Bangladesh J. Nuclear Agric, 38(1): 21-40, 2024 *ISSN 0258-7130*
DOI: https://doi.org/10.3329/bjnag.v38i1.76560

VERMIWASH: AN EFFECTIVE NUTRITIVE BLESSING TO CROPS

K. Nahar[1], R. Ashrafi[1*] and M.A. Haque[1]

Abstract

Under alarming situation of poor soil health, reduction in produce, increase in incidences of pest and disease and environmental pollution due to the application of chemical fertilizers over a period, it is necessary to look for alternatives which are effective and eco-friendly for sustainable agriculture. Therefore, it is very important to seek alternative as a supplement for chemical fertilizers. To cope with these problems, vermiwash can play an important role in ensuring a sustainable agricultural system. A review was conducted on vermiwash to assess the characteristics, potentiality to use and ultimately beneficial effects in sustainable agriculture. Vermiwash is coelomic fluid extraction contains significant quantities of nutrients, a large beneficial microbial population, biologically active metabolites particularly gibberellins, cytokinins, auxins and group B vitamins which can be applied alone or in combination with organic or inorganic fertilizers, so as to get better yield and quality of diverse crops. Evidences proved that qualities of vermiwash depend on the used organic bed producing vermicompost. Vermiwash can serve as a valuable foliar spray, because it is a combination of earthworm mucous discharges, nutrients, microorganisms and plant growth promoting materials composed of excretory products and mucus secretions from earthworms and micronutrients from the organic molecules in the soil. These nutrients are absorbed and then transported to the leaves, shoots, and other parts of a plant. Application of vermiwash improves plant health, yield and nutritional quality. Vermiwash proves to be an effective fertilizer which contributes the growth of plants when sprayed directly as well as mixed with a definite ratio of vermicompost. It was also observed that the plants treated with vermiwash were disease resistant and no any worms like leaf eaters were seen on the leaves and other parts of plants. Vermiwash can be used as a substituent of commercial fertilizers available in the market. Vermiwash acts not only as a liquid organic fertilizer but also act as mild biocide. It can be used as an effective input in organic agriculture for both soil health and disease management for sustainable crop production with low cost which could be ensure food security.

Key word: vermiwash, environmental pollution, chemical fertilizers, plant health.

Introduction

Abundant use of inorganic fertilizers along with herbicides and pesticides in the present agriculture system poses a great threat to the soil and water sustainability. The degradation in soil health in many intensively cultivated areas is manifested in terms of loss of soil organic matter, depletion of native soil fertility, particularly with respect to secondary micronutrients and stagnation or even decline in crop productivity. The depletion in soil

[1]Soil Science Division, Bangladesh Institute of Nuclear Agriculture, Mymensingh-2202
*Corresponding Author e-mail: reema_asharafi@yahoo.com

fertility is due to imbalanced and unscientific use of fertilizer, which is one of the major constraints in improving crop productivity (Dwivedi and Dwivedi, 2007). At present agricultural practices largely rely on high inputs of synthetic fertilizers and pesticides to achieve high yield and protect the crops against pathogens and pests. Excessive use of fertilizers and pesticides leads to gradual degradation of soil fertility and microbiological diversity. This decline in soil quality further leads to water and land pollution, thereby lowering the land's worth. The massive application of pesticides and synthetic fertilizers also leads to high residue levels in crops, which is bad for human health (Awadhpersad *et al.,* 2021). Increase use of chemical fertilizers over a long period of time has led to contamination of food materials. Nowadays, there is a strong interest in alternative strategies to ensure competitive yields, protection of crops, environment, and the health of human kind. Consumers are more aware of the food they consume and the chemicals that are used for crop production. Therefore, it is very important to seek alternative bio-fertilizers as a supplement for chemical fertilizers. Sustainable agriculture seeks to introduce agricultural practices that are environmentally sound, economically viable and socially supportive. Organic agriculture is the form of agriculture that relies on crop rotation, green manure, compost, biological pest control. Organic materials are always recommended to regenerate soil fertility and reduce negative environmental impact compared to chemical fertilizers, which may degrade organic carbon and humus, destroy soil structure and cause toxicity in plants, which in turn causes spread of some illnesses, such as cancer (Yaseen *et al.,* 2020). The new approaches to the use of organic amendments in farming have proven to be effective means of improving soil structure, enhancing soil fertility and increasing crop yields. Vermicomposting is a novel eco-friendly and cost-effective technology of decomposing organic matter and producing organic manure that was the best in all aspects including the nutrient level. Application of vermicompost favourably affects soil PH, microbial population and soil enzyme activities (Yasmin *et al.,* 2021). The vermicomposting technology can also be utilized for generating a bioliquid termed as vermiwash. Vermiwash, is basically a clear, transparent and pale yellow coloured fluid which is prepared by feeding earthworms with raw materials like leaf litter or cow dung or other organic materials (Tharmaraj *et al.,* 2011). The quality of vermiwash produced by earthworms depends on the vermicompost means source of feeding material that is used (Rai and Bansiwal, 2008).

Sustainable agriculture has become important in the present time owing to pollution and soil degradation. The use of organic manures and fertilizers and now days organic nutrients which are of biological origin is one of the important practices in this form of agriculture. Vermiwash is an organic nutrient obtained from units of vermicompost as byproduct. Vermiwash is emerging as important potential tool (Nayak and Yadav, 2019). It is rich in dissolved nutrients and amino acids and therefore, good source for plant nutrients in organic agriculture (Dongare and Gawas, 2021). Very few researches are available in favour of vermiwash and its influence on the growth and development of plants. To our knowledge there is very lacking research finding on vermiwash in Bangladesh. But vermiwash may be used for better yielding of crops as liquid organic fertilizer. Vermiwash

is a rich source of vitamins, hormones, enzymes, macronutrients and micronutrients and help in efficient growth of plants when applied (Varghese, 2014). Thus, we have reviewed the vermiwash on its properties, preparation techniques, role on soil properties and crop production, mechanism of disease suppression and pest control in order to use these scientific facts in agriculture to enhance crop productivity which could be ensure food security.

