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Enhancement of Greengram (*Vigna radiata L.)* Productivity by Using Organic Extracts and Fertilizers

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Greengram (*Vigna radiata L.)* being a leguminous crop has high nutritional value and is one of the most important pulse crops grown in India. In India greengram production is affected by a variety of factors, including biotic stresses like diseases, weeds, and pests as well as abiotic stresses such as drought, floods and poor management practices. Among those the use of inorganic fertilizers has resulted in ground water pollution, deteriorating soil quality, high production cost and poor quality production for livelihood which has resulted in poor productivity. Thus the main objective of this paper is to review the use of organic extracts and fertilizers and their benefits for enhanced productivity in greengram. As organic sources are known to considerably effect the growth and development of a crop yielding significant results, as a result utilization of such organic sources like seaweed extract, vermiwash, humic acid, panchagavya and jeevamruth can play a major role in enhancing the productivity in greengram.

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Keywords: Greengram; organic fertilizer; productivity.

1. INTRODUCTION

In India, pulses are consumed more often than any other protein source, highlighting their crucial role in the daily eating habits of the people. But the rising demand for pulses in India has outpaced domestic production, necessitating the need for imports [1]. In recent decade pulses saw a growth rate that was 32% less compared to cereals due to farmer's having major dependence on cultivation of cereal crops over pulses. This is due to pulses having low yielding capacity and poor resistant to diseases which is a major limitation in adoption of pulses by farmer's [2]. In India, the cultivation of pulses covers an area of about 23.55 million hectares, leading to an annual production of approximately 17.15 million tonnes, with an average yield of 728 kilograms per hectare [3]. The productivity of pulses in India is considerably low as compared to other major countries thus improved management practices are in need of hour [1,3].

Greengram scientifically known as *Vigna radiata (L.)* is a staple food rich in protein. It comprises approximately 25% protein, nearly triple the protein content found in cereals. It is an ancient and well-established leguminous crop in Asia, favored for its successful growth during the kharif season. It is a self-pollinated crop with a chromosome number of 2x = 2n = 22. It can be cultivated either as a sole crop, intercropped, or as a fallow crop. It plays a significant role in Indian agriculture because of its capacity of fixing atmospheric nitrogen via its nodules which helps in improving soil fertility [4]. In India, it covers an area of 64.56 lakh hectares with a production of 4.05 million tones [5]. In India, it accounts for nearly eight percent of the total pulse area and ranks second based on area and production among other pulse crops. The seeds contain 24.7% protein, providing a cost-effective protein source, which is why it is known as "poor man's meat." Green gram is highly digestible and palatable, with its pods commonly used as a green vegetable. Both its whole and split grains are utilized in dishes like dal and curry. Due to its high digestibility, its curry is often recommended for patients [6].

Organic fertilizer plays a crucial role in enhancing soil fertility and increasing crop production but farmers typically overlook its utilization in agricultural practices. The production of greengram in India is considerably low due to factors like poor soil fertility which results from cultivation practices without adequate soil fertility management. This is due to the result of extensive use of synthetic chemical fertilizers which posses a serious threat in maintaining sustainable production. The prolonged and indiscriminate use of chemical fertilizers leads to a serious issue concerning soil health, particularly in terms of reduced efficiency in input utilization, and particularly fertilizer use efficiency [7].

Crop residue and other organic residues are valuable to small-scale farmers because they are cost effective, readily accessible source of nutrients, and environmental friendly as compared to inorganic fertilizers [8]. The use of organic manures, either on their own or in combination with liquid fertilizers, aids in enhancing the physical and chemical properties of the soil, as well as optimizing the effective utilization of applied organic fertilizers to improve seed yield and quality [9]. Enhancing soil quality involves increasing soil organic carbon, cation exchange capacity, soil water content, and promoting beneficial soil microorganisms through the addition of organic matter to the soil. Moreover, organic fertilizer is often the key limiting factor for crop production in major agricultural regions globally, and thus, embracing effective organic fertilizer strategies frequently yields substantial economic benefits for farmers [10].

