



Research article

Efficiency of cow dung based vermi-compost on seed germination and plant growth parameters of *Tagetes erectus* (Marigold)

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ABSTRACT

Vermi-composting is an environmental friendly and economic process to decompose organic waste. The objective of this study was to produce vermi-compost using *Eisenia fetida* and to investigate the impact of vermi-compost (VC) and organic manure (cow dung) on seed germination, seedlings, and growth parameters of *Tagetes erecta*. Physio-chemical parameters of vermi-compost and organic manure were recorded. A potting experiment was designed, germination medium containing soil, sand, and various concentrations of vermi-composts. The composition of germinating media was: TO (Sand + Soil), TCC (Sand + Soil + Cow dung), 10% VC (Sand + Soil + 0.1 kg VC), 15% VC (Sand + Soil + 0.15 kg VC), 20% VC (Sand + Soil + 0.2 kg VC), 25% VC (Sand + Soil + 0.25 kg VC), 30% VC (Sand + Soil + 0.3 kg VC), and 35% VC (Sand + Soil + 0.35 kg VC). Seed germination, seedling, vegetative plant growth, and flowering parameters were evaluated in different germinating media. Pre and post-physio-chemical parameters of germination media were also recorded to check their stability and quality. Results showed that 20% VC was effective for the early initiation of seed germination (2.0 ± 0.0 days) and all growth parameters of marigold seedlings. The germination percentage at 20% VC was recorded as 87.5 ± 1.40 %. The best vegetative plant growth and flowering parameters of marigold plants were observed with 35% VC after transplantation. Findings showed that vermi-compost is the best-suited germination and growing media, which not only improved the soil health but also promoted seed germination and plant growth. Our study undoubtedly indicates that vermi-compost is a more encouraging and advantageous bio-fertilizer and can be used as a powerful and effective for immediate marigold production.

1. Introduction

Tagetes erecta (African marigold, American marigold) belongs to the family *Asteraceae*. It is an erect, annual plant that can grow up to 180 cm tall but is more likely to around 35 cm, probably native to Mexico, despite its being native to the Americas. This plant produces yellow to orange flowers and germinates within 5–8 days from seeds at 21 to 24 °C (Kadam et al., 2013). In the present scenario, Marigold is not only important for social, political, historical occasions, birthdays, wedding and marriage

greetings, and religious offerings but also used in the pharmaceutical industry to cure diseases. The infusion of the plant has been used against rheumatism, colds and bronchitis, juice of leaves for ear-ache, leaves, florets, and decoction used as a diuretic, treatment of eye diseases, skin wash, ulcers, abdominal pain, muscular and bone pain, ulcers, antimalarial, antioxidant, and carminative (Kadam et al., 2013; Manisha et al., 2013; Dixit et al., 2013; Khulbe et al., 2013; Rasoanaivo et al., 1992). Besides medicinal importance, it is also used as a flavoring in food, a popular dye plant, effective repellent i.e. mosquitocidal, insecticidal, and

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larvicidal (Marcia et al., 2011; Nikkon et al., 2011; Patrick et al., 2011). Therefore, the current research aimed to screen the impact of vermi-compost and organic manure (cow dung) on the seed germination, seedling and plant growth parameters, and flowering of Marigold and enhance the production of ornamental plant for pharmaceutical purposes.

Organic wastes are becoming a serious threat to the environment. The tremendous economic growth, industrialization, and urbanization during the last couple of decades are resulting in the generation and accumulation of organic wastes in huge amounts which is also playing havoc with the environment severely (Giuntini et al., 2006). Another globally important issue is the use of agrochemicals with high costs because of the high demand for food (Kaplan, 2016), though their use has boosted food productivity but at the cost of environment and human health because these chemically grown food have adversely affected human health all over the world (Sinha and Rajiv 2008). Composting is a well-established biological process of recycling these organic wastes into amorphous and stable humus-like substances by microbial decomposition under controlled conditions (Ahmad et al., 2007). Composting is, however, an old technology of recycling organic waste material under controlled conditions of temperature, moisture, and aeration (Ahmad et al., 2007). Interest is renewed in composting for sustaining the environment and agriculture side by side. The finished compost product has desirable characteristics regarding odor, weed seed, and pathogens. It is the most suitable and economical waste management strategy than others as handling, storage, and farm application of the composted product is environmentally safe (Ahmad et al., 2008).

Vermi-composting is the biotechnological method of composting by using different species of earthworms to boost waste conversion mechanism and achieve better product (Devi and Prakash 2015; Adhikary 2012). Vermi-composting is a joint action of microorganisms and earthworms for degradation or breakdown of organic materials. Through this procedure, the fundamental nutrients of plants like calcium, potassium, phosphorus, and nitrogen present in the mixture are changed into plant-available nutrients and soluble forms. The most important earthworms used in the composting process are *Eudrilus eugeniae*, *Eisenia Andrei*, *Metaphire Californica*, *Eisenia fetida*, and *Perionyx excavates* (Singh et al., 2014; Yadav et al., 2011). Besides serving as a source of organic matter, vermi-compost increase moisture-holding capacity and provide nutrients having large particulate surface areas that provide many micro-sites for microbial activities and the strong retention of nutrients (Edwards et al., 2011; Arancon et al. 2004, 2006). It is reported that vermi-compost contained growth-promoting hormones such as auxins, cytokinins, and flowering hormone gibberellins that are secreted by earthworms (Neilson 1965; Tomati et al., 1988).

Previous studies illustrated that vermi-compost constitutes a promising alternative to inorganic fertilizers in promoting plant growth (Ansari et al., 2016; Chauhan and Singh 2015; Sinha et al., 2011). Stimulation of plant growth may depend mainly on the biological characteristics of vermi-compost, the plant species used, and the cultivation conditions (Edwards et al., 2004). Vermi-compost has a positive effect on vegetative growth development and yield, especially at germination and seedling stages, stimulating shoot and root development, stimulate plant flowering, increasing the number and biomass of the flowers produced (Atiyeh et al., 2002; Arancon et al., 2004; Ievinsh 2011), as well as increasing fruit yield (Atiyeh et al., 2001). Furthermore, the application of vermi-composts in the field enhances the quality of soils by increasing microbial activity and microbial biomass which are key components in nutrient cycling, production of plant growth regulators, and protecting plants soil-borne disease and arthropod pest attacks (Chauhan and Singh 2013a, b; Ansari and Jaikishun 2011). Therefore, it must be used cautiously for agricultural and horticultural activities (Ievinsh 2011). So, the determination of desirable and economic growth inducing concentrations of vermi-compost for reducing costs of agriculture is critical (Ladan et al., 2012). Considering the above factors, the present experiment has been undertaken to evaluate the possible effects of various

concentrations of vermi-compost on the seed germination and morphological growth parameters and flowering of marigold.

2. Materials and methods

2.1. *Tagetes erectus* collection

The experiment was carried out in the Vermi-tech Unit, Department of Zoology, University of Azad Jammu and Kashmir (AJ&K), Muzaffarabad, Pakistan. In current research seeds of *Tagetes erectus* (marigold) were purchased from Evergreen Nursery Islamabad, Pakistan, and potting experiments were conducted in open house conditions to raise the marigold production and development as an important part of horticulture.

2.2. Waste material and earthworm collection

E. fetida were collected from the local area (Mahajar camp) of Muzaffarabad (34°21'30"N, 73°28'20"E), Azad Jammu and Kashmir (AJ&K), Pakistan using hand sorting method (Edwards et al., 2004). Clitellate *E. fetida*, identified using a custom-built machine learning-based webserver (available at: <https://eside.pythonanywhere.com/> and <https://github.com/wajidarshad/ESIDE>), were used for vermi-composting. Cow dung was collected from local residential houses of Muzaffarabad, Azad Jammu and Kashmir, Pakistan and was air-dried for 10–15 days to remove the various associated organisms (beetles, spiders, snails, etc), noxious gases, and chopped into small pieces (Bhatnagar and Palta, 1996). Old cow dung was used for *E. fetida* culturing and vermi-composting. The organic waste materials such as grass clippings, raw vegetables and fruits (their peels as well), maize straw, coconut peel, rice straw, eggshells, raw papers, and dry leaves were also collected from the residential houses and local market of Muzaffarabad, Azad Jammu and Kashmir, Pakistan. Raw waste products such as vegetables and fruits were pre-digested before use. Fresh spinach or green vegetables were used for vermi-culturing. Waste papers were dipped in water before bedding.