Vermiwash:

Vermiwash is a natural product formed by vermicomposting of organic matter from rich population of earthworms (Aghamohammadi *et al.,* 2016; Thakur and Sood, 2019). It is the extracted body fluid of earthworms. It is a liquid substance of vermicompost, extracted in the presence of earthworms and contains several enzymes, plant growth hormones, vitamins along with micro and macronutrients (Bendalam and Kaviti, 2020). It comprises numerous chemicals viz, hormone, mucous, enzyme, vitamins, proteins, different macro and micronutrients, and a large number of microbes (Das *et al.,* 2014; Tripathi *et al.,* 2005; Nadana *et al.,* 2020). It also contains sugars, amino acids and phenols along with plant growth promoting hormones such as in indole acetic acid and humic acid. The fresh vermiwash houses a large number of beneficial microorganisms, which help in plant growth and protects it from a number of infestations (Gulsar and Iyer, 2006). Vermiwash is a liquid extract collected after the passage of water through the different layers of earthworm culture units (Gorakh Nath, *et al.,* 2009). It contains nitrogen as nitrogenous excretory product and growth promoting hormones and essential enzymes and infuses resistance in plants (Kaur *et al.,* 2015). Vermiwash is used as a liquid major nutritive and enzymatic element for promoting growth of all green plants. (Gorakh Nath *et al.,* 2009). Various enzymes cocktail of protease, amylase, urease and phosphatase contained in vermiwash are beneficial for growth and development of plant and stimulate the yield and productivity of crops and nitrogen fixing bacteria like *Azotobacter*, *Agrobacterium* and *Rhizobium* and some phosphate solubilizing bacteria (Kaur *et al.,* 2015). Due to the presence of plenty vital bioavailable nutrients, it is demonstrated to enhance growth of plants and improve nutrients (Gudeta *et. al.,* 2021) and also possesses an inherent property of acting as a mild biocide (Ismail, 1997; Ansari, 2008; Hatti *et al.,* 2010). In recent days the vermiwash is used as foliar spray which is transported to the leaf, shoots and other parts of the plants in the natural ecosystem (Kaur *et al.,* 2015).

Vermiwash alone or mixed with cow urine is an excellent growth promoter. Before the application of vermiwash on any plants dilute with water (10 percent) and saturate the soil to prevent soil-borne diseases. At the time of transplanting, seedlings are dipped in vermiwash solution for about one hour and thirty minutes after diluting it with water (five times). Vermiwash alone or mixed with cow urine and dilute it with water to use it as a pesticide and foliar spray (One liter vermiwash + one liter cow urine+ eight liters water) or dilute with 10% cow urine or garlic extract or *neem* extract to use it as a natural

biopesticide. When vermiwash liquid added to compost pits to accelerate the degradation process. Liquid is diluted 5 to 10% hinders the mycelial growth of pathogenic fungi, initiate flowering and long-lasting inflorescence also use as rhizospheric liquid fertilizer, act as a tonic of plants and to induce the rate of photosynthesis in crops/plants (Jaysawal *et al.*, 2020)

Properties of vermiwash:

Vermiwash is considered as a storehouse of nutrients and microorganisms containing mucus, excretory products of worms and various concentration of macro (N, P, K, S, Ca, Mg etc.), micro (Zn, Fe, Cu) and beneficial nutrients (Buckerfield *et al.*, 1999) along with beneficial microorganism, vitamines, enzymes and amino acids (Nayak and Yadav, 2019) and plant growth hormones like cytokinins, gibberlines and vitamins (Buckerfield *et al.*, 1999). The pH and electrical conductivity were reported lower in the vermiwash compared to the vermicompost. The nitrogen and potassium content were also reported 57% and 79.6% lower in the vermiwash compared to the vermicompost respectively. Furthermore, the vermiwash was also reported 84%, 89.1%, 97.6% and 97.8% richer in the phosphorous, calcium, magnesium and sodium content compared to the vermicompost respectively (Manyuchi *et al.,* 2013).

Vermiwash contains total solids (2448 mg/L), volatile solids (738 mg/L), silica (8 mg/L), auxin (0.98 µg/L) and cytokinin (0.68 µg/L) (Patil *et al.*, 2007). Dead earthworm's tissue releases nitrogen in form of nitrates (25%), ammonia (45%), organic soluble compound (3%) and uncalculated material (27%) which improves the nutrient quality of it. It can be used as a foliar spray as well as soil application whereby it acts as a biocontrol agent and natural fertilizer for the crop plants in sustainable agriculture. Vermiwash is a part of Good Agriculture Practice (GAP) (Dongare and Gawas, 2021).

Vermiwash contains vitamins, plant growth-promoting hormones (auxin and gibberellins), enzymes (cocktail of protease, amylase urease and phosphatase that acts as antimicrobic), symbiotic microbes (nitrogen fixing bacteria such as Azotobacter sp., Agrobacterium sp., and Rhizobium and Phosphate Solubilizing Bacteria (PSB) in addition to the macronutrients and micronutrients and other substances helpful for growth, quality and yield of plants. It acts as a pesticide and natural fertilizer for the crops in sustainable agriculture and increases the resistance power of crops against various diseases and enhance the growth and productivity of crops (Karuna *et al.,* 1999). Different nutritional value for vermiwash, the nutrient value is dependent on the organic feed used for the vermicomposting process (Awadhpersad *et al.*, 2021). Physical, chemical and microbial properties of vermiwash are stated in Table 1.

Different soluble plant nutrients such as N, P, K, S, Ca, Mg and micronutrients are the main nutrients present in vermiwash (Dongare and Gawas, 2021). Nitrogen present in various forms like nitrates, ammonia, mucus, nitrogenous excretory substances and organic nitrogenous compounds, which are released by the dead earthworm's tissues (Meena *et al.*,

2021). Different types of hormones such as cytokinin's, auxin, different amino acids, vitamins, enzyme cocktails of proteases, amylases, urease and phosphatase, some other secretions and many useful microbes such as heterotrophic bacteria, fungi, actinomycetes including nitrogen fixing bacteria like *Azotobacter spp*., *Agrobacterium spp.*, *Rhizobium spp*., phosphate solubilizers are present in the vermiwash. Vermiwash is rich in dissolved nutrients and amino acids which are easily available for plants. It is also a non-toxic and ecofriendly compound (Dongare and Gawas, 2021). It acts as a plant tonic and thus helps in reducing several plant pathogenic fungi, increases the rate of photosynthesis in crops or plants and increases the number of micro-organisms in the soil which helps in decomposing soil organic matter.

Table 1. Physico-chemical and microbial properties of vermiwash (Source; Patil, 2020; Varghese and Prabha, 2014; Nayak *et al.*, 2019; Awadhpersad *et al.*, 2021)

Color	Gray
pH	6.9-7.01
Electro conductivity	8.88-8.93 mm hos/cm
Organic Carbon %	0.008 ± 0.001
Total Kjeldahl Nitrogen %	0.01±0.005
Available Phosphate %	1.69 ± 0.05
Potassium (ppm)	25 ± 2
Sodium (ppm)	8 ± 1
Calcium (ppm)	3 ± 1
Copper (ppm)	0.01 ± 0.001
Ferrous (ppm)	0.06 ± 0.001
Magnesium (ppm)	158.44 ± 23.42
Manganese (ppm)	0.58 ± 0.040
Zinc (ppm)	0.02 ± 0.001
Total Heterotrophs (CFU/ml)	1.79×10^3
Nitrosomonas (CFU/ml)	1.01×10^3
Nitrobacter (CFU/ml)	1.12×10^3
Total Fungi (CFU/ml)	1.46×10^3

Preparation of vermiwash

Vermiwash could be prepared with the help of different materials like a barrel (250 L) or small bucket, broken stones, coarse sand, earthworms, cattle dung, straw and water. Two species of red earthworms (Red wiggler – *Eisenia foetida* and *Lumbricus rubellus* – Red worm) are used for commercial composting or worm farming, due to their relatively high tolerance of environmental variations. Vermiwash can be prepared by the different methods such as ECO – SCIENCE research foundation method, Ismail's method, Karunas method, Economic technique, KAU's method, Plastic drum method (1000 L), Households device, Kales method, Fluid method, etc. (Bendalam and Kaviti, 2020).

