Vermi products and biodegradable superabsorbent polymer improve physiological activities and leaf nutrient contents of gerbera

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Abstract
Consistent with the fact that limited water and nutrient availabilities adversely impact the growth of potted plants, we investigated the effects of vermi-products and Pusa Hydrogel on physio-biochemical relations of gerbera cv. Yosemite. The potting media having CPV (Cocopeat: Perlite: Vermiculite in 4:1:1 ratio) and the soils amended with vermicompost (VC), pusa hydrogel (PHG) and/or horn bio-manure (HBM) had significant positive effects on plant physiological parameters that greatly influence growth and flower yield. Amelioration of growing media with 20% VC, 0.25% PHG and 1.0% HBM and the application of 20% vermiwash (VW) proved superior over other treatments in terms of marked improvements in leaf chlorophyll content, gas exchange characteristics and mineral acquisition by gerbera plants.

In most of the cases, incremental additions of amendments and supplemental VW spray positively influenced these traits. Notably, 20% VW almost invariably proved superior over its lower (10%) concentration with regard to the parameters studied. Correlation study revealed that photosynthesis significantly increased with increase in stomatal conductance.

Similarly, plants having high relative water content in leaves also maintained higher chlorophyll levels. The beneficial effects of soil substitution and/or enrichment with different media seemed partly due to favourable changes in the physico-chemical properties of the growing media. It also appeared that conjunctive use of amendments and supplementary VW applications acted synergistically to enhance the plant performance. These findings lead to the conclusion that incorporation of vermi-products and superabsorbent polymers in conventionally used media may prove beneficial for gerbera plant growth and flower yield.

Keywords: *Gerbera jamesonii,* growing media, hydrogel, physiological parameters, vermicompost leachate.

Introduction

Gerbera (*Gerbera jamesonii* H. Bolus) is highly valued for its beautiful flowers characterized by their exquisite shape and size and attractive colours. When grown in pots, gerbera plants require frequent irrigation and nutrient inputs for optimum physiological functions and growth. It is due to this reason that a good potting media should retain water for longer duration of time so as to minimize the adverse impacts of water stress on plant growth. In drying soils, stomatal conductance decreases leading to restricted water uptake which then affects the plant growth.

Water stressed plants also exhibit the loss of photosynthetic pigments and decline in photosynthesis which account for reduced biomass production. Under limited water conditions, stomatal closure results in low CO_2 fixation and decreased availability of oxidized $NADP^+$ as an electron acceptor for photosystem resulting in the accumulation of harmful reactive oxygen species detrimental to key biomolecules such as nucleic acids and lipids[26].

Fresh water shortages and relentless land degradation could cause heavy losses in agricultural production, especially in irrigated lands, in the foreseeable future. Different agronomic interventions including the adoption of drought tolerant cultivars and water saving irrigation techniques have been proposed to maintain the water balance under limited water supply conditions; especially in water stress sensitive crops such as gerbera where restricted water supplies may cause enormous losses in flower yield and quality[26]. A number of amendments and conditioners enhance the plant growth by improving the soil properties and enhancing the water retention in the growing media[14]. Vermicompost (VC) containing worm castings and/or digested excretions is a soil conditioner used in both field and horticultural crops. It is rich in plant nutrients and improves the soil structure by enhancing its porosity, aeration and moisture holding capacity[7].

Addition of VC to the growing media increases seed germination, growth, flowering and fruit production in a range of plants[4]. When used with vermiwash (VW), VC gives even better results probably due to synergistic action[27]. It has also been implicated in reducing the physiological disorders, removal of pesticide residues and other undesirable substances harmful to soil health and plant growth[20]. Vermiwash contains several enzymes, plant growth hormones, vitamins and essential macro and micronutrients[28] which increase plant tolerance to diseases and other stresses[25]. The foliar spray of VW often improves protein and lipid biosynthesis leading to better plant growth[9]. The effects of VW are often similar to those of plant growth substances such as auxins, gibberellins and cytokinins[25].

The potential use of hydrogel polymers as soil conditioners and/or growing substrate depends, *inter alia*, on their potential swelling capacity and the release of absorbed water and mineral nutrients to the plant roots[19]. The incorporation of hydrogel also alleviates salt stress by increasing the concentration of photosynthetic pigments and carbon assimilation[6]. Addition of super-absorbent polymers (SAP) improves water absorption and retention in both soil and soil-less media with favourable effects on plant growth suggesting that they have potential for diverse applications under water stress conditions[22]. Considering these facts, we tested the efficacy of different potting amendments either alone or in combination with each other on important physio-biochemical parameters of gerbera that influence plant biomass and flower production.

Material and Methods

Experimental location and planting materials: The experiment was conducted under greenhouse at the Centre for Protected Cultivation and Technology, ICAR-Indian Agricultural Research Institute (IARI), New Delhi, India (latitude 28°41' N, longitude 77°13'E; altitude 228.4 above mean sea level). The tissue cultured plants of gerbera cv. Yosemite were planted in 10" diameter earthen pots. Vermicompost (VC), horn-bio manure (HBM) and vermiwash (VW) were procured from the ICAR-Indian Veterinary Research Institute, Izzatnagar, Bareilly (UP). Superabsorbent polymer Pusa Hydrogel (PHG; a semi-synthetic cross-linked hydrophilic polymer) developed by the ICAR-IARI was used. The pots were filled with soilless media [cocopeat + perlite + vermiculite (CPV; 4:1:1 v/v)] and soils treated with different amendments (i.e. VC 20% v/v, PHG 0.25% and HBM 1% on dry weight basis).

Different treatment combinations were: soil (control), Soil+PHG, Soil+PHG+VC, Soil+PHG+HBM, CPV+PHG, CPV+PHG+VC and CPV+PHG+HBM to study their effects on growth and development of gerbera cv. Yosemite. A single plant was transplanted per pot. Vermiwash was used in three different concentrations i.e. 0% (control), 10% and 20% diluted with double-distilled water. Vermiwash solutions were filled in sterilized and pre-cleaned dark-coloured glass containers and stored at 4°C for spraying at active growth stages after 20, 40 and 60 days transplanting.