Organic substances like panchagavya and jeevamrutha are important for boosting plant growth and immunity, as they provide essential nutrients, growth-promoting hormones, and beneficial microorganisms including lactic acid bacteria, yeast, actinomycetes, and photosynthetic bacteria. These microorganisms, coupled with well-known fertilizers like azotobacter, azospirillum, and phosphobacterium, also aid in improving soil health, fostering crop growth, and boost yield [11]. Seaweed extract an organic extract exhibits phytostimulatory properties that leads to the enhancement of growth, health, yield, and quality in a wide range of important agricultural and horticultural crops. Application of seaweed extract stimulates plant growth by boosting seedling growth, root development, and the absorption of minerals and nutrients through the activation of physiological and molecular mechanisms [12]. Organic fertilizers contain microorganisms that break down organic matter, releasing nutrients into the soil. These microbes obtain their energy from decomposing plant and animal residues, thus providing the soil with a diverse range of nutrients [13]. Restoring soil fertility necessitates nourishing the soil microorganisms, which can be accomplished through the addition of organic material, minimizing tillage, and eliminating synthetic fertilizers and chemicals [14].

Earlier reports indicate that due to rising fertilizer costs and scarcity, as well as mounting environmental concerns and government support for organic farming, we have been prompted to explore alternative methods of nutrient application such as panchgavya, vermiwash and cow urine [15]. In order to achieve sustainable soil fertility and crop productivity, the utilization of organic manures and other nutrient management practices, including fermented liquid organic fertilizers like Panchagavya, Jeevamrut, Beejamrut, Sasyamrut, Gomutra, Angara, Vermiwash, is essential. These fermented liquid organic fertilizers not only provide nutrients but also contain microbial populations and plant growth-promoting substances (PGPR), which contribute to stimulating plant growth, increasing yield, enhancing metabolic activity, and boosting resistance to pests and diseases [16]. Hence the objective of this paper is to review the use of organic extracts and fertilizers for enhancement of productivity in greengram.

2. ECOLOGICAL REQUIREMENT OF GREENGRAM

Various abiotic and biotic factors, including temperature, soil moisture, soil acidity, salinity, drought, waterlogging, pest, and disease pressure, can reduce greengram productivity by altering physiological processes and plant water relations [17,18,19,20,21,22]. The crop has the ability to thrive and produce in regions experiencing lower ranges of rainfall, although its optimal growth and productivity depend on receiving well-distributed precipitation ranging between 350 and 700 millimeters per year [23]. As a short-day plant with quantitative characteristics, the green gram crop exhibits sensitivity to changes in day length [24]. Short days result in early flowering without adequate vegetative biomass while long days promote delayed flowering. While photoperiod responses may differ among various varieties, the crop tends to thrive optimally when temperatures range between 25°C and 35°C [25]. The green gram crop can grow well in a broad spectrum of soils, including those with red laterite, black cotton, and sandy textures. However, it shows optimal growth in deep, fertile, well-drained loamy to sandy loam soils with a pH level ranging between between 6.0 and 7.0.

3. SOIL FERTILITY STATUS OF INDIA

Evaluating soil characteristics to ascertain its fertility status within a particular area or region is essential for advancing sustainable agricultural production, given the significant influence of soil fertility on crop yields. The widespread occurrence of micronutrient deficiencies globally has been triggered by the use of imbalanced and excessive use of straight fertilizers, the lack of organic fertilizer application, and unscientific farming practices [26]. The extensive barren stretch of the central plain in Uttar Pradesh posses a significant barrier to agricultural productivity and efforts are aimed at restoring the land [27]. In kapurthala district of punjab the majority of farmers engage in three or more crop rotations per year and utilize large quantities of fertilizers, insecticides, and pesticides to maximize their gross returns, typically without considering the soil's fertility status [28]. Farmers in the Pilibhit district of Uttar Pradesh heavily utilize urea chemical fertilizer in their fields, causing an elevation in nitrogen levels within the soil system while maintaining consistent levels of other macronutrients, resulting in a change in soil texture. Moreover, farmers employ various chemicals such as pesticides, insecticides, herbicides, and mixtures like calcium oxide and sodium chloride, toxic substances like Sulfas pills, kerosene oil, and tobacco leaves, to eradicate insect pests and weeds from both their agricultural soil and standing crops [29].

