Ecological Engineering 132 (2019) 23–30

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

Conditioning effects of biodegradable superabsorbent polymer and vermi-products on media properties and growth of gerbera

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ARTICLE INFO

Keywords:
Biodegradable superabsorbent polymer
Growth and flowering
Media properties
Vermicompost
Vermiwash

ABSTRACT

With the objective of identifying an ecologically sustainable substrate for commercial gerbera production, we conducted an experiment to assess the effects of super absorbent polymer and organic vermi-products on the physico-chemical properties of the growing media, and plant growth and flower yield in gerbera cv. Yosemite. CPV (Cocopeat: Perlite: Vermiculite) and soil amended with vermicompost (VC, 20%), Pusa hydrogel (PHG, 0.25%) and horn bio-manure (HBM, 1%) had significant positive effects on growth and flowering of gerbera. The lowest ($0.29 \pm 0.02\,g\,cm^{-3}$) bulk density was recorded in CPV + PHG + HBM while the maximum ($59.75 \pm 0.63\%$) water holding capacity was observed in CPV + PHG + VC substrate. The maximum electric conductivity ($0.99 \pm 0.06\,dS\,m^{-1}$) and pH ($7.90 \pm 0.04$) were recorded in Soil + PHG + VC. Plants grown on CPV + PHG + VC media and sprayed with 20% of vermiwash produced the highest number of leaves during the entire period (31 ± 0.58), maximum leaf length (30.18 ± 0.18 cm) and width (8.30 ± 0.16 cm), maximum number of primary roots (42 ± 1.53), highest flowers per plant (19.67 ± 0.33), stalk length (41.08 ± 0.10 cm) and flower head diameter (10.11 ± 0.03 cm). Flowers produced on this medium also had an extended attractive appearance (20.33 ± 0.33 days) and longer vase life (14.33 ± 0.33 days). Water requirement of gerbera (litre/crop season) on CPV + PHG + VC medium, with or without Vermiwash spray was also considerably lower than other treatments. Overall results suggest that CPV amended with PHG and VC coupled with Vermiwash spray provide congenial conditions for gerbera plant growth and flower production while also simultaneously reducing irrigation water use considerably.

1. Introduction

Growing medium plays a critical role in ensuring optimum plant growth by promoting the growth and development of the root system (Awang et al., 2009). Plants with properly developed roots have a firm anchorage; absorb soil nutrients and water easily and maintain optimum gaseous exchange between the roots and the atmosphere (Abad et al., 2001). Potting medium for flowering and other plants may either be soil-based or consist entirely of non-soil constituents. The physical and chemical properties of growing media may further be improved by the addition of amendments. In potted plants, the soilless media generally consist of peat, perlite, coco peat, vermiculite, rock wool and compost in the varying proportions. The main advantages of soilless culture over soil-based media are precise control over the supply of water and nutrients, favourable pH, better root aeration and temperature moderation as well as virtual elimination of soil borne pests and diseases, reduced labour requirement and no need for soil sterilization resulting in lower production costs and higher productivity (Sindhu et al., 2010).

Presently, different vermi-based value added products are being used commercially as media amendments. The vermicompost, commercially produced from farm wastes, improves the plant growth and yield when used as an amendment in the soilless plant media (Arancon et al., 2008). Nutrients released by the composting of organic wastes are subsequently adsorbed onto, or incorporated into the humus particles of the composted material. Different composts including vermicompost are also known to stimulate nutrient uptake and assimilation by the plants, and exhibit hormone-like activities as well (Tomati et al., 1995).

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https://doi.org/10.1016/j.ecoleng.2019.03.012
Received 1 June 2016; Received in revised form 14 March 2019; Accepted 25 March 2019

Vermicompost is currently being used as an organic fertilizer, soil amendment and potting medium constituent. Plant growth promoting effects of vermicompost application are mainly ascribed to the improvements in the physical and chemical properties of the growing media (Hernandez-Apaolaza et al., 2005). Nonetheless, available evidences suggest that plant hormone-like activity of secondary metabolites (Atiyeh et al., 2002) present in vermicompost could also have plant growth enhancing effects. Tomati et al. (1995) reported that vermicompost and vermiwash contain growth promoting hormones, *viz*., auxins, gibberellins and cytokinins secreted by the earthworms. Owing to these favourable effects, vermicompost has even been suggested as a potential ameliorant for the degraded soils (Mahmoud et al., 2015).

Vermiwash, a liquid fertilizer collected after the passage of water through a column of worm activation, shows very good results when used as foliar spray. It is essentially an amalgam of several excretory/secretory products from earthworms, and is rich in micronutrients and organic molecules useful for plants (Hatti et al., 2010). In addition to excellent fertilizer properties, vermiwash also acts as a mild biocide similar to vermicompost. Vermiwash also contains plant growth promoting substances such as auxin, cytokinin, gibberelic acid, amino acids, vitamins and enzymes possibly derived from microbes associated with earthworms (Zambare et al., 2008).

Although polymeric soil conditioners (hydrogel) are known since 1950s (El-Hady and Abo-Sedera, 2006), they have been predominantly used in pharmaceutical and tissue engineering applications. Of late, however, their varied agricultural usage have also come to fore. The use of soil conditioners like superabsorbent polymer (SAP) has a great potential to enhance the water use efficiency in crops. Hydrogel is increasingly being seen as a potential technology for enhancing the water and nutrient use efficiencies in plants, creating a congenial and nourishing rhizospheric micro-environment for better plant growth and yield. Such polymeric substances also improve the soil physical properties, *inter alia*, water holding capacity, permeability and infiltration; especially in structure less and drought affected soils (Singh et al., 2011). The SAP particles virtually act as a "miniature water reservoir" in that they slowly release the available water through osmotic pressure difference to the plant roots. The large quantity of water retained by the polymer provides extra available water to plants, stimulating shoot and root growth (Islam et al., 2011). Extended availability of water in the growing medium implies less frequent watering (Anupama et al., 2007), resulting in reduced irrigation water requirements and increased crop yields (Yazdani et al., 2007). Once incorporated into the soil, SAPs usually remain fully functional for 3–5 years (Dehkordi, 2016). Large amount of water can be retained depending on material, *i.e.*, 400–1500 g of water per gram of hydrogel (Tolstikh et al., 1992). Hydrogel treated plants show considerable increase in root length and root surface area; sometimes three and half fold higher than the plants grown in un-amended soil (Chen et al., 2004). When these hydrophilic polymers are used correctly and in ideal situations, they will have at least 95% of their stored water available for plant absorption (Johnson and Veltkamp, 1985). It is expected that combined applications of compatible organic and hydrogel materials to the growing medium may be more effective and economic than their solitary use (El-Hady et al., 2003). Addition of appropriate amounts of hydrogel can also arrest nutrient depletion from the media. It is increasingly becoming evident that hydrogel application could revolutionize water management in irrigated crops under climate change scenario, particularly in tropical and subtropical regions having high to very high evapotranspiration losses. Considering such putative benefits, a study was conducted to confirm the positive effects of different vermiproducts and superabsorbent polymer on plant growth and flower yield in gerbera (*Gerbera jamesonii*) cv. Yosemite.