Most commonly and commercially followed methods are ECO – SCIENCE research foundation method and Ismail's method. In this method a base layer of gravel or broken

pieces of bricks are placed up to height of 10-15 cm. Then pre decomposed organic waste layer is placed on the coarse sand layer of 40-45 cm and moisten the different layers by using water. About 2000 worms are introduced into the container. Water sprayed regularly for 7-10 days. After 10 days vermin wash will be produced in the bucket. Hang one pot with a bottom hole over the bucket in a way so that leachate falls drop by drop. Every day 4-5L of water is poured in the hanging pot. Another pot is kept under the stop cork and 3-4L of vermiwash is found every day (Bendalam *et al.,* 2020).

By following (Industries, 2020) another method for the preparation of vermiwash, a plastic container of 15 to 20 liters capacity is required and the base of the container is fitted with tap to collect the watery worm extract (Figure 1). The container is filled with different succesive layers. First base layer, medium sized bricks or stones up to a height of 10-15 cm filled. Above the base layer a layer of coarse sand (up to 6 inches) and fine sand (5 inches) are spread. Then introduced of the effective earthworms (*Eisenia foetida*) into the filled containers. After that, a layer of partially decomposed cow dung (20-25 cm) and organic residues of 40-45 cm were poured. All the layers in the container is moistened by sprinkling water over it. Container is sprinkled with approx 2 L water per day. After 16 to 20 days preperation of vermiwash in the unit, about 1-2 L of vermiwash can be collected everyday. For nutrient supplement, vermiwash (1:10) i.e @ 1 litre is generally mixed with 7-10 litres of water and the solution is sprayed on leaves of the growing crop at the evening. However, to control various pest and diseases, 1 litre of vermiwash is thoroughly mixed with 1 litre of cow urine and 10 liters of water and is kept overnight before spraying.

Figure 1. Setting up a Vermiwash unit (Industries, 2020)

To obtain vermiwash, continuously suspend water from a small bucket with a single hole at the center. Cotton wicks or bamboo sticks are placed in the holes so that the water trickles down. The water gradually percolates to the bottom through the compost carrying with it nutrients through the filter unit.

The vermiwash must be diluted before its application on the plants (Jayashree, 2006). This has been found to be effective in several plants. Vermiwash must be diluted 5 to 10 times with water and then applied. Vermiwash can also be mixed with cow's urine at the ratio of (1:1:8) = Vermiwash: Cow's urine: Water and diluted for use as foliar spray and pesticide (Industries, 2020).

Function of earthworms in vermiwash preparation

Earthworms are also categorized as 'biological indicator' of soil fertility and 'soil conditioner'. They help in the improvement of the physical nature (soil porosity and tenderness), chemical nature (good pH and essential plant nutrients) and biological nature (beneficial soil microbes and organisms) and quality of soil where they inhabit. They eat away a large amount of soil with organic matter like microbes, plant and animal debris and grind them in their gizzard and digest them in their intestine with the help of various enzymes microbes (Scheu, 1987). The excretory material consists of 'vermicastings' which is rich in NPK (nitrates, phosphates and potash), micronutrients and beneficial soil microbes (Kaur and Kaur, 2017).

Role of vermiwash:

(i) Improving crop productivity

Vermiwash plays an important role in the plant growth and development, contribute to initiation of rooting, root growth, plant development, increasing the soil organic matter and increase in nutrient content which are readily available for the plants, resulting in good crop yield (Sundararasu, 2016). Vermiwash is rich in NPK components, micronutrients, plant growth hormones, microbes, and enzymes. It is used as a foliar spray that plants can easily absorb (Kaur *et al.* 2015) and also have a pesticide effect, with plants showing less or no incidence of diseases and pests (Verma *et al.* 2018). The combined uses of vermiwash and vermicompost leads to the highest yielding plants with improve physicochemical, biological, and microbiological properties of the soil. Vermiwash is a rich source of vitamins, hormones, enzymes, macronutrients and micronutrients which help in efficient growth of plants (Prabakaran, 2005). It provides copious amount of bioavailable macro and micronutrients for synthesis of their biomass. Application of vermiwash showed high growth rate due to increased uptake of macronutrients and micronutrients present in it. This leads to increased root length, shoot length and number of leaves in the vermiwash applied plants. This bio-liquid is rich in nutrients and plant growth hormones (Varghese and Prabha, 2014). Manuring with vermicompost or in combination with foliar spray of vermiwash (5 or 10%) recorded higher number of pods plant^{-1} (12.7-15.8) as compared to that in untreated control (7.9 pods plant^{-1}) and positively influenced nodulation and plant growth, and significantly increased number of pods plant^{-1}, number of seeds pod^{-1} (Mahto and Yadav, 2005). Vermiwash elevated the levels of total macronutrients (N, P, K and C) and micronutrients (Fe, Cu, Mg and Zn). In addition, vermiwash increased root and shoot length. The number of leaves was also found to be increased in vermiwash treated plants (Subha Mary and Lakshmi Prabha, 2014).

Mahendra and Narendra (2012) reported enhancement of higher nodule counts and root biomass in a soybean field treated with vermiwash/vermicompost, which may prove to be a boon for improving productivity of agricultural crops. As the number of nodules per plant increases, the fixation rate of nitrogen increases resulting in higher biomass, leaf size,

pod and seed size. Vermiwash contains higher concentration of available nitrogen improving Rhizobial colonization of nodules (Pathma and Sakthivel, 2012). Application of 100% RDF + vermiwash was recorded significantly the highest pods plant^{-1}, grains pod^{-1}, test weight, grain and stalk yield of pigeonpea as compare to other treatments (Verma, 2016). The foliar spray of vermiwash recorded higher number of branches over water spray. The mean grain yield was significantly higher (10.42 q ha^{-1}) with vermiwash compared to water spray (9.68 q ha^{-1}) (Khairnar *et al.*, 2012).