2.3. Vermi-bed preparation for vermi-composting

The vermi-composting was carried out in cemented pits (10 × 5 feet) for 3 months. Vermi-bed was prepared using moisten papers/shredded twigs/grass clippings/coconut peel, varying according to what is available locally. Cow dung was mixed with the pre-digested substrate in a 3:1 ratio (Yuvaraj et al., 2018) and dumped into the constructed pits. At the beginning of vermi-composting 100 to 200 clitellate *E. fetida* were added and feed matter like wheat straw, cow dung, green leaves, crushed eggshells, brown leaves, and tea bags were given to *E. fetida*. To protect the population of *E. fetida* from predators such as birds, rats, cockroaches, and ants the pits were covered by wire mesh or cloth cover. The vermi-composting process was checked once a week and thorough mixing of all substrate material was done to ensure the availability of all feeding materials required for vermi-culturing. The temperature (26 °C–30 °C) and moisture contents (65%–70 %) were maintained by the sprinkling of water. After 3 months, the change in the texture, appearance, color, electrical conductivity, temperature, moisture, and the earthy smell was observed which indicated the formation of vermi-compost. Finally, the prepared vermi-compost was sieved through a 2 mm sieve. At the end of vermi-composting process the total biomass of *E. fetida*, a total number of juveniles, adults, and cocoons were recorded. The fecundity rate was calculated as: number of earthworms/total number of earthworm's used x 100.

2.4. Physiochemical analysis of vermi-compost and cow dung

All physiochemical parameters were measured at the Soil testing laboratory of Soil Research institute, Gojra, Muzaffarabad (34°21'30"N,

73°28'20"E), AJ&K, Pakistan. Physical parameters such as color, texture appearance, smell, electrical conductivity (EC), temperature, moisture, and pH of vermi-compost, and cow dung were recorded. The EC and pH were recorded by EC meter (Model 1056) and pH meter (Model-Li 120-Elico). Hundred gram of tested samples was added in 100 ml of distilled water, stirred for 10 min, placed at room temperature for 24 h, and pH was recorded. On the other hand, the same mixture was left for 1 h at room temperature and then EC was recorded. The soil organic matter, organic carbon (%), and nitrogen (%) were measured using the Walkley-Black method with slight modifications (Walkley and Black, 1934). One gram of dried samples was taken and mixed with 10 ml of $K_2Cr_2O_7$ (1 N), followed by the addition of concentrated H_2SO_4 (20 ml), swirl gently to mix the sample, and allowed to stand for 30 min. After this, samples were diluted with 200 ml of distilled water, 10 ml of orthophosphoric acid was added and finally 1 ml of phenolphthalein indicator was added. A deep violet color appeared. This solution was titrated with 0.5N ferrous ammonium sulfate till the color changes from violet to blue and finally bright green. The volume of the ferrous ammonium sulfate used in titration was noted. In the same way blank titration (without sample) was carried out. Following calculations were carried out: Organic carbon% in soil = $(X-Y) \text{ ml} \times 0.003 \times 100 \div 2 \times W = Z \times 1.3$ (Where, X = blank titration reading, Y = sample reading, W = Weight of soil used); Organic matter in soil (%) = $\%C \times 1.72$; % Nitrogen = $O.M \times 0.05$. For phosphorus (%) levels in the vermi-compost and cow dung were measured by the modified Olsen method (Olsen and Sommers 1982). One gram of air-dried samples and 20 ml of $NaHCO_3$ (0.5 M) were shaken for 30 min, and blue color was developed with molybdate-ascorbic acid reagent and the phosphate in solution was determined on a flame photometer. To determine the potassium (%) levels in the vermi-compost and cow dung ammonium acetate method was used (Watanabe and Olsen, 1965). About 1 g of sample was mixed with 20 ml of N-neutral ammonium acetate for 5 min and then filtered through Whatman No.1 filter paper. The filtrate was atomized in a microprocessor flame photometer and read. Zero settings of flame photometer were done using ammonium acetate solution (77.80 g of N-neutral ammonium acetate in 1000 ml of distilled water). Total potassium (%) was calculated as: $0.1 \times \text{flame value} / 10 \times \text{wt. of sample}$. The cation exchange capacity was calculated by the ammonium chloride method (Tucker and Beatty, 1974). One-gram sample was washed with ethanol to remove soluble salts and cations were displaced with NH_4Cl (1M; pH 8.5) followed by 0.05 M NH_4Cl . The combined ammonium and chloride ion in the extracted sample was calculated as: $CEC (\text{meq}/100\text{g}) = (A-B) \times 100 / W$ [where A = conc. of ammonium ion (meq); B = conc. of chloride ion (meq); W = over dried sample weight (g)]. Besides, the concentration of trace metals such as manganese, calcium, sulphates, copper, magnesium, zinc, and iron were measured through atomic absorption spectrometry (Shahmansouri et al., 2005).

2.5. Physiochemical analysis of sand and soil

Physical parameters such as color, texture appearance, color, electrical conductivity, temperature, moisture, pH of soil and sand were recorded. The total organic matter (%), total carbon (%), nitrogen (%), potassium (%), and phosphorus (%) levels in soil and sand were also measured via using above mentioned protocols before germination media preparation.

2.6. Treatment setup under plastic bags

The plastic pots of 1 kg capacity were used and filled with the germination medium. Different concentrations of vermi-compost were used in germination media along with soil and sand to screen the its impact on marigold seed germination, and seedling parameters. The pots were individually filled with the germination media containing soil, sand, and various concentrations of vermi-composts. The treatment details are given as: TO-control (0.33 kg sand and 0.67 kg soil), TCC-control (0.33 kg sand + 0.32 kg soil + 0.35 kg cow dung), 10% VC (0.33 kg sand

+ 0.57 kg soil + 0.1 kg VC), 15% VC (0.33 kg sand + 0.52 kg soil + 0.15 kg VC), 20% VC (0.33 kg sand + 0.47 kg soil + 0.2 kg VC), 25% VC (0.33 kg sand + 0.42 kg soil + 0.25 kg VC), 30% VC (0.33 kg sand + 0.37 kg soil + 0.3 kg VC), and 35% VC (0.33 kg sand + 0.32 kg soil + 0.35 kg VC). To check the nutrient profile [carbon (%), nitrogen (%), potassium (%), and phosphorus (%)], pH, and EC of prepared germination media before sowing of each treatment were measured using protocols as mentioned above.

2.7. Seed sowing and maintenance

Each treatment was used in triplicates. Eight seeds were manually sown with equal spacing between the seeds at a uniform depth of 3 cm in each of 24 pots having a capacity of 1 kg and were watered thoroughly 2 times a day (morning and evening), so that all the treatments received the same amount of irrigation. The pots were arranged randomly in the natural sunlight with the positions re-randomized every week. Daily observations were made on radicle emergence. Proper care was given to avoid damage to the seed.

2.8. Observations of seed germination and seedling growth parameters

The sowing day was considered as the first day and the effect of germination media on seed germination was observed in the morning every day. The total number of germinated seeds was counted every day. On the other hand, the germination percentage was recorded after 30 days of seedlings. The germination percentage was calculated as: $\text{germination \%} = \text{number of seedlings} / \text{total number of seeds} \times 100$. On the other hand, initiation of germination [IoG = seed germination started day], Speed of germination [SoG = $n1/d1 + n2/d2 + n3/n3 + \dots$ (where, n = number of germinated seeds, d = number of days)], Mean germination Time [MGT = $n1/d1 \times n2/d2 \times n3/n3 \times \dots$ (where, n = number of germinated seeds, d = number of days)], Mean daily germination [MDG = total number of germinated seeds/total number of days], Peak Value [PV = Highest seed germinated/Number of days], and Germination values [GV = PV x MDG], completion of germination [CoG = day at which all seeds germinated] were also calculated (Czabator, 1962; Ellis and Roberts, 1981; ISTA, 1999). After 30 days of the experiment, seedling growth parameters such as length of shoot (cm), total no. of leaves per plant, diameter of leaves (cm), length of leaves (cm), leaf area (L x B x K) (cm), whole seedling length (cm), root length (cm) were also recorded. The nutrient profile [carbon (%), nitrogen (%), potassium (%), and phosphorus (%)], pH, and EC of germination media after harvesting of seedlings from each treatment were measured using protocols as mentioned above.

2.9. Transplantation of marigold seedlings

The marigold seedlings were transplanted after 30 days in plastic pots of 7 kg containing germination media in the mid of September when the climatic temperature (25–30 °C) is best for their growth. To study the impact of vermi-compost on plant growth parameters same germination media were used. In each 7 kg pot, three seedlings were transplanted. Potting experiment was conducted in an open house having no other environmental control with a maximum range of temperature from 30-35 °C, the minimum range of temperature 15–25 °C with bright sunlight, and active photoperiod of 7–9 h. The nutrient profile [carbon (%), nitrogen (%), potassium (%), and phosphorus (%)], pH, and EC of germination media before transplantation and after harvesting of marigold plants from each treatment were measured using protocols as mentioned above.