2. Materials and methods

2.1. Materials, growing media and growing condition

Tissue cultured plants of gerbera cv. Yosemite were raised in earthen pots of 10″ diameter. Vermicompost (VC), Horn Bio-Manure (HBM) and Vermiwash (VW) procured from ICAR-Indian Veterinary Research Institute, Izzatnagar, Bareilly (UP), and Pusa Hydrogel (PHG) developed by ICAR-Indian Agricultural Research Institute (IARI) were tested in different combinations. Widely used potting media, *i.e.*, cocopeat, perlite and vermiculite (CPV) mixed in a ratio of 4:1:1 and the soils treated with different amendments were used as substrates. Untreated field soil was used as the control. The pots were filled with soilless media (cocopeat + perlite + vermiculite) and soil containing different amendments *i.e.*, VC (20% v/v), PHG (0.25%) and HBM (1% on weight basis). Different media combinations were soil (control), Soil + PHG, Soil + PHG + VC, Soil + PHG + HBM, CPV + PHG, CPV + PHG + VC and CPV + PHG + HBM. A single gerbera plant was transplanted in each pot, and irrigation and weeding were done as per recommendation. The average greenhouse temperature, relative humidity and the amount of light (light flux) were 18–28 °C, 50–70%, and 23000–25000 Lumen m^{-2}, respectively, during the experimental period.

2.2. Media sampling

The media samples were collected at the time of planting by properly mixing all the constituents and subsequent quartering so as to retain about 500 g of the composite sample. Samples were then air dried and crushed gently using the wooden pestle and mortar. The crushed material was sieved through 2 mm stainless steel or plastic sieve. Nearly all the determinations were carried out using the fractions below 2 mm size. When less than 1 g of sample was required for a particular analysis (*e.g.*, organic carbon), then 25–50 g of 2 mm fraction was further ground with pestle and mortar to pass through 0.5 or 0.2 mm sieve. The samples were put in plastic bag with one tag placed inside the bag and another tied on the bag.

2.3. Observations recorded

Data were recorded using the standard protocols to study the combined effects of vermi-products and Pusa hydrogel on plant growth in gerbera. The observations on physicochemical properties of growing media and growth parameters were recorded. Soil properties were estimated using the standard procedures. The bulk density (g/cm^3) of the growing media was determined by filling the dry media in flask at normal compaction at the time of filling of pots and measuring their weights (Shinohara et al., 1999). Water holding capacity of the media was measured by saturating the media with water and determining the moisture content of media by oven drying (48 h at 105 °C) until two consecutive readings gave a constant value. Soil pH and electrical conductivity (EC) were measured using a soil-water suspension (1:5 w/v) following Jackson (1980). Organic carbon was determined by wet oxidation method as described by Walkley and Black (1934). Water requirement was recorded treatment wise and was calculated as per plant per year.

2.4. Statistical analysis

The experiment was laid out in a factorial design. The data were analyzed using the statistical software SPSS 16.0 (SPSS Inc., Chicago, IL, USA). ANOVA factors were tested at 5, 1 and 0.1% levels of significance. The means were compared using the Tukey's HSD test at significance level of 5%. All data represent the mean ± standard error (SE) of three replications.

Table 1
Characteristics of different growth media composition before planting of gerbera.

Growth Media	Bulk Density (g/cm^3)	Water Holding Capacity (%)	EC_e (dS m^{-1})	pH	Organic carbon (%)	Available N (mg kg^{-1})	Available P (mg kg^{-1})	Available K (mg kg^{-1})
Soil	1.48 ± 0.02^a	24.87 ± 0.84^e	0.42 ± 0.02^c	7.86 ± 0.05^a	0.34 ± 0.01^c	102.28 ± 1.67^e	11.85 ± 0.80^c	186.06 ± 4.11^d
Soil + PHG	1.46 ± 0.03^a	40.08 ± 0.85^d	0.43 ± 0.01^c	7.61 ± 0.03^b	0.36 ± 0.01^c	100.45 ± 2.71^e	11.49 ± 1.23^c	185.29 ± 2.16^d
Soil + PHG + VC	1.28 ± 0.02^b	48.00 ± 0.98^c	0.99 ± 0.06^a	7.90 ± 0.04^a	0.41 ± 0.01^b	168.36 ± 4.69^c	31.68 ± 1.78^{ab}	211.99 ± 1.77^c
Soil + PHG + HBM	1.40 ± 0.01^a	41.79 ± 1.09^d	0.83 ± 0.04^{ab}	7.81 ± 0.01^{ab}	0.37 ± 0.01^c	152.51 ± 2.01^d	26.92 ± 1.04^b	198.21 ± 4.44^{cd}
CPV + PHG	0.30 ± 0.01^c	53.89 ± 1.04^b	0.81 ± 0.03^b	6.55 ± 0.06^d	0.52 ± 0.01^a	174.45 ± 3.00^{bc}	28.51 ± 0.90^b	274.09 ± 4.81^b
CPV + PHG + VC	0.35 ± 0.01^c	59.75 ± 0.63^a	0.94 ± 0.03^{ab}	6.87 ± 0.04^c	0.56 ± 0.01^a	201.96 ± 1.73^a	36.01 ± 1.58^a	307.42 ± 7.49^a
CPV + PHG + HBM	0.29 ± 0.02^c	54.44 ± 0.64^b	0.85 ± 0.03^{ab}	6.67 ± 0.06^{cd}	0.53 ± 0.01^a	185.46 ± 3.87^b	30.88 ± 1.14^{ab}	283.58 ± 6.03^b

Within each column, means followed by same letter are not significantly different at 5% level of significance using Tukey's HSD test.
Data represent the mean ± SE of three replications.