Combined uses of vermiwash with vermicompost (5 or 10%) gave higher fresh yield of vegetable pea by approximately 70% over control (Mahto and Yadav, 2005). The vermiwash is less expensive than chemical fertilizers, easily producible, eco-friendly and one of the best organic manure for foliar spray on the different crops. The study of Ansari and Sukhraj (2010) revealed that combination of vermicompost and vermiwash showed a significantly greater yield response of okra by 64.27% as compared with the control. Application of vermiwash increases growth, flowering and corm yield characters of gladiolus when they are applied (Verma *et. al.*, 2018). Vermiwash is rich in dissolved nutrients and amino acids which are easily available for plants. It is also a toxic free and ecofriendly compound, which cease the bacterial growth and forms a protective layer for their survival and growth. As a foliar spray, it was reported to initiate flowering and long-lasting inflorescence. It can also be used as a liquid fertilizer applied to the rhizosphere. No pathogen can survive in this fluid, thereby protecting the earthworms from the diseases caused by pathogens. It acts as a plant tonic and thus helps in reducing many plant pathogenic fungi. It increases the rate of photo synthesis in crops/plants. The vegetative parameters viz., carotenoid, leaf weight, chlorophyll, the height of Phaseolus vulgaris. L bean reported by Belmeskine *et al.* (2020) to increase significantly. Plants treated with pure vermiwash during their growth could be productive. Soya bean, a leguminous plant, harnesses nitrogen-fixing bacteria in their nodules and contain healthy protein. An enhancement of higher nodule counts and root biomass was observed in a soya bean field treated with vermiwash, which may prove to be a boon for improving productivity of agricultural crops (Bhavya *et al.*, 2021). As the number of nodules per plant increases, the fixation rate of nitrogen increases resulting in higher biomass, leaf size, pod and seed size. Vermiwash contains higher concentration of available nitrogen improving Rhizobial colonization of nodules. Sufficient availability of soluble nitrogen enhances plant growth and increases productivity. Some related results are stated below:

Table 2. Results showing the utilization of vermiwash to increase the crop yield

Findings	References
Study revealed that combined uses of vermicompost + vermiwash (5 or 10%) gave higher fresh yield of vegetable pea/plant by approximately 70% over control	Mahto and Yadav, 2005
Combination of vermicompost and vermiwash showed a significantly greater yield response of okra by 64.27% as compared with the control.	Ansari and Sukhraj, 2010
Result showed that the foliar application of aqueous mixture of combination of vemiwash with neem oil, leaf and bark have increased the plant growth, early flowering and productivity of brinjal.	Tiwari and Singh, 2015
It was observed that vermiwash spray enhanced growth (plant height and number of leaves) and yield (number of flowers and fruits per plant) parameters when applied to brinjal plant.	Nayak *et al.,* 2019
It has also observed increase in quality of fruit with the application of vermiwash.	Edwards *et al.,* 2004
The highest average brinjal fruit yield (29.99 t ha-1) was found in the treatment containing foliar spray of 20% concentration of vermiwash and the lowest (26.35 t ha^{-1}) came from control. On the other hand, nutritional quality (moisture content, TSS, β carotene and nutrient content) were seen to be higher in vermiwash treated treatment compared to control treatment. The study suggests that, 20% concentration of vermiwash could be used as effective foliar spray for eco-friendly and higher yield of brinjal	Yasmin *et al.,* 2021
The average yield of okra during trial showed a significantly greater response in vermicompost and vermiwash compared with the control by 64.27%. The fruits have a greater percentage of fats and protein content in vermicompost and vermiwash when compared with those grown with chemical fertilizers by 23.86% and 19.86%, respectively.	Ansari and Sukhraj, 2010
Foliar application of vermiwash significantly improved black gram's productivity and quality over the control. Among the vermiwash treatments, vermiwash showed the highest growth, yield, nutrients and protein content in organic black gram.	Kumar *et al.,* 2022
All the parameters like growth, yield and quality of chilli shows better result in vermiwash as compare to chemical fertilizer.	Chavan *et al.,* 2022
Application of vermiwash in pot and field experiments through foliar application led to remarkable improvement in the growth, nutrient contents of shoot and yield of young and mature tea compared to the untreated plants.	Phukan and Savapondit 2011

(ii) In sustainable crop production

The first green revolution enormously enhanced the crop production, but on the other hand, massive application of chemical fertilizers over a period has resulted in poor soil health, reduction on agricultural produces, and increases in incidences of insect pest and disease and environmental pollution (Ansari and Ismail, 2001). Long term use of various agrochemicals like fertilizers, plant growth promoters and pesticides adversely affected ecosystems like soil, water, and food contamination and gene pool of wild seeds. Vermicomposting is widely used to turn solid organic waste materials into hygienic and valuable products due to its efficiency, sustainability and eco-friendliness (Singh *et al.,* 2013; Gajalakshmi and Abbasi, 2002). Vermicomposting has shown tremendous impacts on crop development in the field. In addition, during the vermicomposting, the vermireactor feed's pathogenic content is reduced (Huang *et. al.,* 2020).

The main three objectives of sustainable agriculture are: a healthy environment, economic profitability and social and economic equity. For achieving these objectives application of vermiwash can play an important role in ensuring a sustainable agricultural system (Nayak *et. al.,* 2019). The effect of vermiwash was observed on the plants and soil. It was found that vermiwash seems to possess an inherent property which acts not only as a liquid organic biofertilizer which promot growth of plants and yield but also as a mild biopesticide. So, it can be used as a potent input in organic farming and sustainable crop production for both soil health and insect, pest and disease management (Nayak *et. al.,* 2019).

Sustainable development in agriculture and yield improvement of crops can be achieved through restoration and scientific management of land productivity. For yield maximization in intensive cropping, supply of appropriate source and amount of nutrients is indispensable. In conventional practice, improved cropping system involving high value crops rely on the use of chemical fertilizer due to its immediate availability of nutrients. Indiscriminate and continuous use of such chemical fertilizers leads to instability in yield and also poses a threat to soil health particularly due to micronutrients deficiency and fertilizer related environment pollution (Kalloo, 2003). Use of organic farming techniques to grow crops has gained popularity in recent years as a result of both an increase in consumer demand for organically grown produce and a genuine desire on the part of many growers to sustain or improve the soil health (Murmu and Swain, 2013). The organic manure is eco-friendly and economically viable and has played a significant role in soil biology, chemistry and physics. Both the vermicompost and vermiwash are used as bio-fertilizers in the practice of sustainable agriculture. It is reported that the combined use of vermiwash and vermicompost have the highest plant yield with more branches, higher number of capsules, higher plant dry weight, improved root growth parameters, enhanced physico-chemical, biological and microbiological properties of the soil (Makkar *et al.* 2017). Use of vermiwash and vermicompost enhances the quality of the crop by increasing their nutrition status that also improves the sustainability of commercial agriculture in a less tangible.