Observations recorded: To study the effects of different growing substrates on plant growth and physiological relations, data were recorded on relative water content (RWC), chlorophyll (a, b and total), pigments using SPAD-502 (Minolta, Japan), gas exchange characteristics net photosynthetic assimilation (Pn), stomatal conductance (gS) and transpiration (T) in fully expanded young leaves using the portable Infrared Gas Analyzer (LI-COR 6400 Model) in the closed mode between 10.00 and 11.00 a.m. with relative humidity 55–60% and temperature 25-30°C. Correlations between individual physiological traits were also studied.

Leaf nutrients analysis: Fully expanded leaves from the mid-shoots were collected during harvest period from two experiment years. The nutrient concentrations in plant samples were determined from the thoroughly rinsed and then oven dry the leaves at 54°C for 72 h. After complete drying in a Wiley mill, the samples were mixed well and stored in the air tight containers. The leaves were analyzed for different macro and micro contents. The dry weights were recorded and dried tissues were ground to determine the total N and the concentrations of the major elements. Determinations of micro-nutrients (Cu, Fe, Zn and Mn) were done by an atomic absorption spectrophotometer (GBC-Avanta PM) directly from the diacid digest using a nitrous oxide-acetylene flame.

Statistical analysis: The data were evaluated with analysis of variance (ANOVA) using the statistical software SPSS 16.0. Correlation coefficient (r) between vegetative and flowering parameters was also computed. The means were separated by Tukey's HSD test at the 5% level of significance and all data are presented as the mean ± standard deviation (SD) of three replications.

Results

Relative water content (%): Results presented in fig. 1 showed that relative water content (RWC) increased in CPV media supplemented with different amendments and sprayed with 20% VW in comparison to both control plants and those grown in amended soils receiving similar VW concentrations. The plants grown on CPV+PHG+VC and sprayed with 20% VW showed the maximum (94.48 ±0.46%) RWC value which was about 17% higher compared to control without any supplemental VW spray and significantly higher than rest of the treatments with the exception of the plants grown in CPV+PHG+HBM (93.3 ± 0.18%) and CPV+PHG (92.84 ± 0.14%) media and sprayed with 20% VW solution.

The fact that plants grown in the same media but sprayed with lower (10%) concentrations of VW had significantly less RWC relative to plants sprayed with 20% VW suggested a positive influence of higher concentrations of VW in improving RWC.

Chlorophyll content (mg/g DW): Application of different amendments significantly enhanced leaf photosynthetic pigments content in gerbera cv. Yosemite (fig. 2, 3 and 4). Chlorophyll (Chl) a content was invariably higher in amendment treated soil and CPV medium than control (fig. 2). The maximum (11.99±0.13 mg/g DW) Chl a content was recorded in plants grown in CPV+PHG+VC substrate and sprayed with 20% VW. Notably, Chl a concentration was statistically at par in CPV+PHG+VC medium when plants were sprayed with either 10% or 20% VW.

Plants grown in CPV+PHG+HBM medium and receiving 20% VW spray also showed Chl a level (9.15 ± 0.10 mg/g DW) statistically similar to those raised in CPV+PHG+VC and treated with either 10 (9.18 ± 0.08 mg/g DW) or 20% (9.56 ± 0.28 mg/g DW) VW solution. A comparison among different media combinations in absence of VW spray revealed that Chl a significantly declined relative to CPV+PHG+VC with the highest (~29%) and the lowest (~2%) reductions noted in soil and CPV+PHG+HBM treatments. These data tend to show the positive influence of supplemental additions and VW sprays in increasing the leaf Chl a in gerbera. As with Chl a, Chl b concentration also significantly increased when PHG, VC and HBM were added to the soil or CPV.

The highest (4.41±0.01 mg/g DW) Chl b was recorded in CPV+PHG+VC medium with the application of 20% VW and it was about 40% higher than control plants (Fig. 3). The beneficial effects of PHG, VC and HBM additions to the soil, even in the absence of VW application, were evident. Chl b levels increased by 6.4%, 20.7% and 11.5% in soil+PHG, soil+PHG+VC and soil+PHG+HBM treatments over soil alone. When soil was substituted by CPV, Chl b was about 26%, 48% and 35% higher than control under the respective treatments reflecting the effectiveness of CPV over soil as a growing medium for gerbera. A similar trend was noted for total Chl content with the maximum (16.40±0.14 mg/g DW) value recorded in the plants grown in CPV+PHG+VC medium and treated with 20% VW (Fig. 4).

Total leaf carotenoids (mg/g DW): Data presented in table 1 showed that different combinations of soil and CPV media were significantly superior over control with or without VW application with regard to leaf carotenoids. Control (soil alone) plants had 1.48±0.06 mg/g DW carotenoids which significantly increased with the additions of PHG, VC and HMB, either alone or in combination, to the soil. In comparison to soil, carotenoids content was 8%, 27% and 15% higher under soil + PHG, soil+ PHG +VC and soil+ PHG+HBM treatments respectively.

Leaf carotenoids further increased when soil was replaced with CPV and plants were sprayed with either 10 or 20 % VW. In plants grown in CPV medium amended with PHG, VC and HBM and sprayed with 20% VW, leaf carotenoids were almost two-fold higher than control.

Transpiration rate (µmol $m^{-2}s^{-1}$): Leaf transpiration linearly increased with the addition of different media to the soil and CPV. Control plants showed the lowest T (2.54 ± 0.11) which increased by ~14% in PHG enriched soil by ~52% when both PHG and VC were added and by ~40% when PHG and HBM were incorporated into the soil. Substitution of soil by CPV, with other media ingredients remaining the same, increased the leaf T by 64%, 103% and 72% respectively over control. Vermiwash application invariably enhanced T over the respective control regardless of the media used.

The highest T (11.43 ± 0.06) recorded in the plants grown in CPV+ PHG+ VC media and receiving 20% VW spray was substantially (4.5-fold) higher than control without VW application. Comparison among different media under 20% VW spray showed that T increased with incremental additions to the basal (soil or CPV) medium. While T was much lesser (~45%) in soil grown plants, it was only ~18% less in soil +PHG+VC medium and ~8% lower under CPV+PHG+HBM treatment as compared to CPV+ PHG+ VC.