Table 2
Effect of different combinations of growth media and vermiwash on repetitive measure of leaves counts.

Growing Media	Vermiwash (%)	No. of Leaves at 30 DAS	No. of Leaves at 60 DAS	No. of Leaves at 90 DAS	Average No. of Leaves/Plant
Soil	0	5.33 ± 0.33^g	7.67 ± 0.67^g	15.33 ± 1.20^h	9.44 ± 0.11^k
	10	5.67 ± 0.33^{fg}	9.00 ± 0.58^{efg}	18.67 ± 2.03^{efgh}	11.11 ± 0.97^{ijk}
	20	6.67 ± 0.33^{defg}	10.33 ± 0.88^{defg}	21.33 ± 1.20^{bcdefgh}	12.78 ± 0.59^{fghi}
Soil + PHG	0	5.67 ± 0.33^{fg}	8.33 ± 0.33^{fg}	16.67 ± 1.76^{gh}	10.22 ± 0.40^{jk}
	10	6.33 ± 0.33^{efg}	10.33 ± 0.67^{defg}	19.67 ± 1.76^{defgh}	12.11 ± 0.29^{ghij}
	20	7.00 ± 0.00^{cdefg}	11.00 ± 1.00^{cdefg}	22.33 ± 1.20^{bcdefg}	13.44 ± 0.59^{defghi}
Soil + PHG + VC	0	6.33 ± 0.33^{efg}	9.33 ± 0.88^{efg}	19.33 ± 1.76^{efgh}	11.66 ± 0.33^{hijk}
	10	6.67 ± 0.33^{defg}	12.67 ± 0.33^{abcdef}	22.67 ± 1.86^{bcdefg}	14.00 ± 0.67^{defgh}
	20	7.67 ± 0.33^{bcde}	13.00 ± 1.58^{abcde}	25.33 ± 1.20^{abcde}	15.34 ± 0.33^{bcde}
Soil + PHG + HBM	0	6.67 ± 0.67^{defg}	9.00 ± 0.58^{afg}	18.33 ± 1.20^{fgh}	11.34 ± 0.33^{ijk}
	10	6.67 ± 0.33^{defg}	11.33 ± 0.88^{bcdefg}	21.67 ± 1.33^{bcdefgh}	13.22 ± 0.22^{efghi}
	20	8.67 ± 0.33^{abc}	12.33 ± 0.88^{abcdef}	24.33 ± 1.45^{abcdef}	15.11 ± 0.49^{bcdef}
CPV + PHG	0	7.67 ± 0.33^{bcde}	10.33 ± 0.33^{defg}	20.33 ± 1.20^{cdefgh}	12.78 ± 0.55^{fghi}
	10	8.00 ± 0.00^{bcde}	13.33 ± 0.33^{abcde}	23.67 ± 1.45^{bcdef}	15.00 ± 0.51^{bcdef}
	20	9.33 ± 0.33^{ab}	14.00 ± 1.15^{abcd}	26.33 ± 0.33^{abcd}	16.55 ± 0.22^{bc}
CPV + PHG + VC	0	8.33 ± 0.33^{abcd}	11.33 ± 0.67^{bcdefg}	23.00 ± 0.58^{bcdef}	14.22 ± 0.22^{cdefg}
	10	9.33 ± 0.33^{ab}	15.67 ± 0.33^{ab}	26.67 ± 0.33^{abc}	17.22 ± 0.11^{ab}
	20	10.00 ± 0.58^a	16.33 ± 0.88^a	31.00 ± 0.58^a	19.11 ± 0.62^a
CPV + PHG + HBM	0	7.33 ± 0.33^{cdef}	11.00 ± 1.15^{cdefg}	21.67 ± 0.88^{bcdefgh}	13.33 ± 0.33^{efghi}
	10	8.67 ± 0.33^{abc}	14.00 ± 1.53^{abcd}	25.00 ± 1.00^{abcdef}	15.89 ± 0.40^{bcd}
	20	9.33 ± 0.33^{ab}	15.00 ± 0.58^{abc}	28.00 ± 0.58^{ab}	17.44 ± 0.11^{ab}
Analysis of Variance					
Growing Media			***		
Vermiwash (%)			***		
Time of Observation			***		
Media × Vermiwash			NS		
Growing Media × Time of Observation			**		
Vermiwash × Time of Observation			***		
Growing Media × Vermiwash × Time of Observation			NS		

Within each column, means followed by same letter are not significantly different at 5% level of significance *, **, ***significant differences at $P < 0.05$, 0.01, or 0.001 respectively.
Data represent Mean ± SE.

3. Results

3.1. Physical properties of amended media

Bulk density is an important measure of soil quality because of its relationship with other properties such as porosity, soil moisture and hydraulic conductivity. Data presented in Table 1 demonstrate that bulk density invariably decreased with the addition of amendments. The maximum (1.48 ± 0.02 g cm^{-3}) bulk density was recorded in soil (control) followed by Soil + PHG (1.46 ± 0.03 g cm^{-3}), Soil + PHG + HBM (1.40 ± 0.01 g cm^{-3}) and Soil + PHG + VC (1.28 ± 0.02 g cm^{-3}), and it was found to be the minimum (0.29 ± 0.02 g/cm^3) in CPV + PHG + HBM medium. Data pertaining to water retention characteristics of seven growing media (Table 1) also revealed that water holding capacity (WHC) significantly increased with the addition of PHG. The highest (59.75 ± 0.63%) WHC was observed in CPV + PHG + VC treatment followed by CPV + PHG + HBM (54.44 ± 0.64%). In comparison, control soil showed the lowest (24.87 ± 0.84%) WHC.