2.10. Vegetative plant growth studies

Plants were harvested at the yield stage (after 8 weeks of transplantation). Different plant growth parameters like plant height (cm),

volume of roots (cm³), number of shoots per plant, diameter of stem (cm), number of open flowers per plant, number of floral buds, diameter of flower (cm), dry and fresh weight of flowers (g) per plant were investigated.

2.11. Statistical analysis

Each experiment was repeated in triplicates and Mean \pm Standard Deviation from absolute data was calculated (<http://easycalculation.com/statistics/standard-deviation.php>). To analyze the impact of different treatments on marigold growth and development, a one-way analysis of variance was used. Statistical analyses were performed using GraphPad Prism for Windows (version 5.03) and also used to plot graphs with error bars of standard errors of the means (SEM). 'a, b, c' indicates a significant difference between control and other treatment groups. Statistical icons: single letter such as a/b/c = $p \leq 0.05$; double letter such as aa/bb/cc = $p \leq 0.01$; triple letter such as aaa/bbb/ccc, = $p \leq 0.001$.

3. Results

3.1. Physicochemical analysis of soil, sand, cow dung and vermi-compost

Current research has been carried out to screen the impact of vermi-compost and cow dung on the ornamental plant marigold. The vermi-compost was blackish-brown in color, fine grain, and porous in appearance with earthy smell rather than bedding that was used at the beginning of the experimental setup. It was observed that the waste material was completely converted into humus-like material (vermi-compost) via *E. fetida*. The temperature (25 °C), 7.8 pH, 2.82 mS/cm EC, and 32 % moisture contents of vermi-compost were also recorded. On the other hand, cow dung was greenish to dark brown color, pasty and the pile of shaving cream-like appearance, pungent or rotten egg-like smell, 40–45 °C temperature, 8.7 pH, 3.52 mS/cm EC and 18 % moisture contents, respectively. The chemical results revealed that vermi-compost possessed a high level of nutrients such as nitrogen (2.28%) phosphorous (0.030%), potassium (0.033%), calcium, and magnesium compared to cow dung (1.86%, 0.0098%, and 0.020%) while the total organic carbon and organic matter was reduced i.e. 25.2% and 43% in vermi-compost

compared to cow dung (50.4 % and 86 %). The cation exchange capacity of vermi-compost was greater (72.48 me/100g) compared to cow dung (62.30 me/100g). Vermi-compost showed higher levels of micro-nutrients such as sulphates (0.55 %), iron (1.3313 %), manganese (0.2038 %), zinc (0.110 %), magnesium (0.78 %), Copper (0.0048 %), and calcium (1.35 %). Before sowing the chemical parameters of soil (1.049% organic matter, 0.61% organic carbon, 0.52% nitrogen, 0.0072% phosphorus, and 0.0014% potassium) and sand (2.64% organic matter, 1.53% organic carbon, 1.32% nitrogen, 0.001% phosphorus, and 0.0112% potassium) were also recorded.

3.2. Earthworm growth rate and cocoon production during vermi-composting

At the end of the experiment (after 90 days), the biomass, length, and number of cocoons of *E. fetida* were varied. The maximum number of adult worms were recorded after 12 weeks (4714 \pm 10.6). Maximum worm biomass was attained during the 8th week (0.35 \pm 0.00 mg/earthworm) and 7th week (0.27 \pm 0.05 mg/earthworm) whereas minimum biomass was recording during the first week of the experiment (0.05 \pm 0.00 mg/earthworm). No juvenile worm was seen during the first three weeks of the experiment, however, the maximum number (360 \pm 1.88) of juveniles was recorded during the 8th week of the experiment. Similarly, the maximum increase in cocoon production was recorded in the 8th week (186 \pm 0.01).

3.3. Physicochemical analysis of germination media before sowing

The nutrients profile, pH, and EC of all prepared germination media before sowing marigold seeds are given in Table 1. The results showed significant ($p \leq 0.001$) reduction in EC of germinating media having vermi-compost i.e. 2.82 mS/cm in 10%VC, 2.84 in mS/cm in 15% VC, 2.90 mS/cm in 20%VC, 2.97 mS/cm in 25%VC, 2.96 mS/cm in 30%VC, and 2.97 mS/cm in 35% VC compared to TCC (3.50 mS/cm) while increased level was recorded in all germination media having vermi-compost compared to TO (2.31 mS/cm) (Table 1). On the other hand, pH was slightly decreased (7.6 \pm 0.0 to 7.4 \pm 0.0) in all treatments after the addition of vermi-compost compared to TO while a significant difference was recorded when compared to TCC ($p \leq 0.01$ and $p \leq 0.001$).

Table 1. Statistical significant difference between pre and post physicochemical analysis of germinating media used for marigold seed germination and seedling growth parameters.

Treatments	Parameters							
		pH	Appearance	EC mS/cm	C (%)	N (%)	K (%)	P (%)
Control TCC	Pre	8.7 \pm 0.0	Thick crumpled, greenish brown	3.50 \pm 0.01	1.006 \pm 0.01	0.86 \pm 0.0	0.041 \pm 0.00	0.01 \pm 0.00
	Post	8.7 \pm 0.0	Thick crumpled, greenish brown	3.48 \pm 0.01	0.80 \pm 0.05	0.80 \pm 0.05	0.006 \pm 0.00	0.038 \pm 0.00
Control TO	Pre	7.6 \pm 0.0	Brown, compact, less porous	2.31 \pm 0.01	0.88 \pm 0.00	1.14 \pm 0.0	0.041 \pm 0.00	0.01 \pm 0.00
	Post	7.6 \pm 0.0	Brown, compact, less porous	2.20 \pm 0.05	0.97 \pm 0.01	0.83 \pm 0.05	0.006 \pm 0.00	0.038 \pm 0.00
10% VC	Pre	7.4 \pm 0.0 ^{aaa,bb}	Blackish brown, slightly porous	2.82 \pm 0.02 ^{aaa,bbb}	1.35 \pm 0.01 ^{aaa,bbb}	1.15 \pm 0.01 ^{aaa,bbb}	0.0318 \pm 0.00 ^{aaa,bbb}	0.048 \pm 0.00 ^{aaa,bbb}
	Post	7.4 \pm 0.0 ^{aaa,bb}	Blackish brown, slightly porous	2.80 \pm 0.02 ^{aaa,bbb}	1.30 \pm 0.05 ^{aaa,bbb}	1.01 \pm 0.01 ^{aaa,bbb}	0.024 \pm 0.00 ^{aaa,bbb}	0.041 \pm 0.00 ^{aaa,bbb}
15% VC	Pre	7.4 \pm 0.0 ^{aaa,bb}	Blackish brown, porous	2.84 \pm 0.01 ^{aaa,bbb}	1.40 \pm 0.0 ^{aaa,bbb}	1.16 \pm 0.05 ^{aaa,bbb}	0.0592 \pm 0.0 ^{aaa,bbb}	0.051 \pm 0.00 ^{aaa,bbb}
	Post	7.4 \pm 0.0 ^{aaa,bb}	Blackish brown, porous	2.77 \pm 0.02 ^{aaa,bbb}	1.34 \pm 0.01 ^{aaa,bbb}	1.13 \pm 0.05 ^{aaa,bbb}	0.051 \pm 0.00 ^{aaa,bbb}	0.044 \pm 0.00 ^{aaa,bbb}
20% VC	Pre	7.4 \pm 0.0 ^{aaa,bb}	Blackish brown, porous	2.90 \pm 0.0 ^{aaa,bbb}	1.46 \pm 0.01 ^{aaa,bbb}	1.24 \pm 0.05 ^{aaa,bbb}	0.0618 \pm 0.0 ^{aaa,bbb}	0.058 \pm 0.00 ^{aaa,bbb}
	Post	7.4 \pm 0.0 ^{aaa,bb}	Blackish brown, porous	2.73 \pm 0.03 ^{aaa,bbb}	1.44 \pm 0.01 ^{aaa,bbb}	0.57 \pm 0.05 ^{aaa,bbb}	0.03 \pm 0.00 ^{aaa,bbb}	0.026 \pm 0.00 ^{aaa,bbb}
25% VC	Pre	7.4 \pm 0.0 ^{aaa,bb}	Blackish brown, more porous	2.97 \pm 0.02 ^{aaa,bbb}	1.51 \pm 0.01 ^{aaa,bbb}	1.31 \pm 0.01 ^{aaa,bbb}	0.0650 \pm 0.0 ^{aaa,bbb}	0.064 \pm 0.0 ^{aaa,bbb}
	Post	7.4 \pm 0.0 ^{aaa,bb}	Blackish brown, more porous	2.73 \pm 0.03 ^{aaa,bbb}	1.40 \pm 0.05 ^{aaa,bbb}	1.01 \pm 0.01 ^{aaa,bbb}	0.054 \pm 0.00 ^{aaa,bbb}	0.051 \pm 0.00 ^{aaa,bbb}
30% VC	Pre	7.4 \pm 0.0 ^{aaa,bb}	Blackish brown, more porous	2.96 \pm 0.02 ^{aaa,bbb}	1.66 \pm 0.0 ^{aaa,bbb}	1.43 \pm 0.04 ^{aaa,bbb}	0.0735 \pm 0.0 ^{aaa,bbb}	0.071 \pm 0.0 ^{aaa,bbb}
	Post	7.4 \pm 0.0 ^{aaa,bb}	Blackish brown, more porous	2.73 \pm 0.03 ^{aaa,bbb}	1.51 \pm 0.01 ^{aaa,bbb}	1.23 \pm 0.05 ^{aaa,bbb}	0.533 \pm 0.00 ^{aaa,bbb}	0.051 \pm 0.00 ^{aaa,bbb}
35% VC	Pre	7.4 \pm 0.0 ^{aaa,bb}	Blackish brown, more porous	2.97 \pm 0.01 ^{aaa,bbb}	1.73 \pm 0.05 ^{aaa,bbb}	1.46 \pm 0.01 ^{aaa,bbb}	0.076 \pm 0.00 ^{aaa,bbb}	0.79 \pm 0.0 ^{aaa,bbb}
	Post	7.4 \pm 0.0 ^{aaa,bb}	Blackish brown, more porous	2.73 \pm 0.03 ^{aaa,bbb}	1.35 \pm 0.05 ^{aaa,bbb}	0.94 \pm 0.01 ^{aaa,bbb}	0.062 \pm 0.00 ^{aaa,bbb}	0.47 \pm 0.00 ^{aaa,bbb}