Photosynthetic rate (µmol CO_2 $m^{-2}s^{-1}$): Photosynthetic assimilation significantly increased with the use of VW as well as when soil was enriched with different amendments (Table 1). The plants sprayed with either 10% or 20% VW exhibited over two-fold higher Pn compared to control plants not treated with VW. When only PHG was added to the soil and plants were sprayed with VW, increase in Pn was non-significant as compared to soil grown, VW treated plants suggesting that PHG alone was not much effective in increasing the photosynthesis.

In contrast, conjunctive use of PHG and VC coupled with VW spray significantly enhanced Pn. When CPV was used in the place of soil, PHG addition resulted in ~1.2-fold (with VW) and ~1.6-fold (without VW) increases in Pn over the combined use of soil and PHG with or without VW application indicating the possible synergistic interaction between CPV and PHG. The highest Pn rates (11.23 ± 0.38 and 10.63 ± 0.23 µmol CO_2 $m^{-2}S^{-1}$) recorded under CPV+ PHG+VC and CPV+ PHG+HBM treatments receiving 20% VW spray did not significantly differ with each other.

Stomatal conductance (cm s^{-1}): Results showed that stomatal conductance linearly and significantly increased with VW application and soil amelioration/substitution with different amendments. In comparison to control plants, application of 10% and 20% VW enhanced gS by 100% and 167% respectively. Addition of PHG to the soil, in absence of VW spray, had no significant influence on gS. In contrast, over two-fold increase in gS occurred when soil +PHG grown plants were sprayed with VW.

Interestingly, addition of either VC or HBM to soil + PHG medium and VW application did not significantly enhance gS except in the plants grown in soil + PHG + VC substrate and sprayed with 20% VW. A quite similar trend was noted in the plants grown using different combinations of CPV, PHG, VC and HBM when VW was not sprayed. VW application, however, invariably and significantly increased gS in the plants raised in different substrates.

Correlation studies: To identify the relationship between different plant physiological parameters in ameliorated soils, Pearson's correlation coefficient was computed (Table 2). It was noticed that leaf relative water content was highly positively correlated with both carotenoids (r = 0. 974) and total chlorophyll content (r= 0.946). A high degree of correlation was also observed between stomatal conductance, photosynthesis rate (r = 0.921) and transpiration rate (r = 0.912).

The increase in stomatal conductance, net photosynthesis and respiration rate were observed to have simultaneous effects on photosynthesis and transpiration. The strong correlation among these variables indicates that overall growth of plants depends on these variables. The increase in these variables including photosynthesis enhanced the plant growth.

Effect on leaf macro nutrients: Data presented in table 3 revealed that leaf nitrogen content only marginally increased when soil grown plants were sprayed with either 10% or 20% VW. Additions of PHG, VC and HBM into the soil also had little influence on leaf N over control. As compared to soil grown plants, significant increase in leaf N was noted only with the conjunctive addition of PHG and VC. Furthermore, plants grown in amended soils and treated with VW did not show significantly higher leaf N levels over control. However, substitution of soil with CPV exerted an appreciable influence as evident by ~28% increase in leaf N in CPV+PHG grown plants as compared to control.

VC and HBM accretions coupled with VW application further increased leaf N. Plants grown on CPV+PHG+VC as well as CPV+PHG+HBM substrates and sprayed with 10% or 20% VW exhibited 14-40% and 10-29% increases in leaf N over those grown in CPV+PHG without any VW treatment. These data suggested synergistic interactions between CPV and other media supplements, especially the vermi products with regard to nitrogen nutrition in gerbera plants. Irrespective of the substrate (either soil or CPV and supplemental additions), 10% VW did not significantly increase leaf P except in the plants grown in soil+ PHG+ HBM media.

Increase in VW concentration from 10% to 20%, however, markedly improved leaf P under different soil- and CPV-based treatments as compared to control as well as the plants grown in these media without VW application. It is pertinent to mention that relative differences in leaf P were not much pronounced between soil- and CPV-based substrates as the extent of increase in leaf P varied from 29-38% in the former and 22-36% in the latter case vis-à-vis corresponding control i.e. without VW spray.

As with leaf N, the highest P (0.33 ± 0.01%) was recorded in the plants grown in CPV+ PHG+ VC media receiving 20% VW spray which was over two-fold higher as compared to soil grown plants. In contrast to both leaf N and P, the plants grown in amended substrates and sprayed with VW showed significant increase in tissue K concentrations over control and those grown in enriched media but not receiving VW. In fact, leaf K kept steadily and significantly increasing with each successive refinement in the growing condition. The greatest increase (~100%) in leaf K over control occurred in the plants grown in CPV+ PHG+ VC media under 20% VW spray which was statistically at par with those raised in CPV+PHG+ HBM substrate and receiving similar VW concentration.

Data presented in table 4 indicated that leaf Ca, Mg and S levels significantly varied among the treatments. Soil enrichment with different amendments and VW application had a positive influence on tissue Ca levels. Comparison among the plants grown in soil and amended media showed that leaf Ca increased by about 11%, 31% and 22% over control when PHG alone, PHG + VC and PHG +HBM respectively were added to the soil. Leaf Ca further increased by about 23%, 43% and 34% when 10% VW was used and by 37%, 58% and 50% when 20% VW was sprayed over plants grown in enriched soil vis-à-vis control plants not receiving VW.

Soil substitution with CPV with other media ingredients remaining unchanged had a greater effect on Ca nutrition as evident by 50-86% increase in leaf Ca over control. As with Ca, both leaf Mg and S increased with each incremental addition. In contrast to leaf Ca, however, both Mg and S only marginally increased in amended soils in the absence of VW application implying that combined effects of VW and other amendments were greater than their individual effects. The highest leaf Mg (0.399%) and S (0.175%) levels, up by 68% and 105% over the respective control, were recorded in the plants grown in CPV+ PHG+ VC substrate and treated with 20% VW.

Effect on leaf micronutrients: Leaf Fe levels did not significantly vary under different treatments except in CPV media ameliorated either with PHG+ VC or PHG+ HBM in the absence of VW. In control plants, VW application had little effect on Fe acquisition. Interestingly, supplemental use of 10% VW significantly enhanced leaf Fe levels over control but failed to appreciably improve Fe concentrations in most of the soil- and CPV-based media than respective control i.e. those having the same growing substrate but not receiving VW spray.