3.2. Chemical properties of amended media

Electrical conductivity (EC_e) of different media varied with their composition (Table 1). Soil amended with PHG + VC had the maximum saturation extract salinity (EC_e; 0.99 ± 0.06 dS m^{-1}) that was nearly 2.5 times higher than that of unamended control. Although EC_e slightly decreased in CPV + PHG + VC (0.94 ± 0.03 dS m^{-1}) medium, it ranged from 0.81 to 0.85 dS m^{-1} in other treatments and remained unchanged in the PHG treated soil. Electrical conductivity reflects the degree of salinity in the growing substrate. Excessively high salinity in root zone results in high osmotic pressure that in turn adversely affects the water absorption by the plant roots. Elevated salinity also diminishes the uptake of essential nutrients with a concurrent increase in tissue Na^+ and Cl^- concentrations. While addition of PHG, VC and

HBM, either alone or in combination, did not appreciably influence the soil pH, incorporation of these amendments into CPV substrate led to 12.6–16.6% decrease in pH as compared to control soil. The pH of any growing media directly affects the availability of nutrients to the plants. Addition of VC into both soil and soilless media significantly increased the organic carbon with the maximum (0.56 ± 0.01%) and the minimum (0.34 ± 0.01%) organic carbon contents noted in CPV + PHG + VC and soil, respectively. Data presented in Table 1 also reflect that available N, P and K contents also increased significantly in after various amendments were added. In comparison to control soil, addition of PHG and VC or PHG and HBM increased available N by nearly 1.5 times. The maximum available N (201.96 ± 1.73 mg kg^{-1}) in CPV + PHG + VC was nearly twice the available N in untreated soil. Like available N, addition of PHG alone to the soil did not increase available P and K contents significantly. Contrarily, conjunctive additions of PHG and VC or HBM to the soil/CPV led to almost threefold increase in available P and K levels than control. The highest available P (36.01 ± 1.58 mg kg^{-1}) and K (307.42 ± 7.49 mg kg^{-1}) were recorded in the CPV + PHG + VC substrate.

3.3. Effect on plant growth, flowering and water requirement

Data presented Table 2 indicate that number of leaves at different growth stages *i.e.*, 30, 60 and 90 days after sowing (DAS) was invariably higher in the soil and CPV containing various combinations of PHG, VC and HBM. Although maximum number of leaves at 30 (10.00 ± 0.58), 60 (16.33 ± 0.88) and 90 DAS (31.00 ± 0.58) was recorded in plants grown on CPV + PHG + VC medium and sprayed with 20% vermiwash, it was non-significantly different with CPV + PHG + HBM plus 20% Vermiwash treatment. Data shown in Fig. 1 and Table 3 reveal that different amendments and vermiwash application had a significant influence on increasing various plant growth parameters like leaf length and width, number of primary roots and plant dry weight. The maximum leaf length (30.18 ± 0.18 cm) recorded in plants grown on CPV + PHG + VC and sprayed with 20% vermiwash was nearly 17% higher compared to plants grown on the same substrate but not receiving vermiwash. Among different treatments consisting of Soil and different amendments (PHG + VC) was found to be the best with regard to leaf length (23.49 ± 0.27 cm). A similar trend was also noted for leaf width; plants on CPV + PHG + VC substrate receiving 20% vermiwash showed the maximum leaf width (8.30 ± 0.16 cm) while its lowest value (6.42 ± 0.04 cm) was recorded in control. Gerbera plants on CPV + PHG + VC medium and sprayed with 20% vermiwash also had the maximum plant dry weight (33.50 ± 0.48 g) that was over two fold higher than control. Interestingly, plants grown in the soils amended with PHG, VC and HBM had less dry weight compared to those grown on CPV treated with these amendments. Amelioration of growing media with vermi-products and PHG also significantly increased the number of primary roots (Figs. 1 and 2). Plants grown on media containing CPV + PHG + VC and sprayed with 20% vermiwash had the maximum primary root count (42 ± 1.58); considerably higher than rest of the treatments (Table 3). The most conspicuous effect of the hydrogel and vermicompost application was seen with regard to reduced frequency of irrigation as their incorporation in the medium significantly reduced the water requirement (per plant per year). The minimum (99.32 + 1.45 l) water requirement per plant was recorded in plants grown on CPV + PHG + VC without vermiwash spray. In the same medium, plants sprayed with 10% and 20% of vermiwash required 103.5 ± 1.10 L and 107.95 ± 0.83 L of water, respectively per year (Fig. 2 and Table 3). Among the soil amended media, the maximum reduction in water requirement (34.19%) than control was recorded in Soil + PGH + VC followed by Soil + PHG (30.18%).

Data on flower parameters furnished in Table 4 revealed that flower production improved with the addition of different media into soil and CPV. The highest (19.67 ± 0.0.33) number of flowers was obtained when the plants were grown on CPV + PHG + VC and sprayed with 20% vermiwash. Significant effect of different amendments and vermiwash levels was also seen with regard the flower head diameter that was the highest (10.11 ± 0.0.03 cm) on CPV + PHG + VC substrate with 20% vermiwash spray and the lowest (7.98 ± 0.05) in control. Maximum (82.67 ± 1.86) number of ray florets were observed in flowers grown on CPV + PHG + VC and sprayed with 20% vermiwash followed by CPV + PHG + HBM (79.67 ± 0.67) and CPV + PHG (78.00 ± 0.58). Stalk length was also considerably higher in plants raised on soil or CPV amended with PHG, VC and HBM; especially when two of these amendments were added together and plants were sprayed with 10 or 20% vermiwash. While the highest stalk length (41.08 + 0.10 cm) was noted in CPV + PHG + VC and 20% vermiwash treatment, stalk length on CPV + PHG + VC or CPV + PHG + HBM media receiving 10 and 20% vermiwash, respectively, was also much higher than rest of the treatments including control. While the flowers obtained from CPV + PHG + VC + 20% vermiwash treatment withstood deterioration for an extended time (20.33 ± 0.33 days). In comparison, those produced on the same medium but sprayed with 10% vermiwash perished only in 18.33 ± 0.33 days. In contrast, flowers borne on soil grown plants without vermiwash application remained healthy for a much shorter time (14.00 ± 0.58 days). There was a significant effect of media amendments and vermiwash concentration on the vase life of flowers. Data show that vermiwash spray

Fig. 1. Effect of different vermi-products and Pusa hydrogel on root parameters.