4. GREENGRAM PRODUCTION CONSTRAINT IN INDIA

Among the various factors influencing greengram production and productivity, the utilization of varieties with low yield potential at the farmer level is noteworthy. Farmers encountered challenges associated to the use of improved or recommended green gram seeds, including issues like the non availability of required high-quality seeds, higher seed costs and a lack of information about recommended varieties among the farmers [30]. Biological challenges consist of the indeterminate growth pattern found in local cultivars like Jhain Mung, unproductive plant types, flower and pod shedding, low harvesting efficiency, and shattering tendencies which results in low productivity.The crop is primarily grown as a rain-fed crop in marginal and sub-marginal conditions, often without any nutrient management practices implemented. Typically, farmers refrain from utilizing any nutrient or biofertilizer applications, with YMV (Yellow Mosaic virus) serving as the predominant factor contributing to low yields [31].

5. RESPONSE OF GREENGRAM TO VARIOUS ORGANIC FERTILIZERS

5.1 Humic Acid

Humic acid (HA), a crucial ingredient in many organic fertilizers and a highly influential component of soil and organic matter, could potentially mitigate production limitations in pulse crops. Humic acid enhances plant growth and increases yield by improving nutrient absorption and influencing multiple physiological processes, such as cellular respiration, photosynthesis, protein synthesis, and enzymatic activity.It shows potential as a natural resource for substituting fertilizers to enhance crop productivity [32]. Humic acid distinguished by its deep black colour, is produced through the microbial decomposition of plant and animal matter and remains resilient to further weathering [33]. Humic acid comprises 51% to 57% carbon (C), 4% to 6% nitrogen (N), and 0.2% to 1% phosphorus (P), alongside minute quantities of other micronutrients [34]. Humic acid can be applied either to the soil or as a foliar spray. When used as a soil amendment, it promotes the formation of soft, aerated soil with added nutrients, while its application as a foliar spray enhances nutrient absorption, permeability, and photosynthetic rates [35].

5.2 Effect of Humic Acid on Crop Production

Humic acid regulates the release of nutrients such as nitrogen and phosphorus, potentially boosting growth and yield measures, thereby reducing the dependence on inorganic fertilizers for plant growth. According to Ali et al. (2019) [36] application of humic acid at the rate of of 12 kg ha^{-1} followed by 9 kg ha^{1} resulted highest seed yield, number of seeds per pod, maximum pod length and number of pods per plant. The probable explanation for increased number of pods per plant and number of seeds per pod may be due to humic acid led to an enhanced reproductive efficiency in mungbean and the heightened presence of certain nutrients caused an increase in cell division, subsequently leading to higher grain yield. The increased seed weight of mungbean following soil application of HA reflects improvements in soil nutrient availability and its positive impact on plant growth [37]. Humic acid improves the absorption and accumulation of nutrients, particularly nitrogen, by facilitating the permeability of cell membranes [38,37]. Study conducted by Metre et al*.* (2013) [39] mentioned that application of humic acid as foliar spray through cowdung at the rate of 350 ppm resulted in increase seed yield, number of pods per plant and 100 seed weight. The increase in yield among the yield contributing parameters might be due to mineralization, including nutrient input, which resulted in enhanced growth and more efficient allocation of assimilates to different metabolic pathways.

5.3 Seaweed Extract

Seaweeds, the macroscopic marine algae, have multiple applications such as serving as human food, fodder for animals, replacing chemical fertilizers, and providing various useful chemicals. In recent years, natural seaweeds have been utilized as replacements for synthetic fertilizers.Seaweed extracts are promoted as liquid fertilizers and bio-stimulants owing to their inclusion of various growth regulators such as cytokinins, auxins, gibberellins and other macro and micronutrients necessary for crop growth and development [40]. Seaweeds contain the majority of the necessary trace elements and plant growth hormones crucial for facilitating plant growth and development. Studies have found that seaweed-based fertilizers are rich in potassium, nitrogen, and phosphorus. Seaweed's metabolic functions are similar to those of terrestrial plants, as it contains Auxin, Gibberellin, Cytokinin, and other phytohormones essential for plant growth, maturity, and yield [41]. Various seaweed species are divided into three categories based on the pigments they generate: Brown (Phaeophyta), Red (Rhodophyta), and Green (Chlorophyta) [42]. Table 1 shows the chemical composition of various seaweed species [43].