Appreciable increase in Fe over control (~1.3-fold) was recorded in the plants grown in CPV+ PHG+ VC or CPV+ PHG+ HBM media and treated with 20% VW. A more or less similar trend was noted with respect to Zn levels that did not significantly increase with the addition of PHG to soil even under VW spray. Conjunctive accretions of PHG+ VC or PHG+ HBM to the soil coupled with VW application also only marginally improved leaf Zn concentrations relative to control. The highest leaf Zn levels recorded in the plants grown in CPV+ PHG+ VC substrate sprayed either with 10% or 20% VW were almost 1.5-fold higher than control.

In contrast to both Fe and Zn, leaf Cu showed relatively better response to the solitary use of VW and different media supplements. For example, leaf Cu increased by over 20% when control plants were treated with VW. Similarly, increase ranged from 25-27% in PHG enriched soils receiving supplemental VW spray. The greatest increase in leaf Cu over control (~45%) was noted in the plants grown in CPV+ PHG+ VC media and treated with 20% VW. In the case of leaf Mn, VW applications failed to significantly increase its levels even in PHG amended soils. Although conjunctive use of amendments and VW significantly increased leaf Mn levels, these increases were relatively smaller as compared to other micronutrients and the highest increase of about 17% over control was recorded in CPV+ PHG+ VC grown plants receiving 20% VW.

Table 1
Effect of different vermi-products and Pusa Hydrogel on carotenoids content, transpiration rate, net photosynthesis and stomatal conductance

Treatment			Carotenoids content (mg/g DW)	Transpiration rate (μmol m^{-2} s^{-1})	Photosynthesis rate (μmol CO_2 $m^{-2}S^{-1}$)	Stomatal conductance (cm s^{-1})
Media Combination		Vermiwash (%)				
Control		0	1.48 ± 0.06^{a}	2.54 ± 0.11^{a}	3.02 ± 0.11^{a}	0.03 ± 0.01^{a}
		10	1.68 ± 0.03^{b}	4.67 ± 0.07^{e}	6.45 ± 0.10^{de}	0.06± 0.00^{cde}
		20	1.95 ± 0.05^{cde}	6.28 ± 0.09^{h}	7.13 ± 0.30^{ef}	0.08± 0.00^{efg}
Soil	PHG	0	1.60 ± 0.04^{ab}	2.89 ± 0.02^{a}	3.84 ± 0.10^{b}	0.03 ± 0.00^{a}
		10	1.72 ± 0.03^{b}	5.73 ± 0.57^{g}	6.94 ± 0.21^{ef}	0.07± 0.01^{def}
		20	2.06 ± 0.03^{de}	7.85 ± 0.09^{j}	7.43 ± 0.27^{fg}	0.08± 0.01^{efg}
	PHG+VC	0	1.88 ± 0.04^{c}	3.86 ± 0.04^{bc}	5.25 ± 0.21^{c}	0.05± 0.00^{abc}
		10	2.09 ± 0.03^{e}	6.75 ± 0.03^{i}	7.87 ± 0.20^{gh}	0.09 ± 0.00^{fg}
		20	2.46 ± 0.04^{hij}	9.32 ± 0.05^{l}	9.31 ± 0.23^{jk}	0.13 ± 0.01^{h}
	PHG+HBM	0	1.71 ± 0.04^{b}	3.56 ± 0.08^{b}	4.40 ± 0.49^{b}	0.04 ± 0.00^{ab}
		10	1.88 ± 0.03^{c}	6.39 ± 0.04^{hi}	7.28 ± 0.24^{fg}	0.07±0.01^{defg}
		20	2.26 ± 0.05^{fg}	8.45 ± 0.06^{k}	8.29 ± 0.36^{hi}	0.09 ± 0.00^{g}
CPV	PHG	0	2.16 ± 0.07^{ef}	4.16 ± 0.07^{cd}	6.18 ± 0.14^{d}	0.06 ±0.00^{bcd}
		10	2.39 ± 0.05^{ghi}	7.54 ± 0.08^{j}	8.45 ± 0.10^{hi}	0.15 ± 0.01^{h}
		20	2.64 ± 0.03^{kl}	9.60 ± 0.02^{l}	9.53 ± 0.11^{jk}	0.18 ± 0.01^{i}
	PHG+VC	0	2.57 ± 0.07^{jk}	5.15 ± 0.03^{f}	7.03 ± 0.04^{ef}	0.06 ±0.00^{cde}
		10	2.74 ± 0.05^{l}	8.35 ± 0.08^{k}	9.60 ± 0.10^{k}	0.18 ± 0.01^{i}
		20	2.92 ± 0.03^{m}	11.43 ± 0.06^{n}	11.23 ± 0.38^{l}	0.22 ± 0.01^{j}
	PHG+HBM	0	2.35 ± 0.06^{gh}	4.37 ± 0.09d^{e}	6.53 ± 0.17d^{e}	0.06 ±0.00^{bcd}
		10	2.51 ± 0.06^{ihk}	7.73 ± 0.03^{j}	8.89 ± 0.12^{ij}	0.15 ± 0.01^{h}
		20	2.77 ± 0.02^{l}	10.47 ± 0.12^{m}	10.63 ± 0.23^{kl}	0.19 ± 0.01^{i}

Data represent the means ± standard deviation of three replicates. Same superscript letters within a column did not differ significantly when compared by Tukey's test at 5% level of significance.

