatments in var. *mayalu* in both conditions. This is due to the presence of phytotoxic substances in higher concentrations of vermicompost and vermicompost extracts (Warman and Anglopez, 2010) which hindered germination of seeds; also vermicompost has a differential effect on different varieties of plant. In opposition, other researchers have shown a stimulatory effect on the number of seeds germinated with increasing vermicompost concentration (Zaller, 2007b). Zaller (2007) conducted an experiment where vermicompost at 0, 20, 40, 60, 80 and 100%proportion with commercial peat substrate was used to grow three varieties of tomato varieties. It was reported that the highest vermicompost concentration produced the highest seed germination % in two of the varieties while lowest in one of the variety.

Seedling length

Hypocotyl length of seedlings of var. *arka keshav* in all vermicompost extract concentrations except R1 is significantly higher than control which is also presented by other researchers where the application of organic fertilizers have increased the shoot length compared to control (Alam *et al.*, 2014). Also, similar hypocotyl lengths were produced by all ratios except R1, shortest length, in var. *mayalu* which is in conformity with other researches (Ievinsh, 2011). Contrariwise, shoot length (in greenhouse conditions) of seedlings increased with increasing vermicompost substitution in each vermicompost sample (Fig. 2 and 3).

It has been reported that root growth is enhanced by a nutrient deficiency (Ericsson, 1995; Wutthida and Karel, 2015) which is also observed in the present research. In laboratory conditions, control of both varieties produced the longest radicle of seedlings. Similar patterns were seen in greenhouse grown seedlings in which root length increased with decreasing vermicompost substitution. This is because, during nutrient deficiency, roots try to grow longer in search of nutrients(Fageria and Moreira, 2011). This suggests that the length of a seedling is differentially affected by vermicompost in different stages of plant development. Precisely, vermicompost is favorable for later stages of plant development than initial germination period.

Seedling vigour index (SVI)

Alam *et al.* (2014) reported increment in SVI with vermicompost application which was similar to this study where only two vermicompost sample in var. *arka keshav* and none in var. *mayalu* yielded higher SVI values than control (Alam *et al.*, 2014) in the laboratory. SVI of seedlings of var *arka keshav* at laboratory condition according to vermicompost samples and ratio are as follows V1, V2>C>V4, V5>V3 and R4>R3>C>R2>R1. However, in greenhouse conditions, the highest ratio of vermicompost substitution yielded highest SVI in both varieties and different vermicompost samples produced different SVI in var *arka keshav* which is as follows V1>V2>V3, V4>V5, C. This can be directly related to the pH of vermicompost samples. pH of V1, V2, and V3 is slightly acidic in nature however that of V4 and V5 are basic suggesting that growing media with lower pH is favorable for eggplant seedling production.

Seedling biomass

In laboratory condition, seedlings grown in the higher concentration of vermicompost extracts produced higher wet biomass compared to control except V3 and V5. These vermicompost samples yielded shorter seedlings which further decreased their biomass. Similar results in the greenhouse experiment were observed where an increasing concentration of vermicompost increased seedling biomass. This clear relation between the vermicompost concentrations in eggplant growing substrate entails that nutrient content in vermicompost directly affects overall plant growth.

Conclusion

The improved seedling quality due to vermicompost application in this study shows that vermicompost enhances early development of plants however; it may vary according to its origin. Irrespective to environmental conditions for seed germination, the results suggested that vermicompost hinders seed germination but improves seedling quality. Also, the concentration of vermicompost in growing media plays an important role in improving seedling quality. Regardless of plant variety used, the most appropriate concentration of vermicompost substitution in growth media for commercial seedling growth of *S. melongena* in greenhouse conditions was R1. However, the application of vermicompost extracts showed an inhibitory effect in laboratory condition and depicted that plant variety should also be considered. Thus quality and appropriate concentration of vermicompost application should be quantified before using it for seedling development of any particular plant.

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