(iii) On soil fertility

Use of organic formulations in agriculture could be a dynamic source to move forward soil fertility (Verma *et al.*, 2017). Combination of vermicompost and vermiwash recorded a significant influence on the biochemical characteristics of the soil with marked improvement in soil micronutrients and better qualitative improvement in the physical and chemical properties of the soil (Ansari and Sukhraj, 2010). Tharmaraj *et al.,* (2011) reported that soil treated with vermicompost and vermiwash mixture had significantly enhanced soil physico-chemical properties when compared to unamended soil. According to Tripathi *et al.* (2005), vermiwash increases the number of microorganisms in the soil which helps in the decomposition of organic matter. Application of vermiwash has been reported to revitalize the soil quality (Gopal *et al.*, 2010). It rejuvenates the depleted soil fertility and enriches available pool of nutrients, conserves moisture and natural and biological recourses. Studies revealed that application of vermiwash increased the crop production capacities of soil by (i) enhancing the organic carbon contents in the soil and (ii) increasing the populations of the soil microorganisms, particularly plant beneficial ones and their activities which would have facilitated increased uptake of the nutrients by the plants resulting in higher growth and yield (Dongare and Gawas, 2021). Some related results are stated below:

Table 3. Results showing the utilization of vermiwash to improve soil fertility

Findings	References
Soil treated with vermicompost and vermiwash mixture had significantly enhanced soil physico-chemical properties when compared to unamended soil.	Tharmaraj *et al.,* 2011
Application of vermiwash has been reported to revitalize the soil quality.	Gopal *et al.,* 2010
The combination of vermicompost and vermiwash have a significant influence on the biochemical characteristics of the soil with marked improvement in soil micronutrients. The combination was found better suggesting qualitative improvement in the physical and chemical properties of the soil.	Ansari and Sukhraj, 2010
Vermiwash contains micro and macro nutrients, hormones which promote plant growth and yield and improves soil fertility status.	Mukhi *et al.,* 2022

(iv) Disease and pest control in soil

Besides the application as a fertilizer, vermiwash can also be applied in disease suppression and pest control due to the presence of essential antimicrobial and anti pest chemicals (Kanchan *et al.*, 2013; Thakur and Sood, 2019; Nadana *et al.,* 2020). Vermiwash comprises decomposer bacteria, fungi, secretion, and mucous of earthworm, which could help in disease suppression and production of metabolites that prevent growth of pathogenic bacteria and different plant pests (Nadana *et al.,* 2020; Sulaiman and Mohamad, 2020). Akinnuoye-Adelabu *et al.* (2019) reported that the effect of vermiwash and mucus extracted

from earth worms on *Fusarium graminearum* greatly inhibited the growth of pathogenic fungus which significantly influenced both quality and production of wheat. Vermiwash also inhibited the growth of eggs of plant eating red spider mite (Thakur and Sood, 2019). It was reported that it could be applied in the agricultural field as an insecticide for controlling red spider mite infestation. The repellant effect of vermiwash attributed to the presence of mucus in it (Nadana *et al.,* 2020). Vermiwash with bio-pesticide is the better option for the growth, productivity as well as management of *Leucinodes orbonalis* infestation on brinjal crop. Increasing concentration of vermiwash suppressed insect-pest population of tomato (Sayyad, 2017). The foliar spray of vermiwash provides necessary nutrients to the growing plant for elongation, early flowering and fruiting phase. The bio-pesticide are more effective against larvae and caterpillar of fruit and shoot borer without contamination of fruits, so it was found the best alternative of chemical fertilizers and pesticides for management of *Leucinodes orbonalis* population and enhancement of the productivity of fruit yield (Verma *et al.,* 2018). Globally, the pathogenic fungus *Fusarium graminearum*, severely affected the roots and reduced the production and quality of wheat by 20%. But, after the application of vermiwash into the farm of wheat, the effect of this harmful fungus was controlled (Akinnuoye-Adelabu *et al.,* 2019). Vermiwash serves as pesticide, disease curative and crop tonic of lab beans (Esakkiammal *et al.,* 2015) and thus demonstrates to have superior biopesticidal activity (Samadhiya *et al.* 2013).

Combined uses of vermicompost and vermiwash (5 or 10%) gave better performance with lower pest infestation in vegetable pea by 24.26% over control (Mahto and Yadav, 2005). Again combined application of vermiwash with other plant based pest controlling method gave a synergetic effect to minimize infestation of pests such as thrips and mites and produce a large number of healthy pods to enhance productivity (Kanchan *et al.,* 2013). Microorganisms in the vermicompost and vermiwash may act as antagonistic agents of a pathogen by their ability to compete for nutrients and space, destroying parasitizing pathogens by producing an antimicrobial compound and systematically reducing their resistance (Mehta *et al.,* 2014). Vermicompost and vermiwash were proven to be able to control disease powdery mildew at 75.14% rate when applied. On the other hand, combination of vermicompost, vermiwash and 10% cow urine which said to be able to control disease at 73.37% rate. Additionally, vermiwash made from animal manure combined with gram bran and neem oil is said to be quite good at controlling pod borer.The production of the gram crop rose by up to three times with the application of vermiwash and biopesticide in comparison to the control (Nath and Singh, 2015). Some related results are stated below:

Table 4. Results showing the utilization of vermiwash to control disease

Findings	References
Result showed that vermiwash from fourteen days vermicomposting inhibited the growth of fungal mycelium by 16%.	Akinnuoye-Adelabu *et al.*, 2019
It was reported that for mildew disease on cowpea, usage of 20-30 percent vermiwash cause suppression of mycelia growth of fungi. Vermicompost and vermiwash were proven to be able to control disease powdery mildew at 75.14% rate when applied. On the other hand, combination of vermicompost, vermiwash and 10% cow urine which said to be able to control disease at 73.37% rate.	Nayak *et al.*, 2019
Vermiwash at 5–10 percent dilution inhibited mycelial growth of pathogenic fungi. It also had capacity to encounter worms, thereby save crops and enhance productivity.	Bhavya *et al.*, 2021

Vermiwash as liquid fertilizer

Liquid organic manure has largely remained in background of bio-dynamic farming. The plant can absorb nutrients about 20 times fast through the leaves than applied through the soil. Liquid manures are helpful to overcome temporary nutrient shortages, mainly used to stimulate growth during the season when nutrient uptake through the roots is hindered. Liquid organic manure has long shelf life, easy to disperse in water and it is rapidly up taken by plants compared to solid organic fertilizer. The use of organic liquid products such as panchagavya, sasyagavya, beejamrutha, sanjeevani, kunapajala, vermiwash, sea weed extract etc. resulted in higher growth, yield and quality of crops. Vermiwash is the by-product of vermicompost applied as fertilizer by directly adding it into soil and as a liquid sprays overall part of the plant body to prevent fungal, bacterial pathogen and pests (Gudeta *et al.*, 2021). It generally applied as a foliar spray act as replacement and supplement for agrochemicals and for their unique capacity to provide nutrients effectively and quickly (Nayak *et al.*, 2019). It is very useful as a foliar spray for plants as it contains the beneficial microorganisms and water soluble fractions of nutrient substances (Ismail, 1997). Many studies showed that vermiwash could be applied as a liquid bio-fertilizer as well as a spray (Shafique *et al.*, 2021). As a foliar spray, it initiated flowering and enduring inflorescence. Vermiwash could be utilized as a liquid fertilizer applied to the rhizosphere (Das *et al.*, 2014; Khan *et al.*, 2015).