Table 2
Pearson's correlation coefficient between the different physiological parameters recorded for influence of vermi-products and Pusa Hydrogel

S. N.	Variables	1	2	3	4	5	6
1.	Relative water content	1.000	.946**	.974**	.838**	.916**	.856**
2.	Total chlorophylls		1.000	.972**	.728**	.834**	.836**
3.	Carotenoids content			1.000	.805**	.877**	.860**
4.	Transpiration rate				1.000	.961**	.912**
5.	Photosynthesis rate					1.000	.921**
6.	Stomatal conductance						1.000

**Correlation is significantly different at $P \leq 0.01$

Table 3
Effect of different vermi-products and Pusa Hydrogel on leaf macronutrients

Treatment			**Nitrogen (%)**	**Phosphorus (%)**	**Potassium (%)**
Media Combination		**Vermiwash (%)**			
Control		0	1.33 ± 0.09^{a}	0.16 ± 0.01^{a}	1.97 ± 0.02^{a}
		10	1.49 ± 0.03^{abc}	0.18 ± 0.01^{ab}	2.60 ± 0.25^{cde}
		20	1.57 ± 0.02^{bcd}	0.21 ± 0.00^{cd}	3.15 ± 0.02^{hi}
Soil	PHG	0	1.44 ± 0.11^{ab}	0.17 ± 0.01^{ab}	2.20 ± 0.11^{ab}
		10	1.60 ± 0.06^{bcde}	0.19 ± 0.01^{bc}	2.71 ± 0.04^{def}
		20	1.63 ± 0.03^{bcdef}	0.22 ± 0.01^{def}	3.37 ± 0.04^{ij}
	PHG+VC	0	1.63 ± 0.10^{bcdef}	0.20 ± 0.00^{bc}	2.55 ± 0.10^{cd}
		10	1.75 ± 0.03^{defgh}	0.22 ± 0.00^{cde}	2.99 ± 0.08^{gh}
		20	1.81 ± 0.03^{efgh}	0.26 ± 0.01^{hi}	3.59 ± 0.06^{jk}
	PHG+HBM	0	1.55 ± 0.07^{abcd}	0.18 ± 0.01^{ab}	2.39 ± 0.06^{bc}
		10	1.67 ± 0.16^{cdefg}	0.21 ± 0.00^{cd}	2.81 ± 0.06^{defg}
		20	1.71 ± 0.02^{cdefg}	0.25 ± 0.01^{fghi}	3.50 ± 0.13^{jk}
CPV	PHG	0	1.71 ± 0.02^{cdefg}	0.22 ± 0.02^{cde}	2.72 ± 0.07^{defg}
		10	1.84 ± 0.02^{fgh}	0.23 ± 0.01^{defg}	3.14 ± 0.05^{hi}
		20	1.97 ± 0.02^{h}	0.30 ± 0.01^{jk}	3.73 ± 0.04^{kl}
	PHG+VC	0	1.88 ± 0.05^{gh}	0.27 ± 0.01^{ij}	2.97 ± 0.02^{fgh}
		10	1.95 ± 0.04^{h}	0.27 ± 0.00^{ij}	3.32 ± 0.12^{ij}
		20	2.39 ± 0.06^{i}	0.33 ± 0.01^{l}	3.95 ± 0.04^{l}
	PHG+HBM	0	1.81 ± 0.03^{efgh}	0.24 ± 0.01^{efgh}	2.85 ± 0.04^{fg}
		10	1.88 ± 0.05^{gh}	0.25 ± 0.01^{ghi}	3.21 ± 0.09^{hi}
		20	2.20 ± 0.11^{i}	0.32 ± 0.01^{kl}	3.86 ± 0.04^{l}

Data represent the means ± standard deviation of three replicates. Same superscript letters within a column did not differ significantly when compared by Tukey's HSD test at 5% level of significance.

Table 4
Effect of different vermi-products and Pusa Hydrogel on leaf calcium, magnesium and sulphur contents.

Treatment			**Calcium (%)**	**Magnesium (%)**	**Sulphur (%)**
Media Combination		**Vermiwash (%)**			
Control		0	1.58 ± 0.01^{a}	$0.237 \pm 0.002a^{a}$	0.085 ± 0.001^{a}
		10	1.77 ± 0.01^{bc}	0.257 ± 0.001^{abc}	0.980 ± 0.001^{abc}
		20	1.92 ± 0.00^{bcd}	0.289 ± 0.001^{defg}	0.112 ± 0.000^{cde}
Soil	PHG	0	1.75 ± 0.00^{b}	0.247 ± 0.001^{ab}	0.091 ± 0.000^{a}
		10	1.94 ± 0.01^{cd}	0.269 ± 0.002^{bcde}	0.109 ± 0.000^{bcde}
		20	2.16 ± 0.01^{ef}	0.303 ± 0.001^{ghi}	0.120 ± 0.001^{def}
	PHG+VC	0	2.07 ± 0.01^{de}	0.277 ± 0.001^{cdef}	0.107 ± 0.001^{bcd}
		10	2.26 ± 0.01^{fgh}	0.279 ± 0.001^{defg}	0.123 ± 0.000^{efg}
		20	2.51 ± 0.01^{ij}	0.334 ± 0.001^{ij}	0.142 ± 0.001^{hi}
	PHG+HBM	0	1.93 ± 0.00^{cd}	0.265 ± 0.000^{abcd}	0.960 ± 0.001^{ab}
		10	2.13 ± 0.00^{ef}	0.273 ± 0.000^{bcdef}	0.115 ± 0.000^{de}
		20	2.36 ± 0.00^{ghi}	0.334 ± 0.001^{hi}	0.131 ± 0.000^{fgh}
CPV	PHG	0	2.21 ± 0.01^{efg}	0.279 ± 0.001^{defg}	0.114 ± 0.001^{de}
		10	2.42 ± 0.00^{hi}	0.299 ± 0.000^{fgh}	0.132 ± 0.001^{fgh}
		20	2.69 ± 0.01^{k}	0.350 ± 0.001^{jk}	0.154 ± 0.000^{ij}
	PHG+VC	0	2.39 ± 0.01^{hi}	0.309 ± 0.001^{ghi}	0.131 ± 0.000^{fgh}
		10	2.52 ± 0.00^{ij}	0.323 ± 0.000^{hij}	0.150 ± 0.001^{ij}
		20	2.94 ± 0.01^{l}	0.399 ± 0.001^{l}	0.175 ± 0.000^{k}
	PHG+HBM	0	2.48 ± 0.01^{i}	0.289 ± 0.001^{efg}	0.122 ± 0.000^{def}
		10	2.68 ± 0.01^{jk}	0.309 ± 0.001^{ghi}	0.138 ± 0.001^{ghi}
		20	2.81 ± 0.00^{kl}	0.367 ± 0.001^{kl}	0.165 ± 0.000^{jk}

Data represent the means ± standard deviation of three replicates. Same superscript letters within a column did not differ significantly when compared by Tukey's HSD test at 5% level of significance.