Mean \pm Standard deviation designed with different superscripts indicated the significant difference among treatments. 'a' represents a significant change among TCC and VC treatment groups; 'b' represents a significant change among TO and VC treatment groups. Statistical icons: double letter such as aa/bb = $p \leq 0.01$; triple letter such as aaa/bbb = $p \leq 0.001$.

Table 2. Significant difference among seed germination parameters of marigold under different compositions of germination media.

Treatments	Germination parameters							
	IoG (Days)	MGT	MDG	SoG	CoG (Days)	GP	PV	GV
Control TCC	4.33 ± 0.47	8.33 ± 0.47	0.14 ± 0.01	0.11 ± 0.01	9.66 ± 1.88	58 ± 0.47	0.41 ± 0.05	0.062 ± 0.0
Control TO	5.33 ± 0.47	5.66 ± 0.47	0.11 ± 0.05	0.14 ± 0.01	9.33 ± 1.6	32.0 ± 0.47	0.23 ± 0.01	0.026 ± 0.0
10% VC	4.66 ± 0.47	6.33 ± 0.94 ^a	1.15 ± 0.01 ^{aaa,bbb}	1.38 ± 0.01	7.33 ± 2.86 ^{aaa,bbb}	54.44 ± 0.41	0.38 ± 0.01	0.45 ± 0.01
15% VC	3.66 ± 0.47	3.66 ± 0.47 ^{aaa}	5.41 ± 0.01 ^{aaa,bbb}	7.76 ± 0.40 ^{aaa,bbb}	8.33 ± 0.94	66.4 ± 0.43 ^{aa,bbb}	3.72 ± 0.19 ^{aaa,bbb}	19.3 ± 0.21 ^{aaa,bbb}
20% VC	2.0 ± 0.0 ^{a,bbb}	2.33 ± 0.47 ^{aaa,bbb}	5.58 ± 0.05 ^{aaa,bbb}	8.33 ± 0.47 ^{aaa,bbb}	5.66 ± 3.39 ^{aaa,bbb}	86.8 ± 0.62 ^{aaa,bbb}	4.57 ± 0.01 ^{aaa,bbb}	25.1 ± 0.08 ^{aaa,bbb}
25% VC	2.33 ± 0.47 ^{a,bbb}	3.66 ± 0.47 ^{aaa}	4.41 ± 0.05 ^{aaa,bbb}	4.66 ± 0.47 ^{aaa,bbb}	6.33 ± 4.10 ^{aaa,bbb}	53.7 ± 0.49	3.06 ± 0.05 ^{aaa,bbb}	13.3 ± 0.21 ^{aaa,bbb}
30% VC	2.33 ± 0.47 ^{a,bbb}	5.33 ± 0.47 ^{aaa}	3.62 ± 0.01 ^{aaa,bbb}	6.33 ± 0.47 ^{aaa,bbb}	6.33 ± 3.29 ^{aaa,bbb}	53.3 ± 0.96	3.59 ± 0.01 ^{aaa,bbb}	13.02 ± 0.01 ^{aaa,bbb}
35% VC	2.66 ± 0.47 ^{a,bbb}	4.33 ± 0.47 ^{aaa}	3.02 ± 0.01 ^{aaa,bbb}	2.66 ± 0.94 ^{aaa,bb}	7.33 ± 3.85 ^{aaa,bbb}	70.3 ± 0.44 ^{aaa,bbb}	4.28 ± 0.05 ^{aaa,bbb}	13.01 ± 0.01 ^{aaa,bbb}

Mean ± Standard deviation designed with different superscripts indicated the significant difference among treatments. Mean germination time (MGT); Initiation of germination (IoG); Mean daily germination (MDG); Speed of germination (SoG); Completion of germination (CoG); Germination percentage (GP); Peak value (PV); Germination value (GV). 'a' represents a significant change among Tcc and VC treatment groups; 'b' represents a significant change among To and VC treatment groups. Statistical icons: single letter such a/b = $p \leq 0.05$; double letter such as aa/bb = $p \leq 0.01$; triple letter such as aaa/bbb = $p \leq 0.001$.

Chemical analysis of germination media showed significant ($p \leq 0.001$) increased values of carbon, nitrogen, phosphorus, and potassium in vermi-compost amended germination media with increasing dose of vermi-compost compared to TCC and TO (Table 1). The maximum percentage of carbon, nitrogen, phosphorus, and potassium was recorded in 35%VC (1.73 ± 0.05%, 1.46 ± 0.01 %, 0.076 ± 0.0%, and 0.79 ± 0.0 %).

3.4. Impact of vermi-compost on seed germination

Daily observations were made on the emergence of radicles for 10–15 days. Various germination associated parameters such as germination percentage, speed of germination or germination index, mean germination time, mean daily germination, peak values, and germination values of seeds at different concentration of vermi-compost were calculated and significant results ($p \leq 0.05$, $p \leq 0.01$, and $p \leq 0.001$) were recorded (Table 2). Significant ($p \leq 0.001$) results revealed that IoG, MGT, MDG, SoG, CoG, GP, PV, and GV was maximum at 20% VC germination media (2.0 ± 0.0 days, 2.33 ± 0.47, 5.58 ± 0.05, 8.33 ± 0.47, 5.66 ± 3.39 days, 86.8 ± 0.62%, 4.57 ± 0.01, 25.1 ± 0.08) compared to others (Figure 1).

3.5. Seedling growth parameters

A considerable increase in all growth parameters was recorded in vermi-compost treated seeds when compared to control plants' growth parameters after 30 days of germination (Figure 1). Significant differences at $p \leq 0.05$, $p \leq 0.01$, and $p \leq 0.001$ among seedling growth parameters of marigold grown in controls (TO and TCC) and germination media having various vermi-compost concentrations are shown in Table 3. Results revealed that 20% VC germinating media showed maximum and significant ($p \leq 0.001$) increase in shoot length (14 ± 0.81 cm), number of leaves (12 ± 0.0), diameter of leaves (4.66 ± 0.23 cm), length of leaves (9.0 ± 0.40 cm), leaf area (36.7 ± 0.87 cm), whole seedling length (14.33 ± 0.47 cm), and root length (5.66 ± 0.47 cm). From the whole data, it was observed that vermi-compost have a significant impact ($p \leq 0.001$) on the seedlings of marigold compared to TCC and TO (Table 3). Consequently, 20%VC is the preferable and superior germination media for marigold seed germination and the nutrient profile of 20%VC supported the seed germination of marigold. After harvesting of marigold seedlings, the germinating media having vermi-compost showed significant ($p \leq 0.05$ and $p \leq 0.001$) reduction of carbon, nitrogen, phosphorus, and potassium compared to media prepared used for seed sowing (Table 1). We can say that vermi-compost not only enhances plant growth and development but also improve soil quality and soil fertility. However, pH values remain the same, 8.7 ± 0.0 in TCC, 7.6 ± 0.0 in TO, and 7.4 ± 0.0 in all VC treatments. Electrical conductivity was slightly reduced in TO and TCC (2.20 ± 0.05 mS/cm and 3.48

± 0.01 mS/cm), and in all VC treatments were recorded in the range from 2.80 ± 0.02 mS/cm to 2.73 ± 0.03 mS/cm.