Plant Growth regulators (PGRs) in general are organic compounds, which bring about an increase or modification of growth in plants. Manufacturing and production of synthetic phytohormones is not economically feasible and the optimum conditions under which they can function efficiently is also difficult to ascertain (Gemici *et al.*, 2000). Vermiwash has excellent growth promoting effects. Vermiwash is a collection of excretory and secretory products of earthworm along with other micronutrients and contains sugars, amino acids and phenols along with plant growth promoting hormones such as in Indole acetic acid and humic acid (Gulsar and Iyer, 2006).

Vermiwwash in hydroponic system

The agriculture sector will have a great challenge to meet the demand of increasing population by 2050. In addition, the farming community is currently confronting critical issues on the application of chemicals and rapidly decreasing arable lands due to salinization, inundation, and desertification (Bennet and Khush 2003; Flowers and Colmer 2008; FAO 2011). Hydroponics can play an important role in finding solutions to this increasing demand. It is a system that allows plants to grow in soilless medium (Jaikishun *et al.,* 2018). Hydroponic agriculture allows for high production of vegetable and herb crops. In areas where water shortages or degraded soils give rise to limitations, hydroponics is viewed as a suitable substitution for traditional agriculture. Hydroponic agriculture allows for precise control and increased efficiency of water, nutrients and aeration directly in contact with the root interface. Water usage can be reduced by 70-90% when using hydroponics compared to conventional agriculture (Raviv and Lieth, 2008).

Vermiwash produced from the different medicinal plants, namely lime, neem and their combination was very effective for supporting the growth of hydroponically grown lettuce (L. sativa). These nutrient solutions produced from medicinal plants gave better results than the commercial hydroponics solution and water. Vermicompost and vermiwash can be implemented as an alternative method of plant growth. Plants can be grown hydroponically without soil to add nutrients and by just using the vermiwash and vermicompost in a medium made of paddy husks and white sand, thereby reducing the need for much space in growing crops (Jaikishun *et al.,* 2018).

Conclusion

Vermiwash seems to possess an inherent property which acts not only as a liquid organic biofertilizer which promote growth of plants and yield but also as a mild biopesticide. Vermiwash is a sustainable, non-toxic and environmentally friendly approach. Vermiwash can be used as an effective input in organic agriculture for both soil health and disease management for sustainable crop production with low cost. It can be concluded that the use of vermiwash as a potent input in organic farming and sustainable crop production that can effectively manage insects, pests, and diseases while also enhancing soil health and protecting the environment, all of which can contribute to the nation's food security.

References

Aghamohammadi, Z., Etesami, H., and Alikhani, H.A. 2016. Vermiwash allows reduced application rates of acaricide azocyclotin for the control of two spotted spider mite, Tetranychus urticae Koch, on bean plant (Phaseolus vulgaris L.). Ecol. Eng., 93, 234-241.

Akinnuoye-Adelabu, D.B., Hatting, J., de Villiers, C., Terefe, T., and Bredenhand, E. 2019. Effect of redworm extracts against Fusarium root rot during wheat seedling emergence. Agron. J., 111 (5), 2610–2618.

Ansari, A.A., and Ismail, S.A. 2001. A case study on organic farming in Uttar Pradesh. J Soil Biol. Ecol., 27, 25-27.

Ansari, A.A., and Ismail, S.A. 2001. A case study on organic farming in Uttar Pradesh. J. Soil Biol. Ecol., 27, 25-27.

Ansari, A.A., and Sukhraj, K. 2010. Effect of vermiwash and vermicompost on soil parameters and productivity of okra (Abelmoschus esculentus) in Guyana. African Journal of Agricultural Research, 5(14), 1794-1798.

Ansari, A.A. 2008. Effect of Vermicompost and Vermiwash on the productivity of Spinach Spinacia oleracea, Onion Allium cepa and Potato Solanum tuberosum. World Journal of Agricultural Sciences, 4(5), 554-557.

Awadhpersad, V.R.R., Ori, L., and Ansari, A.A. 2021. Production and effect of vermiwash singly and in combination with vermicompost on the growth, development and productivity of tomatoes in the greenhouse in Suriname. ASIAN Journal of Agriculture, 5(1), 29-34.

Awadhpersad, V.R.R., Ori, L. and Ansari, A.A. 2021. Production and effect of vermiwash and vermicompost on plant growth parameters of tomato (Lycopersicon esculentum Mill.) in Suriname. International Journal of Recycling of Organic Waste in Agriculture, 10, 397-413.

Belmeskine, H., Ouameur, W.A., Dilmi, N., and Aouabed, A. 2020. The vermicomposting for agricultural valorization of sludge from Algerian wastewater treatment plant: impact on growth of snap bean Phaseolus vulgaris L. Heliyon, 6(8), e04679.

Bendalam, P., and Kaviti, V. L. 2020. Vermiwash. Just Agriculture, p. 42.

Bennett, J., and Khush, G.S. 2003. Enhancing salt tolerance in crops through molecular breeding: a new strategy. J Crop Prod, 7, 11-65.

Bhavya, K., Sumalatha, N., Archana, T., and Lakshmi, K.V. 2021. A review vermiwash: A plant growth booster and a disease suppressor. The Pharma Innovation, 10(11), 2959-2962.

Buckerfield, J.C., Flavel, T., Lee, K.E., Webster, K.A. 1999. Vermicompost soil and liquid form as plant growth promoter. Pedobiologia, 42, 753-759.

Chavan, C., Shete, R., Nikam, V, Kurlapkar, D., and Gaikwad, D. 2022. Effect of different concentrations of vermiwash and chemical fertilizers on growth, yield and quality of chilli (Capsicum annum L.) var. Pusa-jwala. J. of Emerging Tech. and Innovative Res., 9(7), 721-729.

Das, S.K., Avasthe, R.K., and Gopi, R., 2014. Vermiwash: use in organic agriculture for improved crop production. Popular Kheti, 2 (4), 45–46. www.popularkheti.info .

Dongare, S., and Gawas, I. 2021. Use of vermiwash in the field of Agriculture. Just Agriculture, p.32.

Dwivedi, B.S., and V. Dwivedi, 2007. Monitoring Soil Health for Higher Productivity, Indian Journal of Fertilizers., 3(1), 11-23.

Edwards, C.A., Domínguez, J., Arancon, N.Q. 2004. The influence of vermin composts on plant growth and pest incidence. In, S.H Shakir and W.Z.A. Mikhaïl, (Eds. Soil Zoology for Sustainable Development in the 21st century, 397-420.

Esakkiammal, B., Lakshmibai, L., and Sornalatha, S. 2015. Studies on the combined effect of vermicompost andvermiwashprepared from organic wastes by earthworms on thegrowth and yield parameters of dolichous lab Lab. Asian Journal of Pharmaceutical Science and Technology, 5(4), 246-252.