Table 5
Effect of different vermi-products and Pusa Hydrogel on leaf micronutrients.

Treatment			Iron (ppm)	Zinc (ppm)	Copper (ppm)	Manganese (ppm)
Media Combination		Vermiwash (%)				
Control		0	396.31±55.25[a]	90.36±2.87[a]	26.69±0.59[a]	127.78±1.96[a]
		10	417.43±6.59[abc]	95.52±0.95[abc]	33.31±2.06[cde]	131.48±1.95[ab]
		20	441.25±4.12[abcdef]	98.52±2.38[abcd]	34.56±1.41[cdef]	133.73±1.81[abcd]
Soil	PHG	0	408.89±3.31[ab]	95.18±3.10[ab]	28.28±1.29[ab]	132.69±2.20[ab]
		10	435.78±18.07[abcd]	99.52±1.29[abcd]	35.38±0.96[cdefg]	133.04±2.53[abc]
		20	452.59±12.14[bcdefg]	103.11±5.36[abcde]	36.61±1.20[defgh]	135.47±0.56[abcde]
	PHG+VC	0	426.79±16.00[abcd]	105.35±3.32[bcdef]	32.13±1.62[bcd]	136.48±2.92[bcdef]
		10	464.59±12.74[cdefgh]	110.13±1.10[defgh]	39.54±1.61[ghij]	139.51±1.49[bcdefg]
		20	474.81±4.68[defgh]	115.12±3.98[efghi]	40.43±1.65[hijk]	141.51±2.35[defgh]
	PHG+HBM	0	416.79±5.47[abc]	100.65±2.47[abcd]	30.64±1.17[abc]	134.48±1.36[abcde]
		10	449.25±17.22[bcdef]	105.78±5.92[bcdefgh]	37.48±1.51[efghi]	137.56±.28[bcdefg]
		20	463.10±8.71[cdefgh]	109.46±1.72[cdefgh]	38.38±1.39[fghi]	137.99±2.47[bcdefg]
CPV	PHG	0	437.13±16.12[abcde]	109.39±2.00[cdefgh]	34.98±0.10[cdefg]	138.69±2.21[bcdefg]
		10	471.47±5.77[defgh]	117.40±3.84[fghij]	41.29±2.13[hijk]	142.04±3.39[efghi]
		20	485.57±6.16[efgh]	122.74±3.28[hij]	44.46±1.88[jkl]	144.87±3.70[ghi]
	PHG+VC	0	471.31±5.96[defgh]	119.67±1.55[ghij]	38.10±1.11[efghi]	143.58±2.02[fghi]
		10	501.10±3.02[gh]	130.06±8.33[jk]	44.88±1.56[kl]	149.68±4.50[ij]
		20	508.45±8.06[h]	136.72±13.02[k]	49.31±3.25[l]	153.86±4.30[j]
	PHG+HBM	0	451.92±13.11[bcdef]	114.72±2.33[efghi]	36.66±1.16[defgh]	140.89±1.80[cdefgh]
		10	489.87±9.04[fgh]	121.87±4.33[hij]	42.39±0.72[ijk]	145.55±1.69[ghi]
		20	502.25±3.40[h]	128.54±1.44[ijk]	47.43±2.11[l]	148.69±3.21[hij]

Data represent the means ± standard deviation of three replicates. Same superscript letters within a column did not differ significantly when compared by Tukey's HSD test at 5% level of significance.

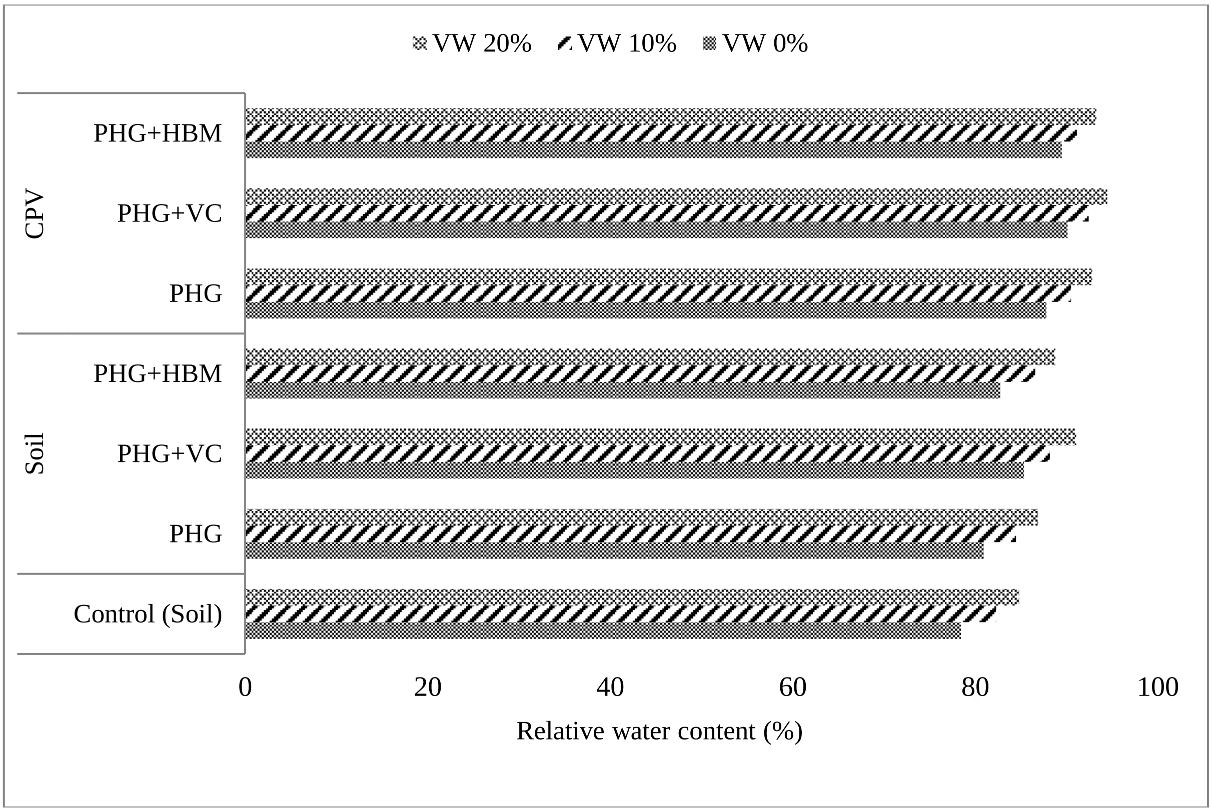

Fig. 1: Effect of superabsorbent polymer, vermicompost, horn bio manure and vermiwash concentrations on relative water content