3.6. Nutrient profile of germinating media before seedling transplantation

Germinating media having vermi-compost showed significant variable values of carbon, nitrogen, phosphorus, and potassium compared to TCC and TO at $p \leq 0.05$ and $p \leq 0.001$ before transplantation of marigold seedlings (Table 4). Average percentage of carbon, nitrogen, potassium, and phosphorus contents was significantly increased with an increasing dose of vermi-compost compared to TCC and TO. The maximum average C, N, K, and P was recorded in 35% VC as 1.73 ± 0.01%, 1.46 ± 0.01%, 0.078 ± 0.00%, and 0.072 ± 0.05%. The recorded value of pH in TCC and TO were 8.7 ± 0.0 and 7.6 ± 0.0 whereas pH values in all VC treatments were 7.4 ± 0.0, respectively. Electrical conductivity in TO and TCC was recorded as 2.22 ± 0.02 mS/cm and 3.50 ± 0.01 mS/cm whereas in all vermi-compost treatments was recorded in a range between 2.93 ± 0.01 mS/cm to 3.06 ± 0.02 mS/cm. The texture, color, and appearance vary in controls and vermi-compost treatments i.e. TCC was thick crumpled with greenish-brown color, TO was compact, less porous having brownish-black color whereas all vermi-compost treatments were blackish-brown with high porosity and soft aerated texture (Table 4).

3.7. Vegetative growth and flowering parameters

The vegetative plant growth and flowering parameters showed a significant results ($p \leq 0.05$ and $p \leq 0.001$) in germination media containing vermi-compost compared to controls TCC and TO after 8 weeks of transplantation (Figure 2; Table 5). Results revealed that 35% vermi-compost showed a significant increase in all vegetative growth and floral parameters like plant height (26.0 ± 0.81 cm), root volume (15.66 ± 0.47 cm³), number of lateral shoots per plant (9.00 ± 0.81) and diameter of stem (1.0 ± 0.0 cm), number of open flowers (2.66 ± 0.94), number of floral buds (7.00 ± 0.81), diameter of flower (9.00 ± 0.81 cm), fresh weight (16.66 ± 0.47 g), and dry weight of flower (7.33 ± 0.47 g) (Table 5). Germinating media having vermi-compost showed significant ($p \leq 0.05$ and $p \leq 0.001$) decline of carbon, nitrogen, phosphorus, and potassium when compared to nutrient contents of germinating media before transplantation (Table 4). The maximum average decline at $p \leq 0.001$ was recorded in 35% VC as 1.73 ± 0.0 to 0.366 ± 0.05% in carbon, 1.46 ± 0.01 to 0.033 ± 0.0% in nitrogen, 0.072 ± 0.05% to 0.030 ± 0.01% in phosphorus, and 0.078 ± 0.0 to 0.046 ± 0.00% in potassium, respectively. Thus, the current research proved that 35%VC is the preferable dose for marigold vegetative and flowering characteristics. The texture and appearance of TCC were thick crumpled with greenish-brown color, TO germinating media was compact, less porous, and hard with brownish-black color, whereas all germinating media having vermi-

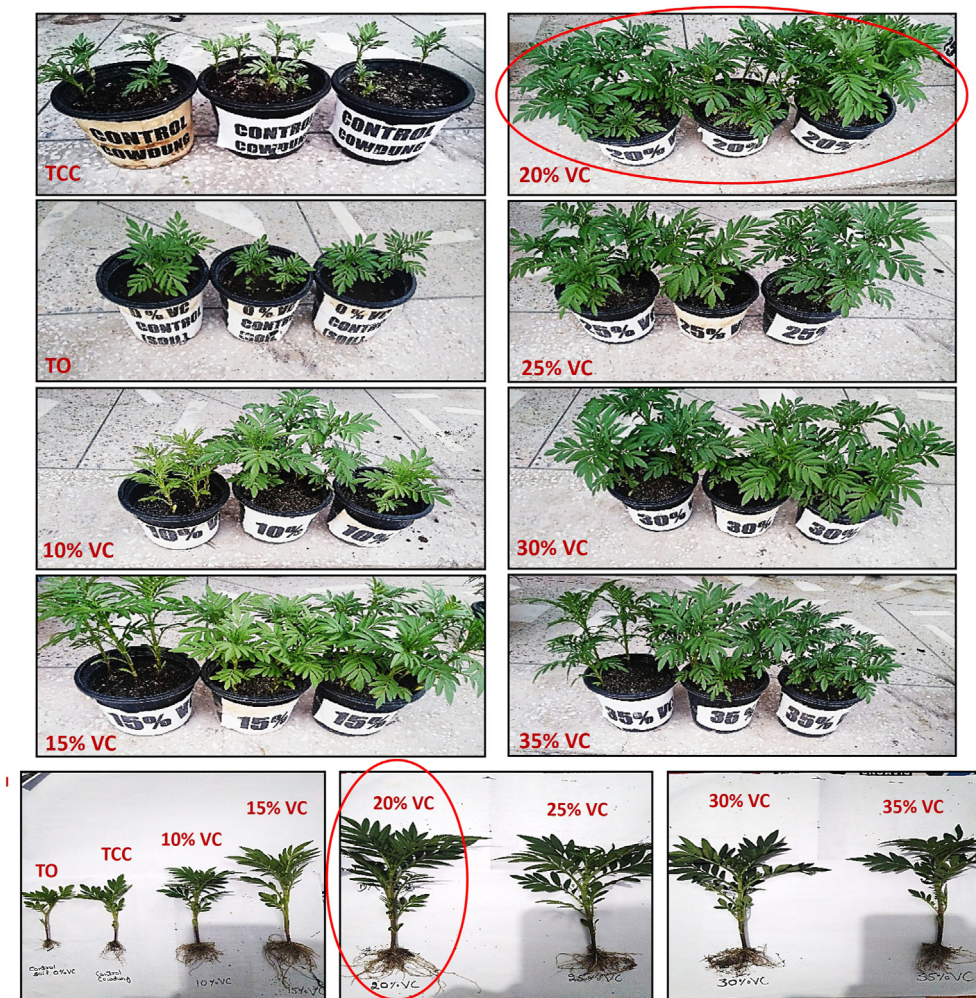


Figure 1. Impact of germinating media on seed germination of marigold.

compost were blackish-brown with high porosity and soft aerated texture. The pH value of TCC and TO were recorded as 8.7 ± 0.0 and 7.6 ± 0.0 . While the same pH values were recorded 7.4 ± 0.0 in all VC treatments. Electrical conductivity in TO and TCC were slightly decreased from 2.22 ± 0.02 to 2.13 ± 0.01 mS/cm and from 3.50 ± 0.05 to 3.45 ± 0.05 mS/cm respectively. Similarly, electrical conductivity was also decreased in all vermi-composting containing media and recorded in the range between 2.84 ± 0.01 mS/cm to 2.97 ± 0.01 mS/cm. All physical and chemical characteristics of vermi-compost indicated the significant impact on the seed germination, vegetative growth, and

flowering of the marigold within 8 weeks of growth and development compared to TCC and TO (Fig.1 and Fig2).

4. Discussion

Vermi-composting is one of the best ways to not only enhance soil fertility but also reduce soil pollution (Ostos et al., 2008; Bhat et al., 2016). In the current study, cow dung manure was used for the vermi-compost production and our results are consistent with the findings of Ackbas and Belliturk (2016) and Zahmacoglu and Belliturk

Table 3. Marigold seedling growth parameters.