FAO. 2011. The State of the World's Land and Water Resources for Food and Agriculture (SOLAW)-Managing Systems at Risk. Food and Agriculture Organization of the United Nations, Rome and Earthscan, London.

Flowers, T.J., and Colmer, T.D. 2008. Salinity tolerance in halophytes. New Phytolol, 179, 945-963.

Gajalakshmi, S., and Abbasi, S.A. 2002. Effect of the application of water hyacinth compost/vermicompost on the growth and flowering of Crossandra undulaefolia, and on several vegetables. Bioresour. Technol., 85, 197–199.

Gemici, M., Goven, A., and Kamil, Y.A. 2000. Effect of Some Growth Regulators and Commercial Preparation on the Chlorophyll Content and Mineral Nutrition of Lycopersicm. Esculent Mill, pp: 215-219.

GorakhNath, Keshav S., and Singh, D.K. 2009. Chemical analysis of vermicompost/vermiwash of different combination of animal, agro and kitchen wastes. Aus. J Bas. & Appl. Sci., 3(4), 3672-3676.

Gudeta, K., Julka, J., Kumar, A., and Bhagat, A. 2021. Vermiwash: An agent of diseases and pest control in soil, a review. Heliyon, 7, e06434.

Gulsar, B.J., and Iyer, R. 2006. Effect of Vermiwash on nematodes Prevalent in coconut based high- density multispecies cropping system. Indian J. of Nemat., 36(2), 195-199.

Hatti, S.S., Londonkar, R.L., Patil, S.B., Gangawane, A.K., and Patil, C.S. 2010. Effect of Eisenia fetida vermiwsh on the growth of plants. J. of Crop Sci., 1, 06-10.

Huang, K., Xia, H., Zhang, Y., Li, J., Cui, G., Li, F., Bai, W., Jiang, Y., and Wu N. 2020. Elimination of antibiotic resistance genes and human pathogenic bacteria by earthworms during vermicomposting of dewatered sludge by meta genomic analysis. Bioresour. Technol., 297, 122451.

Industries, M. 2020. Vermiwash preparation process, benefits, cost. https://mipatex.in/blogs/farming/vermiwash-preparation-process-benefits-cost accessed on 06/11/2023.

Ismai, S.A. 1997. Vemicology. The Biology of Earthworms. Orient Longman Press, Hyderabad, pp. 92.

Jaikishun, S., Hoosen, A., and Ansati, A.A. 2018. The effects of vermicompost and vermiwash from the medicinal plants, neem (Azadirachta indica) and lime (Citrus aurantifolia) on growth parameters of lettuce in a hydroponic system., Nusantara Biosci., 10(2), 91-95.

Jayashree, M.P. 2006. Vermiwash-The wonder tonic in agricultural. Kisan World, 6, 44.

Jaysawal, P.K., Arun, D.P., Verma, S.K., Rakshit, A., Chattopadhyay, A., and Pandey, P. 2020. Vermiwash: Key for the crop production in organic agriculture. Int. J. of Bioresource Sci., 7(1), 21-23.

Kalloo, K. 2003. Research and extension activities on organic agriculture in India. Organic farming in horticulture for sustainable production, 29-30 August, CISH, Lucknow,1p.

Kanchan, M., Keshav, S., and Tripathi, C.P.M. 2013. Management of pod borer (Helicoverpa armigera) infestation and productivity enhancement of gram crop (Cicer aritenium) through vermiwash with biopesticides. World J. Agric. Res., 9 (5), 401–408.

Kanchan, M., Keshav, S., and Tripathi, C.P.M. 2013. Management of pod borer (Helicoverpa armigera) infestation and productivity enhancement of gram crop (Cicer aritenium) through vermiwash with biopesticides. World J. Agric. Res., 9 (5), 401–408.

Karuna, K., Patil, C. R., Narayanswamy, P. and Kale, R. D. 1999. Stimulatory effect of earthworm body fluid (vermiwash) on crinkle red variety of Anthurium and reanumlind. J. of Crop Res., 17(2), 253-257.

Kaur, M., and Kaur, D.P. 2017. Vermiwash: An effective nutritive boon to foliage and crops. J. of Appl. and Natural Sci., 9(3), 1608-1611.

Kaur, P., Bhardwaj, M., and Babbar, I. 2015. Effect of vermicompost and vermiwash on growth of vegetables. Res. J. Animal, Veterinary and Fishery Sci., 3(4), 9-12.

Khairnar, A.V., and Gunjal, B.S. 2012. Effect of potash fertilization and foliar spray of vermiwash on growth and yield of green gram (Vigna radiata L). Int. J Agri. Sci., 8(1), 307-308.

Khan, M.H., Meghvansi, M.K., Gupta, R., Chaudhary, K.K., Prasad, K., Siddiqui, S., Veer, V., and Varma, A. 2015. Combining application of vermiwash and Arbuscular Mycorrhizal fungi for effective plant disease suppression. Organic Amendments and Soil Suppressiveness in Plant Disease Management. Springer, Cham, pp. 479–493.

Kumar, D., Sharma, S.K., Kumar, B., Kumar, S., Kashyap, S., and Kumar R. 2022. Potential of vermiwash prepared from different combinations of organic wastes to improve the growth, yield and quality of organic black gram. Legume Res., DOI: 10.18805/LR-4957.

Mahendra, S., and Narendra, K. 2012. Effect of FYM, vermicompost, vermiwash and NPK on growth, microbial biomass and yield of soybean. Soybean Res., 10, 60–66.

Mahto, T.P., and Yadav, R.P. 2005. Effect of vermicompost alone and in combination with chemical fertilizer on stem fly incidence and yield attributes in vegetable peas under Bihar conditions. J Appl. Zool. Res., 16(1), 70-72.

Makkar, C., Jaswinder, S., Chander, P. 2017. Vermicompost and veriwash as supplement to improve seedling, plant growth and yield in Linum usitaainum L. for organic agriculture. Int J Recycl Org Waste Agricult, 6, 203-218. https://doi.org/10.1007/s40093-017-0168-4

Manyuchi, M.M., Phiri, A., Muredzi, P., and Chitambwe, T. 2013. Comparison of vermicompost and vermiwash biofertilizers from vermicomposting waste corn pulp. In Proceedings of World Academy of Science, Engineering and Technology, World Acad. Sci. Engi. Technol., (WASET), 78, 346.

Meena, A.L., Karwal, M., and Kumari, P. 2021. Vermiwash: A potential tool for sustainable organic farming, Food and Scientific Reports, 2(9), 43-45.

Mehta, C.M., Palni U., Franke-Whittle, I.H. and Sharma, A.K. 2014. Compost: its role, mechanism and impact on reducing soil-borne plant diseases. Waste Manag., 34 (3), 607–622.