Table 3
Effect of different growth media and vermiwash on mean number of leaf length, leaf width, number of primary roots, plant dry weight and water requirement/plant of Gerbera.

Growing Media	Vermiwash (%)	Leaf Length (cm)	Leaf Width (cm)	Plant dry weight (g)	Number of primary Root	Water requirement (litters/crop season)
Soil	0	14.74 ± 0.26^{n}	6.42 ± 0.04^{k}	15.41 ± 0.23^{n}	11.67 ± 0.67^{h}	177.28 ± 1.39^{c}
	10	19.47 ± 0.32c^{kl}	6.86 ± 0.04^{ij}	18.05 ± 0.22^{m}	13.67 ± 0.88^{gh}	185.62 ± 1.37^{b}
	20	20.14 ± 0.48^{jkl}	6.98 ± 0.02^{hij}	20.93 ± 0.47^{ijk}	16.00 ± 0.58^{fgh}	192.92 ± 1.48^{a}
Soil + PHG	0	15.67 ± 0.43^{n}	6.72 ± 0.04^{j}	17.11 ± 0.24^{m}	14.00 ± 0.58^{gh}	123.76 ± 1.06^{fg}
	10	20.33 ± 0.33^{ijk}	7.15 ± 0.02d^{fgh}	20.52 ± 0.24^{jk}	15.67 ± 0.88^{fgh}	132.98 ± 1.61^{e}
	20	21.00 ± 0.28^{hijk}	7.24 ± 0.03^{efg}	22.34 ± 0.31^{ghi}	17.67 ± 1.20^{efgh}	140.31 ± 1.06^{d}
Soil + PHG + VC	0	18.29 ± 0.46^{lm}	7.18 ± 0.02^{fgh}	20.13 ± 0.37^{kl}	21.33 ± 0.88^{ef}	116.66 ± 1.56^{hij}
	10	22.49 ± 0.47^{fgh}	7.37 ± 0.02^{def}	21.89 ± 0.30^{hij}	21.67 ± 1.86^{ef}	121.73 ± 1.63^{fghi}
	20	23.49 ± 0.27^{efg}	7.47 ± 0.04^{de}	25.44 ± 0.23^{ef}	23.33 ± 1.86^{e}	123.73 ± 1.03^{fg}
Soil + PHG + HBM	0	16.48 ± 0.30^{mn}	7.07 ± 0.03^{ghi}	18.74 ± 0.29^{lm}	18.00 ± 0.58^{efg}	121.69 ± 0.99^{fghi}
	10	21.68 ± 0.42^{ghij}	7.22 ± 0.02^{efgh}	20.44 ± 0.28^{jk}	19.00 ± 0.58^{efg}	127.68 ± 1.13^{ef}
	20	22.62 ± 0.42^{fgh}	7.36 ± 0.02^{def}	23.89 ± 0.26^{fg}	22.67 ± 1.45^{e}	131.85 ± 1.36^{e}
CPV + PHG	0	22.10 ± 0.49^{fghi}	7.16 ± 0.05^{fgh}	23.30 ± 0.36^{gh}	29.67 ± 0.88^{d}	109.69 ± 1.16^{klm}
	10	25.18 ± 0.18^{de}	7.58 ± 0.05^{cd}	25.92 ± 0.48^{e}	32.33 ± 1.20^{cd}	115.27 ± 0.63^{ijk}
	20	26.11 ± 0.11^{cd}	7.83 ± 0.05^{bc}	31.07 ± 0.35^{bc}	33.00 ± 1.53^{bcd}	122.84 ± 0.50^{fgh}
CPV + PHG + VC	0	24.95 ± 0.32^{de}	7.97 ± 0.02^{b}	29.44 ± 0.45^{cd}	34.00 ± 1.15^{bcd}	99.32 ± 1.45^{n}
	10	28.91 ± 0.31^{ab}	8.25 ± 0.03^{a}	31.11 ± 0.37^{b}	39.00 ± 0.58^{ab}	103.50 ± 1.10^{mn}
	20	30.18 ± 0.18^{a}	8.30 ± 0.16^{a}	33.50 ± 0.48^{a}	42.00 ± 1.53^{a}	107.95 ± 0.83^{lm}
CPV + PHG + HBM	0	23.62 ± 0.43^{ef}	7.47 ± 0.03^{de}	25.56 ± 0.27^{e}	30.67 ± 1.20^{cd}	109.47 ± 1.13^{klm}
	10	26.23 ± 0.16^{cd}	7.82 ± 0.02^{bc}	26.90 ± 0.23^{e}	36.33 ± 1.33^{abc}	114.42 ± 0.85^{jkl}
	20	27.20 ± 0.17^{bc}	8.07 ± 0.05^{ab}	28.57 ± 0.31^{d}	36.67 ± 0.88^{abc}	118.18 ± 1.72^{ghij}
Analysis of Variance						
Growing Media		***	***	***	***	***
Vermiwash (%)		***	***	***	***	***
Media × Vermiwash		NS	**	***	NS	*

Within each column, means followed by same letter are not significantly different at 5% level of significance using Tukey's HSD test. NS, *, **, *** refer to non-significant difference or significant differences at 5, 1 and 0.1% levels of significance, respectively.
Data represent the mean ± SE.