Treatments	Seedling growth parameters						
	Length of shoot (cm)	Total no. of leaves per plant	Diameter of leaves (cm)	Length of leaves (cm)	Leaf area (L x B x K) (cm)	Whole Seedling length (cm)	Root length (cm)
Control TCC	4.66 ± 1.24	8.33 ± 0.47	1.66 ± 0.47	3.16 ± 0.62	4.39 ± 1.32	7.0 ± 1.63	2.166 ± 0.84
Control TO	5.0 ± 0.81	5.66 ± 0.47	1.33 ± 0.47	2.83 ± 0.62	3.34 ± 0.74	6.0 ± 0.81	1.66 ± 0.94
10% VC	6.33 ± 1.24^a	8.33 ± 1.24^b	2.66 ± 0.47	$5.33 \pm 0.94^{aa,bb}$	$12.76 \pm 2.25^{aaa,bbb}$	$9.66 \pm 0.94^{a,b}$	$3.33 \pm 0.47^{a,bb}$
15% VC	$13.0 \pm 0.81^{aaa,bbb}$	$11.33 \pm 0.94^{aaa,bbb}$	$3.33 \pm 0.47^{a,bb}$	$7.66 \pm 1.24^{aaa,bbb}$	$25.16 \pm 4.29^{aaa,bbb}$	$13.0 \pm 0.81^{aaa,bbb}$	$5.66 \pm 0.47^{aaa,bbb}$
20% VC	$14.0 \pm 0.81^{aaa,bbb}$	$12.0 \pm 0.0^{aaa,bbb}$	$4.66 \pm 0.23^{aaa,bbb}$	$9.0 \pm 0.40^{aaa,bbb}$	$36.07 \pm 0.87^{aaa,bbb}$	$14.33 \pm 0.47^{aaa,bbb}$	$5.66 \pm 0.47^{aaa,bbb}$
25% VC	$13.0 \pm 0.47^{aaa,bbb}$	$11.33 \pm 0.47^{aaa,bbb}$	$4.33 \pm 0.47^{aaa,bbb}$	$9.0 \pm 0.40^{aaa,bbb}$	$35.0 \pm 1.59^{aaa,bbb}$	$12.66 \pm 0.47^{aaa,bbb}$	4.33 ± 0.47^b
30% VC	$12.66 \pm 0.47^{aaa,bbb}$	$11.66 \pm 0.047^{aaa,bbb}$	$4.16 \pm 0.23^{aaa,bbb}$	$8.66 \pm 0.23^{aaa,bbb}$	$32.4 \pm 0.84^{aaa,bbb}$	$14.33 \pm 0.47^{aaa,bbb}$	$5.33 \pm 0.47^{aa,bbb}$
35% VC	$11.33 \pm 0.47^{aaa,bbb}$	$12.0 \pm 0.0^{aaa,bbb}$	$3.83 \pm 0.23^{aa,bbb}$	$8.0 \pm 0.70^{aaa,bbb}$	$27.5 \pm 2.40^{aaa,bbb}$	$14.33 \pm 0.47^{aaa,bbb}$	$5.33 \pm 0.47^{aaa,bb}$

Mean \pm Standard deviation designed with different superscripts indicated the significant difference among treatments. ‘a’ represents a significant change among Tcc and VC treatment groups; ‘b’ represents a significant change among To and VC treatment groups. Statistical icons: single letter such a/b = $p \leq 0.05$; double letter such as aa/bb = $p \leq 0.01$; triple letter such as aaa/bbb = $p \leq 0.001$.

Table 4. Pre and post physiochemical analysis of germinating media used for marigold vegetative growth and flowering parameters.

Treatments	Parameters							
	pH	Appearance	EC mS/cm	C (%)	N (%)	K (%)	P (%)	
Control TCC	Pre	8.7 ± 0.0	Thick crumpled, greenish brown	3.50 ± 0.01	1.2 ± 0.08	0.85 ± 0.05	0.0087 ± 0.00	0.041 ± 0.00
	Post	8.7 ± 0.0	Thick crumpled, greenish brown	3.45 ± 0.05	0.83 ± 0.23	0.10 ± 0.00	0.0071 ± 0.00	0.040 ± 0.00
Control TO	Pre	7.6 ± 0.0	Brown, compact, less porous	2.22 ± 0.02	1.32 ± 0.05	1.2 ± 0.01	0.0085 ± 0.00	0.040 ± 0.00
	Post	7.6 ± 0.0	Brown, compact, less porous	2.13 ± 0.01	0.86 ± 0.05	0.10 ± 0.00	0.0074 ± 0.00	0.040 ± 0.00
10% VC	Pre	7.4 ± 0.0 ^{aaa,bb}	Blackish brown, slightly porous	2.93 ± 0.01 ^{aaa,bbb}	1.34 ± 0.01 ^{aa}	1.15 ± 0.05 ^{aaa,bbb}	0.031 ± 0.00	0.047 ± 0.05
	Post	7.4 ± 0.0 ^{aaa,bb}	Blackish brown, slightly porous	2.84 ± 0.01 ^{aaa,bbb}	0.73 ± 0.05 ^{a,b}	0.066 ± 0.00 ^{aaa,bbb}	0.021 ± 0.00 ^{aaa,bbb}	0.039 ± 0.00
15% VC	Pre	7.4 ± 0.0 ^{aaa,bb}	Blackish brown, porous	2.95 ± 0.01 ^{aaa,bbb}	1.40 ± 0.01 ^{aaa}	1.16 ± 0.05 ^{aaa,bbb}	0.058 ± 0.00 ^{aaa,bbb}	0.051 ± 0.05 ^{aaa,bbb}
	Post	7.4 ± 0.0 ^{aaa,bb}	Blackish brown, porous	2.80 ± 0.00 ^{aaa,bbb}	0.73 ± 0.05 ^{a,b}	0.066 ± 0.00 ^{aaa,bbb}	0.044 ± 0.00 ^{aaa,bbb}	0.036 ± 0.00 ^{aa,bb}
20% VC	Pre	7.4 ± 0.0 ^{aaa,bb}	Blackish brown, porous	2.96 ± 0.02 ^{aaa,bbb}	1.44 ± 0.01 ^{b,aaa}	1.23 ± 0.01	0.0614 ± 0.00 ^{aaa,bbb}	0.057 ± 0.00 ^{aaa,bbb}
	Post	7.4 ± 0.0 ^{aaa,bb}	Blackish brown, porous	2.84 ± 0.01 ^{aaa,bbb}	1.23 ± 0.05	0.10 ± 0.05	0.051 ± 0.00 ^{aaa,bbb}	0.043 ± 0.00 ^{a,b}
25% VC	Pre	7.4 ± 0.0 ^{aaa,bb}	Blackish brown, more porous	2.99 ± 0.05 ^{aaa,bbb}	1.51 ± 0.05 ^{aaa,bbb}	1.31 ± 0.06	0.065 ± 0.00 ^{aaa,bbb}	0.063 ± 0.00 ^{aaa,bbb}
	Post	7.4 ± 0.0 ^{aaa,bb}	Blackish brown, more porous	2.90 ± 0.01 ^{aaa,bbb}	1.01 ± 0.01	0.10 ± 0.05	0.050 ± 0.00 ^{aaa,bbb}	0.049 ± 0.00 ^{aa,bb}
30% VC	Pre	7.4 ± 0.0 ^{aaa,bb}	Blackish brown, more porous	3.01 ± 0.01 ^{aaa,bbb}	1.64 ± 0.01 ^{aaa,bbb}	1.41 ± 0.05 ^{aaa,bbb}	0.0734 ± 0.00 ^{aaa,bbb}	0.071 ± 0.00 ^{aaa,bbb}
	Post	7.4 ± 0.0 ^{aaa,bb}	Blackish brown, more porous	2.92 ± 0.05 ^{aaa,bbb}	0.76 ± 0.05 ^{a,b}	0.066 ± 0.00 ^{aaa,bbb}	0.059 ± 0.00 ^{aaa,bbb}	0.035 ± 0.05 ^{aaa,bbb}
35% VC	Pre	7.4 ± 0.0 ^{aaa,bb}	Blackish brown, more porous	3.06 ± 0.02 ^{aaa,bbb}	1.73 ± 0.01 ^{aaa,bbb}	1.46 ± 0.01 ^{aaa,bbb}	0.078 ± 0.00 ^{aaa,bbb}	0.072 ± 0.05 ^{aaa,bbb}
	Post	7.4 ± 0.0 ^{aaa,bb}	Blackish brown, more porous	2.97 ± 0.01 ^{aaa,bbb}	0.366 ± 0.05 ^{aa,bb}	0.033 ± 0.00 ^{aaa,bbb}	0.046 ± 0.00 ^{aaa,bbb}	0.030 ± 0.01 ^{aaa,bbb}

Mean ± Standard deviation designed with different superscripts indicated the significant difference among treatments. ‘a’ represents a significant change among TCC and VC treatment groups; ‘b’ represents a significant change among TO and VC treatment groups. Statistical icons: single letter such a/b = p ≤ 0.05; double letter such as aa/bb = p ≤ 0.01; triple letter such as aaa/bbb = p ≤ 0.001.