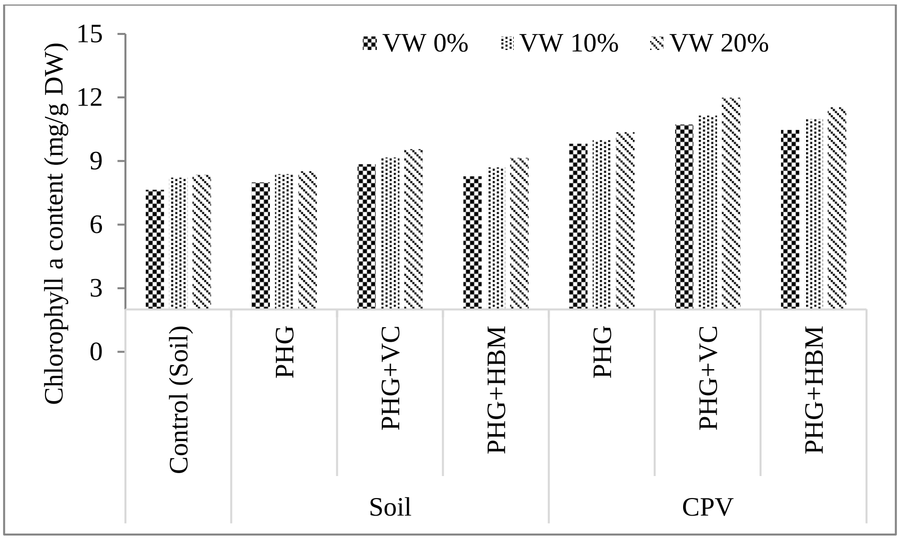

Fig. 2: Effect of superabsorbent polymer, vermicompost, horn bio manure and vermiwash concentrations on chlorophyll a content

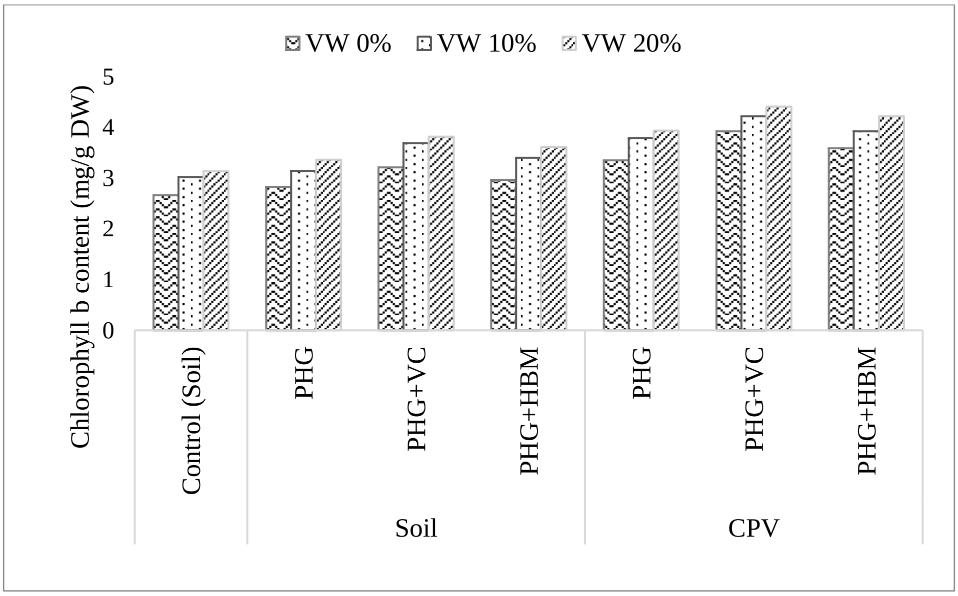

Fig. 3: Effect of superabsorbent polymer and vermicompost leachate on chlorophyll b content

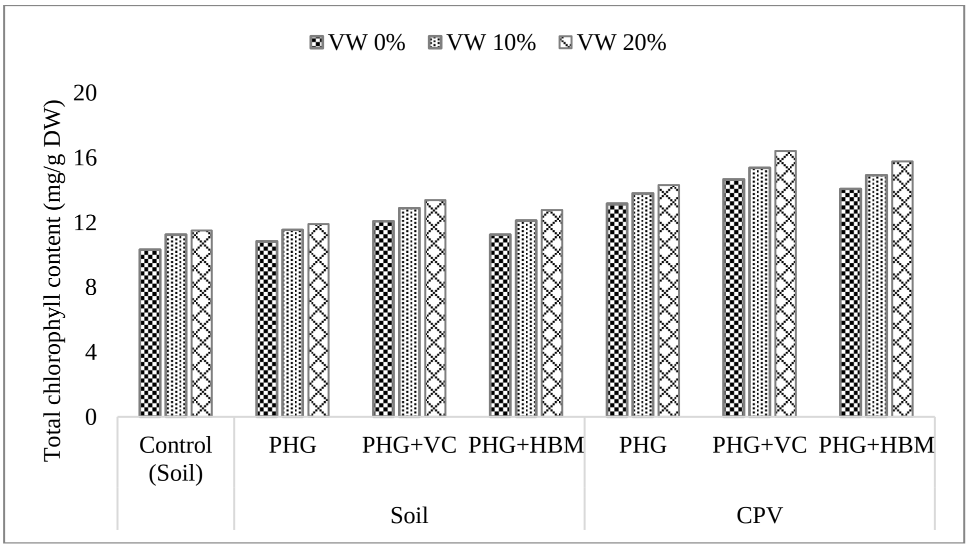

Fig. 4: Effect of superabsorbent polymer, vermicompost, horn bio manure and vermiwash concentrations on total chlorophyll content

Discussion

Effect on plant physiology: Vermiwash application is known to enhance growth and nutrient acquisition in crop plants[11,27]. Favorable effects of VC and VW on gerbera growth under greenhouse conditions have also been reported[21]. Water retained for extended periods in SAPs is more efficiently absorbed by the plant roots than soil water and also acts as an effective buffer during transient water stress protecting the plants from sudden shock[8]. Application of SAPs partly alleviates drought stress in plants by increasing the cell membrane stability and leaf RWC[10].