Mukhi, S.K., Nayak, M.P., Sardar, S.S., and Bar, N. 2022. Vermiwash: A potential tool for crop production in organic agriculture. Int. J. of Plant and Soil Sci., 34, 23.

Murmu, K., and Swain, D.K. 2013. Comparative assessment of conventional and organic nutrient management on crop growth and yield and soil fertility in tomato-sweet corn production system. Asian Journal of Crop Science, 7911), 1617-1626.

Nadana, G.R.V., Rajesh, C., Kavitha, A., Sivakumar, P., Sridevi, G. and Palanichelvam, K. 2020. Induction of growth and defense mechanism in rice plants towards fungal pathogen by eco-friendly coelomic fluid of earthworm. Environ. Tech. Innovation, 19.

Nath, G., and Singh, K. 2015. Combined Effect of Vermiwash withBiopesticides against Infestation of Pod Borer (Helicover paarmigera Hub.). Int. J. of Zoological Investigations., 1(1), 40-51.

Nayak, h., Rai, S., Mahto, R., Rani, P., Yadav, S., Prasad, S.K., and Singh, R.K. 2019. Vermiwash: A potential tool for sustainable agriculture. Journal of Pharmacognosy and Phytochemistry, International Conference on "Food Security through Agriculture and Allied Sciences, May 27-29, 2019, SP5: 308-312. Dongare S. and Gawas I. Use of vermiwash in the field of agriculture. Just Agriculture, p:32-36, https://justagriculture.in/ files/magazine/2021/ december/ 08%20Use%20of%20Vermiwash.pdf accessed on 08/ 11/2023.

Pathma, J., and Sakthivel, N. 2012. Microbal diversity of vermicompost bacteria that exhibit useful agricultural traits and waste management potential. Springer Plus, p26(1).

Patil, P. 2020. Organic Crop Nutrient Vermiwash Preparation and Use of Liquid Fertilizer, January 27, 2020.

Phukan, I.K., and Savapondit, D. 2011. Vermiwash-A effective organic nutrient amendment for foliar spray in tea cultivation. *Sci. and Culture*, 77(9-10), 425-428.

Prabakaran, J. 2005. Biomass resources in vermicomposting, In: Proceedings of the State Level Symposium on Vermicomposting Techonolgy for Rural Development, Madurai, TamilNadu, India; pp 27 - 40.

Rai, N., and Bansiwal. 2008. Vermiwash: An excellent source of nutrition for plant growth. Electronic J. of Environ. Sci., 1, 19-21.

Raviv, M., and Lieth, J. 2008. Significance of soilless culture in agriculture. Soilless culture Amsterdam: Elsevier, pp. 1-12.

Samadhiya, H., Dandotiya, P., Chaturbedi, J., and Agarwal, A.P. 2013. Effect of vermiwash on the growth and development ofleaves and stem of tomato plants. International Journal of Current Research, 5(10), 3020-3023

Sayyad, N.R. 2017. Utilization of vermiwash potential againstinsect pests of tomato. International Research Journal of biological Sciences, 6(1), 44-46.

Scheu, S. 1987. Microbial activity and nutrient dynamics in earthworms casts. Journal of Biological Fertility Soils, 5(3), 230-234.

Shafique, I., Andleeb, S., Aftab, M.S., Naeem, F., Ali, S., Yahya, S., Ahmed, F., Tabasum, T., Sultan, T., Shahid, B. and Khan, A.H. 2021. Efficiency of cow dung based vermi-compost on seed germination and plant growth parameters of Tagetes erectus (Marigold). Heliyon, 7 (1), e05895.

Singh, A., Jain, A., Sarma, B.K., Abhilash, P.C., and Singh, H.B. 2013. Solid waste management of temple floral offerings by vermicomposting using Eisenia fetida. Waste Manag., 33, 1113–1118.

Subha Mary, V., and Lakshmi Prabha, M. 2014. Biochemical characterization of vermiwash and its effect on growth of Capsicum frutescens. Malaya Journal of Biosciences, 1(2), 86-91.

Sulaiman, I.S., and Mohamad, A., 2020. The use of vermiwash and vermicompost extract in plant disease and pest control. In: Natural Remedies for Pest, Disease and Weed Control. Academic Press, pp. 187–201.

Sundararasu, K. 2016. Effect of vermiwash on growth and yielding pattern of selected vegetable crop Chilli (Capsicum annum). International Journal of Advanced Research in Biological Sciences, 3(9), 155-160.

Thakur, S., and Sood, A.K. 2019. Lethal and inhibitory activities of natural products and biopesticide formulations against Tetranychus urticae Koch (Acarina: Tetranychidae). Int. J. Acarol, 45 (6-7), 381–390.

Tharmaraj, K., Ganesh, P., Kolanjinathan, K., Suresh, K.R., and Anandan, A. 2011. Influence of vermicompost and vermiwash on physico chemical properties of rice cultivated soil. Current Botany, 2(3), 18-21.

Tiwari, S.K., and Singh, K. 2015. Potency of combination of liquid biofertilizer with biopesticide on productivity of brinjal and infestation of Leucinodes orbonalis (Pyraustidae: Lepidoptera). Int. J. Pure App. Biosci., 3(5), 62-72.

Tripathi, Y.C., Hazarika, P., Pandey, B.K. 2005. Vermicomposting: An ecofriendly approach to sustainable agriculture. In: Arvind Kumar (eds), Verms and vermitechnology. APH Publishing Corporation, New Delhi, 23-39.

Varghese, S.M, and Prabha, M.L. 2014. Biochemical characterization of vermiwash and its effect on growth of Capsicum frutescens. Malay Journal of Bioscience, 1(2), 86-91.

Verma, S. 2016. Bio-efficacy of organic formulations along with fertilizers on growth, yield and quality of pigeonpea [Cajanus cajan (L.) Millsp] (Doctoral dissertation, Institute of Agricultural Sciences, Banaras Hindu University).

Verma, S., Babu, A., Patel, A., Singh, S.K., Pradhan, S.S., Verma, S.K., Singh, J.P., and Singh, R.K. 2018. Significance of vermiwash on crop production: A review. Journal of Pharmacognosy and Phytochemistry, 7(2), 297-301.

Verma, S., Singh, A., Pradhan, S.S., Singh, R.K., and Singh, J.P. 2017. Bioefficacy of Organic Formulations on Crop Production-A Review. Int. J Cur. Microbiol. App. Sci., 6(5), 648-665.

Yaseen, A.A., Essa, E.M., Marzouk, N.M., and Zaghioul, S.M. 2020. Impact of vermicompost and foliar spray of vermiwash on growth, yield and nutritional status of lettuce plants. Plant Archives, 20(1), 449-455.

Yasmin, M., Rahman, M.S., Rahman, M.A. Shikha, F.S., and Alam, M.K. 2021. Effect of foliar application of vermiwash on growth and quality of brinjal. Journal of waste and biomass management, 3(1), 31-34.