Figure 2. Impact of germinating media on plant growth parameters after 8 weeks of transplantation.

Table 5. Impact of germinating media on vegetative plant growth and flowering parameters of marigold after 8th weeks of transplantation.

Treatments	Vegetative growth parameters									
	Plant height (cm)	Volume of root (cm ³)	No. of shoots per plant	Diameter of stem (cm)	No. of open flowers per plant	No. of floral buds	Diameter of flower (cm)	Fresh weight of flower/plant(g)	Dry weight of flower /plant(g)	
Control TCC	12.66 ± 2.05	7.66 ± 0.47	2.33 ± 0.94	0.5 ± 0.08	0.66 ± 0.94	2.33 ± 0.47	5.00 ± 0.81	4.33 ± 0.47	1.33 ± 0.47	
Control TO	10.33 ± 0.47	8.33 ± 0.47	4.00 ± 0.81	0.5 ± 0.08	0.33 ± 0.47	3.33 ± 0.94	4.33 ± 0.47	3.66 ± 0.47	0.83 ± 0.23	
10% VC	14.00 ± 0.81	10.33 ± 0.47 ^{aa,b}	3.00 ± 1.41	0.466 ± 0.05	1.33 ± 0.94 ^{aaa,bbb}	2.66 ± 1.24	4.33 ± 0.47	6.33 ± 0.47	1.66 ± 0.47 ^{bbb}	
15% VC	18.66 ± 0.94 ^{aaa,bbb}	13.00 ± 0.81 ^{aaa,bbb}	3.00 ± 0.81	0.467 ± 0.05	1.33 ± 0.94 ^{aaa,bbb}	2.66 ± 0.47	6.00 ± 0.0	12.66 ± 0.47 ^{aaa,bbb}	5.33 ± 0.47 ^{aaa,bbb}	
20% VC	22.6 ± 0.94 ^{aaa,bbb}	15.00 ± 0.0 ^{aaa,bbb}	7.00 ± 0.81 ^{aaa,bbb}	0.866 ± 0.05 ^{aaa,bbb}	1.33 ± 0.94 ^{aaa,bbb}	3.66 ± 0.47	6.66 ± 0.47 ^{ab}	10.33 ± 0.47 ^{aaa,bbb}	3.33 ± 0.47 ^{aaa,bbb}	
25% VC	22.33 ± 0.47 ^{aaa,bbb}	15.00 ± 0.0 ^{aaa,bbb}	5.00 ± 0.0 ^{aaa}	0.733 ± 0.05 ^{aa,bb}	1.00 ± 0.81 ^{aaa,bbb}	4.66 ± 0.47 ^{aaa,bbb}	7.33 ± 0.47 ^{aaa,bbb}	11.33 ± 0.47 ^{aaa,bbb}	4.33 ± 0.47 ^{aaa,bbb}	
30% VC	24.0 ± 0.81 ^{aaa,bbb}	15.66 ± 0.22 ^{aaa,bbb}	5.33 ± 0.47 ^{aaa,b}	0.7 ± 0.081 ^{aa,bb}	1.33 ± 1.24 ^{aaa,bbb}	5.00 ± 0.0 ^{ab}	8.33 ± 0.47 ^{aaa,bbb}	11.66 ± 0.47 ^{aaa,bbb}	4.66 ± 0.47 ^{aaa,bbb}	
35% VC	26.0 ± 0.8 ^{aaa,bbb}	15.66 ± 0.47 ^{aaa,bbb}	9.00 ± 0.81 ^{aaa,bbb}	1.0 ± 0.0 ^{aaa,bbb}	2.66 ± 0.94 ^{aaa,bbb}	7.00 ± 0.81 ^{aaa,bbb}	9.00 ± 0.81 ^{aaa,bbb}	16.66 ± 0.47 ^{aaa,bbb}	7.33 ± 0.47 ^{aaa,bbb}	

Mean ± Standard deviation designed with different superscripts indicated the significant difference among treatments. 'a' represents a significant change among Tcc and VC treatment groups; 'b' represents a significant change among To and VC treatment groups. Statistical icons: single letter such as a = p ≤ 0.05; double letter such as aa = p ≤ 0.01; triple letter such as aaa, = p ≤ 0.001.

(2014). They reported that various types of manure (cow, sheep, goat, horse, poultry), paper wastes, coconut peel, rice waste, wheat straws, leaves, raw vegetable waste, raw fruits wastes, and tea wastes could be used for vermi-compost production. Swati and Hait (2017) demonstrated that vermi-compost is eco-friendly, cost-effective, and perfect soil improvement fertilizer.

E. fetida has been used for the vermi-compost production because several kinds of literature illustrated the utilization of earthworms increase the soil organic matter (Gorres et al., 2016; Belliturk et al., 2017), and have a great impact on soil productivity and fertility (Gunadi et al., 2002). In the current research the maximum biomass and number of *E. fetida* was recorded at the end of vermi-composting. Chauhan & Singh (2013a, b) reported that animal dung with agro-waste enhanced *E. fetida* growth and development. According to Belliturk (2016) and Belliturk et al. (2015), *E. fetida* is the best choice for outdoor vermi-composting. Dominguez et al. (2010) described that earthworms enhance microbial activity especially soil quality and crop production (Figure 3). Our study revealed that vermi-compost prepared through *Esinea fetida* was blackish-brown in color, highly porous, well-aerated with an earthy smell which was following the study of Hartenstein and Hartenstein (1981), who reported that vermi-compost has very high porosity, aeration, drainage, and water holding capacity. Our results also agreed with the findings of Teng et al. (2014) and Kuncoro et al. (2014). The pH of vermi-compost is very much essential because it affects the availability of nutrients in the soil (Yuvaraj et al., 2018). At the beginning of the experiment, pH was increased as 8.6 but the reduction was recorded at the end of vermi-compost production as 7.8. Komilis and Ham (2006) reported that the change in pH towards acidic or neutrality may be due to the formation of organic acids and mineralization of organic waste which leads to the production of both ammonium ions and humic acids. According to Ndegwa and Thompson (2000), the changes in pH of final vermi-compost are due to the decomposition of organic waste into organic acids. The observed EC values in our vermi-compost were 2.82 mS/cm and our results are consistent with Lazcano et al. (2008) and Bhat et al. (2016). They reported that EC below 4.0 mS/cm is a good indicator of the suitability and safety of vermin-compost for agricultural purposes. Vermicompost samples showed higher moisture contents (25%) compared to cow dung (18%), which may be due to higher degradation of wastes by *E. fetida* and maximum microbial population gathered in worm's gut environment. Our study agreed with Singh et al. (2003), who reported that the moisture content (25–30%) in vermi-compost proved the maximal microbial activity.

We observed that marigold treated with vermi-compost showed early initiation of seed germination and an overall increase in all growth parameters. Our findings agreed with Atiyeh et al. (2000), who reported the benefits of vermi-compost as bedding media to promote seed germination, seedling growth, and productivity of plants. Our study showed a significant increase in NPK level of vermi-compost compared to cow dung containing germinating media which favors early seed germination and increase in all germination and growth parameters. Previous literature reported that earthworms increase the nitrogen level and increase the nutrient accessibility to the plants which not only promotes the plant growth but also modify the vegetative structure (Tripathi et al., 2013; Jusselme et al., 2013; Mudrak et al., 2012; Ilieva-Makulec and Makulec 2007; Chaoui et al., 2003). Earthworms can lift the level of nitrogen during gut digestion by adding their body fluid, nitrogenous excretory products, enzymes, mucus, and even via decaying of dead materials in vermi-composting and current findings are consistent with the outcomes of Kaushik and Garg (2003), Suthar and Singh (2008), and Suthar (2007). We observed that the increased nitrogen level stimulates plant growth and vegetative structure. Increased nitrogen level may be attributed to the release of nitrogenous products of earthworm metabolism through the casts (excreta), urine, as well as mucoproteins. We agreed on the outcomes of Yuvaraj et al. (2018) and Li et al. (2013). The enhanced P (%) level in our vermin-compost suggests phosphorous mineralization during the composting process. Similarly, the increase in extractable K in