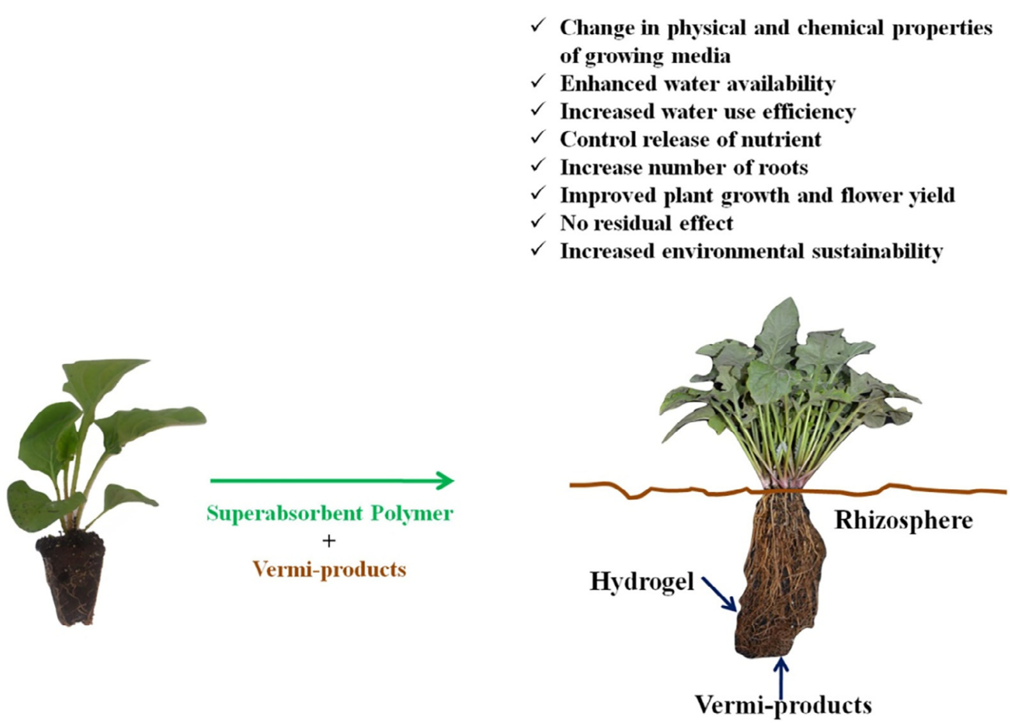

Fig. 2. Effect of biodegradable superabsorbent polymer and vermi-products on growth of gerbera plant.

(20%) extended the vase life of flowers regardless of media and amendments. The highest vase life (14.33 ± 0.33 days) was recorded in flowers produced on CPV + PHG + VC with 20% vermiwash.

4. Discussion

Hydrogel application in general improves water retention in soil and soilless substrates, suggesting its potential role in increasing crop water use efficiency (Cannazza et al., 2014). The Pusa hydrogel used in present investigation is a biodegradable and environmental friendly material (Anupama et al., 2007). It is known that flowers produced on convention soil-based media are often of an inferior quality, reflecting the need to develop low cost potting media having potential to enhance the flower quality while optimizing the resource use. Evidently,

Table 4
Effect of different combinations of growth media and vermiwash on flowering parameters of Gerbera.

Growing Media	Vermiwash (%)	Flowers Plant^{-1}	Flower head diameter (cm)	Number of ray florets	Stalk Length (cm)	Days taken to flower senescence	Vase life (days)
Soil	0	9.67 ± 0.33^{ij}	7.98 ± 0.05^{j}	56.00 ± 0.58^{k}	23.16 ± 0.37^{n}	14.00 ± 0.58^{k}	7.00 ± 0.00^{k}
	10	11.00 ± 0.58^{ghij}	8.60 ± 0.18^{hi}	63.33 ± 0.67^{ij}	26.33 ± 0.44^{lm}	16.00 ± 0.58^{efghijk}	8.33 ± 0.33^{ijk}
	20	11.67 ± 0.33^{ghi}	8.85 ± 0.07^{gh}	66.33 ± 0.88^{fghij}	28.49 ± 0.51^{k}	17.00 ± 0.58^{defghi}	9.00 ± 0.33^{ghij}
Soil + PHG	0	9.33 ± 0.33^{j}	8.37 ± 0.06^{ij}	60.67 ± 0.88^{jk}	25.98 ± 0.38^{m}	14.33 ± 0.33^{jk}	7.67 ± 0.33^{jk}
	10	11.67 ± 0.33^{ghi}	8.82 ± 0.09^{gh}	66.00 ± 0.58^{ghij}	27.35 ± 0.43^{klm}	16.33 ± 0.33^{efghijk}	9.00 ± 0.00^{ghij}
	20	12.67 ± 0.33^{defg}	9.07 ± 0.03^{defg}	69.33 ± 0.88^{efgh}	30.70 ± 0.19^{i}	17.67 ± 0.67^{bcdefg}	10.00 ± 0.00^{efgh}
Soil + PHG + VC	0	11.33 ± 0.33^{ghij}	9.06 ± 0.03^{fg}	67.33 ± 0.33^{fghi}	29.02 ± 0.19^{jk}	15.00 ± 0.58^{hijk}	9.67 ± 0.33^{fghi}
	10	12.67 ± 0.33^{defg}	9.29 ± 0.07^{cdef}	71.00 ± 1.15^{cdefg}	31.92 ± 0.25^{hi}	17.33 ± 0.33^{cdefgh}	10.00 ± 0.00^{efgh}
	20	14.00 ± 0.58^{cdef}	9.54 ± 0.05^{bc}	76.00 ± 2.08^{bcd}	34.06 ± 0.12^{fg}	19.33 ± 0.33^{abcd}	11.33 ± 0.33^{cde}
Soil + PHG + HBM	0	10.33 ± 0.33^{hij}	8.61 ± 0.07^{hi}	64.00 ± 1.53^{hij}	27.66 ± 0.32^{kl}	14.67 ± 0.33^{ijk}	8.67 ± 0.33^{hij}
	10	12.00 ± 0.00^{fgh}	9.07 ± 0.04^{efg}	68.67 ± 0.33^{fghi}	30.33 ± 0.47^{ij}	16.67 ± 0.33^{efghij}	9.33 ± 0.33^{fghi}
	20	13.00 ± 0.00^{defg}	9.28 ± 0.09^{cdef}	71.67 ± 0.33^{cdefg}	32.61 ± 0.27^{fgh}	18.00 ± 0.58^{abcdef}	10.33 ± 0.33^{defg}
CPV + PHG	0	12.33 ± 0.33^{efgh}	9.27 ± 0.04^{cdef}	70.33 ± 0.67^{defg}	32.55 ± 0.32^{gh}	15.33 ± 0.33^{ghijk}	10.00 ± 0.00^{efgh}
	10	14.33 ± 0.33^{cde}	9.48 ± 0.04^{bcd}	75.00 ± 1.15^{bcde}	34.28 ± 0.09^{ef}	17.67 ± 0.33^{bcdef}	10.67 ± 0.33^{cdef}
	20	16.00 ± 0.58^{bc}	9.63 ± 0.02^{bc}	78.00 ± 0.58^{ab}	35.87 ± 0.31^{de}	20.00 ± 0.58^{ab}	12.00 ± 0.00^{bc}
CPV + PHG + VC	0	14.67 ± 0.33^{cd}	9.67 ± 0.02^{bc}	75.00 ± 1.73^{bcde}	36.32 ± 0.28^{d}	16.33 ± 0.88^{efghijk}	10.33 ± 0.33^{defg}
	10	17.67 ± 0.33^{ab}	9.78 ± 0.15^{ab}	79.33 ± 0.88^{ab}	38.34 ± 0.20^{b}	18.33 ± 0.33^{abcde}	11.67 ± 0.33^{cd}
	20	19.67 ± 0.33^{a}	10.11 ± 0.03^{a}	82.67 ± 1.86^{a}	41.08 ± 0.10^{a}	20.33 ± 0.33^{a}	14.33 ± 0.33^{a}
CPV + PHG + HBM	0	12.67 ± 0.33^{defg}	9.48 ± 0.04^{bcde}	72.00 ± 0.58^{cdef}	33.97 ± 0.08^{fg}	15.67 ± 0.33^{fghijk}	10.67 ± 0.33^{cdef}
	10	15.67 ± 0.33^{bc}	9.58 ± 0.05^{bc}	76.67 ± 0.88^{bc}	36.43 ± 0.46^{cd}	18.00 ± 0.58^{abcdef}	11.67 ± 0.33^{cd}
	20	17.00 ± 0.58^{b}	9.78 ± 0.15^{ab}	79.67 ± 0.67^{ab}	38.07 ± 0.04^{bc}	19.67 ± 0.33^{abc}	13.33 ± 0.33^{ab}
Analysis of Variance							
Growing Media		***	***	***	***	***	***
Vermiwash (%)		***	***	***	***	***	***
Media × Vermiwash		NS	NS	NS	*	NS	**