The levels of Chl a were invariably higher than Chl and that elevated Chl levels seemed to be due to higher production of photosynthates in plants. The incorporation of hydrogel polymer into the soil increased the Chl a content in maize crop[6]. The addition of 20% VC and/or chemical fertilizers increased the Chl in gerbera[17]. The foliar spray of VW resulted in the highest Chl, total proteins, total soluble sugars and starch contents in the fresh leaves of gerbera[25].

Our results are consistent with these findings suggesting that growing media amelioration with VC and PHG coupled with the application of VW enhanced the physiological functioning of gerbera plants. Vermiwash may also be used as an organic, low-cost substitute for synthetic plant growth substances widely used to enhance flower yield in different crops. The synthetic plant hormones have been used for better growth and flowering of gerbera. The application gibberellic acid has positive impact with regards to better growth, highest number of flowers, maximum stalk length and larger flower size.

Carotenoids are the accessory plant pigments that impart colour to the leaves and flowers and are involved in photosynthetic. The application of VW significantly increased the leaf carotenoid content in coleus as compared to control[16]. Leaf carotenoid levels increase in different horticultural crops with application of superabsorbent polymers[19] that act as highly effective soil conditioners and plant growth enhancers[6].

Plants grown in containers with a limited quantity of media require frequent irrigations to maintain the adequate moisture. Plants suffer from acute water stress under conditions of high transpiration and limited water availability. Application of suitable superabsorbent polymers in appropriate amounts maintains the desired moisture levels by osmotic adjustment that enables the plants to circumvent water stress[6,19,22]. The stomatal regulation of transpiration is one mechanism that delays the onset of plant water stress due to soil water shortage. The incorporation of VC in growing media exerts a positive influence on gas exchange characteristics leading to the improvements in photosynthesis[2]. Chrysanthemum grown in organically amended media showed significantly higher carbohydrate accumulation compared to control parts probably due to improvement in Pn[5]. Hydrogel polymers are known to alleviate the adverse effects of abiotic stresses such as salinity and osmotic stress in plants by stabilizing and/or enhancing photosynthesis[19]. Owing to high porosity, greater water holding capacity and availability of mineral nutrients in a readily utilizable form, VC improves soil physical conditions and enhances the plant growth. When applied along with mineral fertilizers, even low concentrations of VC have positive effects on plant growth and yield implying that VC mediated plant growth promotion is likely due to other mechanisms as well[12].

In hydrogel amended soils, water remains available for a longer duration of time as reflected by the higher leaf water potential in such plants. The addition of VC had positive effect on leaf gas exchange in pepper plants[2]. Decline in carbon assimilation in water stresses plants is attributed to forced stomatal closure and diffusive resistance to carbon dioxide transport in mesophyll cells resulting in its decreased absorption and assimilation in plants. Stomatal conductance decreased with increasing the water stress. The increasing stomatal diffusive resistance under water deficit condition led to decline of transpiration rate. These adjustment and adaptation functions improve plant survival under water stress[15].

The stomatal functioning is related to photosynthetic active radiation (PAR), temperature, leaf water potential, air humidity and carbon dioxide concentration in the air. The stomatal conductance is also a function of the age of the leaf and its morphological adaptation to its micro environment during growth[1].

Effect on macro and micronutrients: The beneficial effects of VC are often ascribed to the elevated tissue concentrations of macronutrients in plants[3]. VC supplementation is known to enhance the leaf N content[2] and it is likely that increased availability of N will hasten protein synthesis for plant growth. The leaf P decreased with increasing root zone pH in gerbera plants. Application of VC not only enhances soil P availability but also accelerates P uptake by the plants[18]. Similarly report of high water absorption SAPs could also be used to enhance nutrient availability to plants was observed[13]. It has also been reported that adequate amount of potassium supplied promotes the increment of chlorophyll content in plant[29].

The highest leaf Ca^{2+} content was found on CPV media amended with soil and FYM. In contrast, leaf Mg^{2+} levels were the maximum in the VC enriched media. The leaf Mg^{2+} content was within the ranges adequate for healthy and vigorous plant growth[21]. The higher leaf N, P, K and Ca contents in strawberry leaves were recorded by the foliar application of VC leachate at different growth stages. The beneficial effects of addition of vermicompost in growing medium were associated with elevated macronutrients in plants[3] while the macronutrients like sulphur content in plant leaves also increased and or decreased because the nutrient solubility affected by pH of growing medium[23].

Vermicompost, being rich in essential micronutrients, enhances crop growth and productivity[4]. The uptake of iron and manganese has often been shown to be mutually antagonistic and excess soluble iron or manganese can suppress the uptake of the less soluble of the two nutrients[30].

The maximum leaf manganese content was recorded in media amended with soil and organic products. Zinc concentration increased as pH of substrate increases[21]. The variation in leaf copper content is associated with variation in substrate pH and as the pH increased, the copper content decreased and vice-versa. Similar results were found in impatiens and petunia[23].

Conclusion

Experimental results showed that physiological activity of gerbera plants increased with the conjunctive use of improved media, super absorbent polymers and vermi-products. Soil amelioration with different amendments almost always had a positive influence on plant water balance, chlorophyll pigments, gas exchange characteristics and mineral uptake that in turn ensured higher net photosynthetic assimilation crucial to flower yield and quality.

It is assumed that alleviation of water stress ascribed to the use of PHG, enhanced nutrient availability due to VC use and plant growth promoting action of VW accounted for improved physiological activity in gerbera plants. It is also likely that PHG and VC substantially improved the physical and chemical properties of the growing media while both VC and HBM ensured adequate nutrient supplies to the plants required for the optimal metabolism.

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