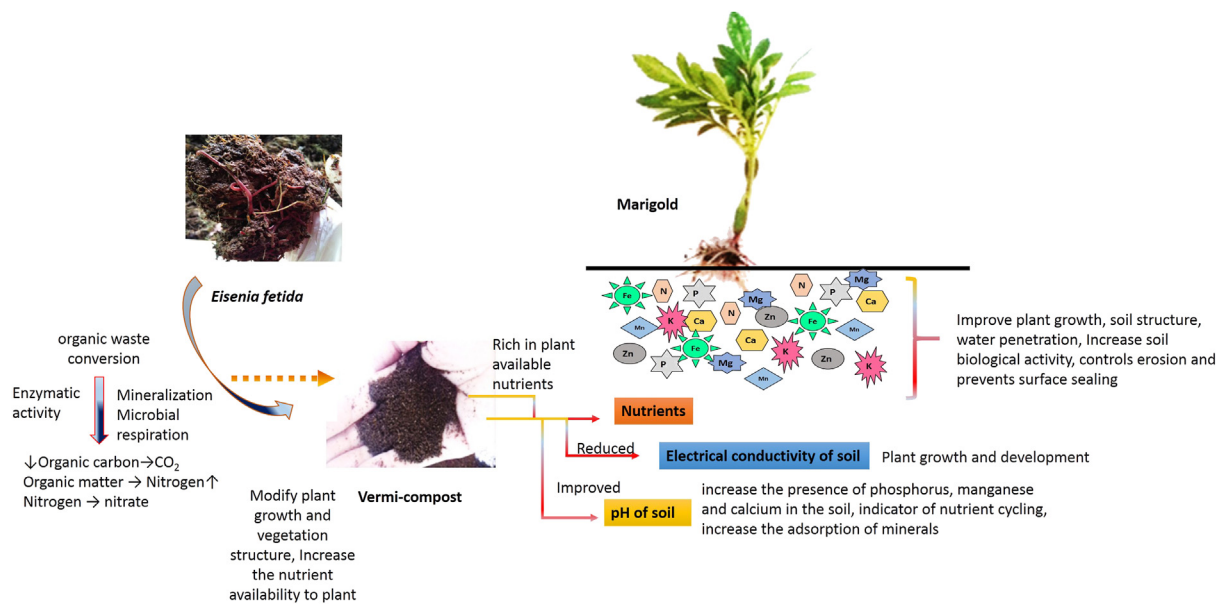


Figure 3. Impact of vermi-compost on the seed germination and growth parameters of marigold.

our vermin-compost may be attributed to the earthworm-mediated microbial activity during vermicomposting. Similar findings were shown by Padmavathamma et al. (2008) and Suthar and Singh (2008). On the other hand, a decreased level of organic carbons was recorded in mature vermin-compost and germination media having vermi-compost, which may be due to the mineralization, effect of earthworm activities, and thermophilic phase. Our findings are consistent with the earlier investigations (Garg et al., 2006; Suthar, 2007; Hait and Tare 2011). The decreased inorganic carbon may be also due to the loss of organic carbon as carbon dioxide (CO₂) via organic matter mineralization and microbial respiration (Padmavathamma et al. 2008). Similar findings were shown by Deepa kurian et al. (2008), when vermi-composting of leaf litter was done using *Eudrilus eugenia*.

Vermi-compost indicated the presence of trace metals like manganese, copper, iron, manganese, copper, calcium, sulphates, and zinc through atomic absorption spectrophotometry, which consistent with the findings of Shahmansouri et al. (2005). The maximum values of Mg and Ca in reported research were also consistent with the findings of Padmavathamma et al. (2008). Our study revealed that the cation exchange capacity of vermi-compost was maximum (72.48 me/100g) compared to cow dung (62.30 me/100g), and similar to findings of Xu and Mou (2016) who reported enhanced CEC value of harvested vermi-compost. The Carbon to Nitrogen (C:N) ratio is also a very important parameter for the stability and maturity of vermi-compost. The C:N ratio was reduced in mature vermi-compost (11:1) compared to cow dung (26:1). The loss of carbon to nitrogen ratio is due to the mineralization process and consistent with the findings of previous literature (Suthar 2008; Suthar and Singh, 2008; Singh et al., 2014; Shak et al., 2014). They reported that C:N less than 12 is preferable for agricultural purposes. The more reduction in the content of C/N ratio reflected efficient worm activity, leading to an accelerated rate of decomposition and mineralization, thereby resulting in high grade, nutrient-rich, good quality compost (Yuvaraj et al., 2018).

Current results showed the remarkable growth of marigold in vermi-compost containing germination medium. The significantly increased plant growth is due to the highly porous texture of vermi-compost and rich in nutrients and minerals, which play important role in the enhancement of physiochemical properties of soil, have a great impact on the movement of nutrients, water, and air to stimulate the plant growth and have a significant effect on the absorption efficiency (Figure 3). Our findings are therefore consistent with the work of previous researchers

(Salehi and Maleki 2012; Chaudhary et al., 2013; Blanchart et al., 2004; Singh et al., 2011). The current research showed the early initiation (2 days) of seed germination, minimum generation time, maximum mean daily generation, maximum speed of germination, maximum germination value, highest germination percentage, and peak value, in 20% VC concentration. Similarly, a considerable increase in all seedling growth parameters was recorded in treated plants; when compared to control plants' growth parameters. Our study revealed 20% vermi-compost concentration showed maximum growth of seedling i.e. increase in shoot length, number of leaves, diameter of leaves, length of leaves, leaf area, whole plant length, and root length. Makkar et al. (2017) reported that substituting soil with 60% (v/v) vermi-compost improved the performance of *Linum usitatissimum* seeds along with morpho-physiological parameters of seedling compared to control treatments. This was opposite to our findings where 20–30% VC doses were effective for nursery raising of ornamental plants and dosage above 40% may harm germination characteristics of plants.

Our study indicated that 35% vermi-compost addition has caused a significant increase in growth parameters like plant height, root volume, number of lateral shoots per plant and diameter of stem, number of open flowers, number of floral buds, diameter of flower, fresh and dry weight of flower, which consistent with the Singh et al. (2008). Atiyeh et al. (2001) studied the effect of pig's manure vermi-compost on the growth and yield of French marigold and showed the maximum vegetative growth at 30% and 40% v/v vermi-compost.

Our results demonstrate that post harvested germinated media contain significantly less bio-nutrients compared to the media used before transplantation and sowing. This may be because as the plant grows it extracts nutrients from the germinating media, and nutrients move up in the plant body thereby reducing the nutrient content in germinating media and also because the bioavailability of nutrients in vermi-compost is more compared to cow dung and synthetic fertilizers, thus all vermi-compost treatments showed significantly less nutrients after harvesting of marigold plants (Fig.1 and Fig.2). Our results reveal that maximum germination of marigold seedlings occurred at 20% VC concentration, more nutrients are uptaken by plants body, that's why 20% VC germinating media showed the least amount of nutrient profile compared to other vermi-compost concentrations. Similarly, the maximum decline of nutrients is shown by 35% VC post harvested media, ensuring the maximum uptake of nutrients in plant body resulting in maximum vegetative and reproductive characteristics. Nutrient analysis

of both controls (TCC and TO) suggested maximum retention of nutrients in media, thus allowing minimum nutrients to become bioavailable and uptaken by plants resulting in sluggish germination as well as overall growth as shown in Fig.1 and Fig.2.

5. Conclusion

In the current research, the impact of organic manure and vermicompost on the seed germination, seedlings, and growth parameters of marigold were comparatively studied. Seed germination and seedling parameters were maximum at 20% VC compared to other treatments. On the other hand, the vegetative growth and flowering parameters were maximum at 35% VC. Whole results reveal the potent effect of vermicompost on marigold compared to the control treatments. We suggested that the appropriate dose for nursery raising of marigold plants should be 20% VC whereas 35% VC is appropriate for the maximum vegetative growth, reproductive growth, and flowering of marigold. Therefore, vermi-compost could be used as a natural bio-fertilizer to increase ornamental plants production and for a sustainable horticulture system instead of inorganic fertilizer.

Declarations

Author contribution statement

Irsa Shafique, Malik Saim Aftab, Summaya Yahya, and Fayaz Ahmed: Performed the experiments and Wrote the paper.

Saiqa Andleeb: Conceived and designed the experiments and Wrote the paper.

Farrukh Naeem, Tauseef Tabasum, Tariq Sultan: Wrote the paper; Analyzed and interpreted the data.

Shaukat Ali, Beenish Shahid, and Abdul Hameed Khan: Contributed reagents, materials, analysis tools or data; Analyzed and interpreted the data.

Ghafoor ul Islam and Wajid Arshad Abbasi: Contributed reagents, materials, and analysis tools.

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Data availability statement

Data included in article/supplementary material/referenced in article.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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