Within each column, means followed by same letter are not significantly different at 5% level of significance using Tukey's HSD test. NS, *, **, *** refer to non-significant difference or significant differences at 5, 1 and 0.1% levels of significance, respectively.
Data represent the mean ± SE.

selection of an appropriate growing substrate alone can lead to noticeable improvements in the flower yield and quality (Awang et al., 2009). Improved potting media offer many benefits over soil and other routinely used materials. These include adequate availability of water and nutrients to the plants, proper gaseous diffusion to the roots, and mechanical support to the plants (Abad et al., 2001). It has also been reported that additions of vermiwash and vermicompost may further improve the physical and chemical qualities of the growing substrate including enhanced nutrient availability, resulting in better plant growth and higher productivity. It is believed that combined application of organic materials and hydrogel to the soil may be more effective and economical than using each of them alone (El-Hady et al., 2003).

4.1. Physio-chemical characteristics of amended media

Roots of the potted plants are not evenly distributed and most of the roots are found at the bottom layers necessitating careful selection and analysis of the media for physico-chemical properties. Additions of amendments (VC, PHG and HBM) had a significant effect on different physical and chemical properties of the growing media. The largest reduction in soil bulk density, in comparison to control, was noted when PHG and VC were added together, while other amendments had little effect. Lower bulk density in CPV treated with different amendments was presumably due to the higher total pore space as previously reported (Nowak and Strojny, 2004). The water holding capacity of the growing medium depends on the percentage pore space of the substrate. We found that PHG application led to appreciable reductions in soil bulk density, resulting in increased water holding capacity. Hydrophilic polymers significantly reduce the irrigation requirement by increasing the water holding capacity of soil and soilless media (Singh et al., 2011; Abedi-Koupai and Asadkazemi, 2006). In addition to water and nutrient savings, hydrogel incorporation into growing medium also reduces time and energy expenditure in crop management (Anupama et al., 2007). Addition of vermicompost into soil and CPV increased the pH and electrical conductivity of the amended media. Increased salinity of VC amended media was probably due to release of small amounts of some salts and minerals. The pH and salinity of growing medium are important properties directly influencing the nutrient availability to plants. Soil pH affects almost all the physical, chemical and biological properties of soils. Inclusion of amendments is known to increase the pH of media (Savvas et al., 2003). Awang et al. (2009) and Caballero et al. (2009) observed favourable pH and EC in coco fiber while comparing the different substrates for celosia and gerbera production. Nutrient availability is one of major factors determining the suitability of a potting substrate (Caballero et al., 2009). Results indicated that amendments (VC, PHG and HBM) had a positive effect on nutrient availability as evidenced by better gerbera growth and higher flower yield in amended media than in control soil. Sindhu et al. (2009) reported higher available N in vermicompost treated than in basic medium. Similarly, available P content increased after addition of organic substances into the main medium (Ahmad et al., 2012). Herencia et al. (2008) suggested increase in K content could be due to high K content of compost and increase in exchange sites due to organic matter addition. Organic material treated potting media show increased availability of macro and micronutrients (Edmeades, 2003; Warman, 2005). It is also known that application of organic materials properly mixed with hydrogel is more effective and economical than using each of them alone (El-Hady et al., 2003), which supports our findings in gerbera.

4.2. Growth, flowering and water requirement

In the present work, applications of organic products (vermi-products, vermiwash and horn-bio-manure) and Pusa hydrogel improved different media properties to varying extents. The number, length and breadth of leaves, plant dry weight, number of roots and flowers, stalk length, flower head diameter, days taken for flower senescence and vase life were the highest in the plants grown on CPV ameliorated with PHG + VC and sprayed with 20% of vermiwash. Amelioration of growing media with PHG alone did not appreciably improve the physical and chemical properties. In contrast, combined application of both PHG and VC positively influenced different properties leading to better plant growth. Increase in the number of leaves was presumably due to higher accumulation of photosynthates utilized in plant growth and development (Verma et al., 2018). Incorporation of PHG + VC into soil resulted in considerable improvements in growth and flowering as compared to control (soil) and other combinations of soil and amendments. Better results obtained in Soil + PHG + HBM and CPV + PHG + HBM treatments over Soil + PHG and CPV + PHG, respectively, were probably due to addition of macro and micronutrient rich HBM. Despite being rich in nutrients, HBM application alone did not give better results over VC as HBM addition alone resulted in little improvements in the physical and chemical properties of media. Therefore, it is suggested to raise gerbera plants in soil ameliorated with 0.25% hydrogel and 20% vermicompost if soilless media are unavailable. Nowak and Strojny (2004) reported significant increase in leaf length of gerbera plants grown on different growing medium. Increase in the plant height, number of leaves, fresh and dry weights of plants and suckers were noted when gerbera was grown on CVP + Samridhi in the ratio of 8:1 (Sindhu et al., 2010).

Incorporation of either vermicompost at 20, 40 and 60% or sphagnum peat at 30 and 60% into the base medium improved the leaf growth, shoot fresh and dry weights and flower production in petunia compared to both control and peat amended media. Plant performance was the best on 20% vermicompost medium (Chamani et al., 2008). Sardoei et al. (2014) reported that relatively higher doses (40, 50 and 60%) of vermicompost increased the growth and flower yield in marigold. Vermicompost, containing higher levels of essential macro and micronutrients, improves the plant growth and development. Although some of these nutrients are present in readily available inorganic forms, most are released gradually through mineralization. Vermicompost, therefore, acts as a slow-release source of nutrients (Mupambwa et al., 2016). Vermicompost has also been found to have positive effects on plant growth and development by Atiyeh et al. (2002) in tomato and cucumber; by Hidalgo and Harkess (2002) in chrysanthemum and by Arancon et al. (2008) in petunia. Production of significant amounts of plant growth regulators such as auxins, gibberellins and cytokinins by the microorganisms present in vermicompost also seems to improve the plant growth. Similarly, large quantities of humic acid produced during vermicomposting have also been reported to improve the plant growth (Atiyeh et al., 2002). Humic substances extracted from earthworm compost and capable of inducing lateral root growth exhibit a mechanism of action similar to that of root growth promoting auxin indole acetic acid (Canellas et al., 2002).

Vermiwash, consisting of excretory and secretory earthworm products, is a rich source of micronutrients and organic molecules useful for plants (Hatti et al., 2010). Devan et al. (2013) reported that among the various foliar treatments used in okra, 15% vermiwash showed the maximal growth enhancing effects followed by 10% vermiwash, 100 ppm gibberellic acid and 100 ppm naphthalene acetic acid. Results indicated that vermiwash can be exploited as a potential bio-fertiliser in gerbera. These findings support our results as spray of 20% vermiwash further enhanced the growth promoting effects of amendments. Changes in the nutrient dynamics resulting in improved availability of macro and micro nutrients due to use of the vermicompost and vermiwash markedly enhances the plant growth (Manyuchi et al., 2013).

Increasing global attention on environmental sustainability in general and water saving technologies in agriculture in particular have enhanced the interest in biodegradable polymers such as hydrogel prompting researchers to explore their potential commercial applications in irrigated agriculture. Application of SAP increases water availability to the plants and reduces the drought induced oxidative stress at tissue and cellular levels leading to increased biomass production (Islam et al., 2011). In the present experiment, plants grown on hydrogel-amended medium showed vigorous rooting as compared to control plants. SAPs increase the turgor pressure inside the cells by maintaining sufficient amount of water to meet the plant needs and thus increase in leaf area and root growth (Yazdani et al., 2007). Montesano et al. (2015) reported that cucumber and sweet basil grown in soil and soilless media amended with hydrogel showed an overall increase in plant growth. In our study vermicompost and hydrogel had beneficial effects on water retention in soil and soilless substrate; otherwise known to have poor water retention properties. Hydrophilic polymers such as hydrogel improve the seedling growth and establishment by increasing the water retention in soil and by regulating the plant water supply (Orikiriza et al., 2009). Incorporation of acrylamide hydrogels significantly increased the water use efficiency in tomato grown in a sandy calcareous soil (El-Hady and Camilia, 2006). Anupama et al. (2007) found that application of 0.5% and 1.0% hydrogel in chrysanthemum growing medium led to remarkable reductions of 60.8% and 58.4%, respectively, in plant consumptive water use compared to control. However, further increase in hydrogel dose to 1.5% and 2.0% caused reduction in water use by 37.8% and 36.1%, respectively, which seemed to be due to virtually no space available for the swelling of hydrogel when applied in higher amounts. Chrysanthemum plants grown on media amended with 1.0% hydrogel also had higher number of leaves and the vase life of flowers. The hydrogel showed best response in terms of efficient water and ion holding capacity at low rates of application. Addition of hydrogel in growing medium saves the water and nutrients as well as time and energy in crop management (Anupama et al., 2007).

5. Conclusion

Our findings reveal that application of appropriate amendments plays a key role in improving the physical and chemical properties of the growing media, and in turn, plant growth in gerbera. Amendment modulated improvements in soil properties and plant growth could even be more pronounced in media having poor growth conditions. Amelioration of media with hydrogel and vermicompost improved the physical and chemical properties leading to better plant growth in gerbera cv. Yosemite. Blended application of PHG and vermicompost was found to be more effective than their solitary use. Vermiwash (20%) application further improved the growth and flowering of gerbera by increasing the nutrient availability. PHG mediated alleviation of water stress and hormone-like effects of vermicompost and vermiwash contributed to better plant growth. PHG was also found to remain functional in soil for a longer period, thus enhancing the plant water use efficiency. Results of this study are expected to benefit the gerbera growers in the regions suffering from fresh water scarcity. The fact that addition of SAP significantly improved the moisture content of soil and soilless media points to its potential applications in field and horticultural crops for substantial water savings.

Acknowledgement

The corresponding author sincerely acknowledges the Director, ICAR-Indian Agricultural Research Institute, New Delhi, India for providing the research facilities and financial assistance (Senior Research Fellowship).

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