Seaweed enhances the soil's ability to retain water and fosters a more balanced relationship between air and water within it. Liquid extracts from seaweed have been linked to numerous beneficial outcomes, such as boosted crop productivity, improved plant resistance to frost,

Table 1. Chemical composition of various seaweed species

Analysis	*Ascophyllum Nodosum*	*Sargassum sp.*	*Palmaria palmata*	*Ulva sp.*
Crude Protein (%)	8±2.7(5)	8.5±1.8(10)	19.1 ±6.1(12)	18.6 ± 7.3 (14)
Crude fibre (%)	5.5(4.1-6.8)	10.1±2.4(9)	1.5	6.9 ± 4.1 (7)
Lignin (%)	13.8(6.2-21.4)	4.4(1.0-7.9)	NA	3.5 ± 2.1 (3)
Ash(%)	22.5±2.1(12)	35.9±12.8(9)	24.5(17.5- 31.5)	23 ± 7.4 (13
Ca (g/kg)	20	3.8± 2.6(4)	NA	29.2 ± 28.9 (3)
P(g/kg)	1	2.2±1(5)	NA	2.7 ± 2.1 (3)
K(g/kg)	24	46.2(15.9-76.6)	NA	22.1 (15.1 -29.0)
Na(g/kg)	NA	-	NA	20.2 (11.0–29.3)
Mg(g/kg)	8	7.7(7.5-7.9)	NA	16.7 ± 3.2 (3)
Mn(mg/kg)	12±3(8)	214±106(4)	11	101
Zn(mg/kg)	181±114(8)	214±151(5)	143	45 (28–61)
Cu(mg/kg)	28±16(1)	7±4(5)	24	12 (7–17)
Fe(mg/kg)	134±36(8)	7291±6327(5)	153	1246 (1052–1440)

Source: Makkar et al. [43]

increased absorption of soil nutrients, and heightened resilience to various environmental stresses [44]. Seaweeds are underutilized in Indian agriculture for specific reasons. Farming methods employed in coastal areas involve incorporating dried seaweed in powdered or flake form into the soil or using spray extracts derived from ground seaweed [45]. Limited awareness among indigenous farmers regarding the accessibility of seaweeds contributes to their underutilization in Indian agriculture, while Indian farmers typically favor chemical fertilizers, displaying greater confidence in their efficacy. Furthermore, farmers residing in non-coastal or inland regions of India often lack awareness regarding the availability and significance of seaweeds.The lack of awareness among farmers hinders their purchasing of seaweed extracts from the market, posing a challenge for industries aiming to expand production. This obstacle is also influenced by the techno-economic evaluation of the seaweed industry, its products, and their various applications [44].

5.4 Effect of Seaweed Extract on Crop Production

Seaweed extracts contain key primary and secondary nutrients, amino acids, vitamins, and growth-promoting compounds like cytokinins, auxins, and abscissic acid. Their application has been observed to stimulate plant growth, increase yield, and enhance resistance to various environmental stresses [46]. As per study conducted by Iswarya et al. [47] seeds soaked in a 0.1% seaweed extract solution for 30 minutes, and then applied as a foliar spray once at 25 days after sowing and at 35 days after sowing recorded highest seed yield (1242 kg ha^{-1}) over control treatment. It may be due to seaweed-based liquid fertilizers provide a range of essential plant nutrients and hormones that positively affect both the growth and physiological aspects of plants, ultimately leading to increased crop yields. Zodape et al. [48] reported a similar trend of findings, as they observed a substantial boost in yield of 30.11%, 26.30%, and 16.78% respectively in greengram through foliar application of *Kappaphycus spp* extract, compared to the control group. Another study conducted by Chitra and Sreeja [49] observed *Gracilaria corticata* seaweed when applied on greengram at the rate of 4% showed superior performance in all aspects of growth, yield, and soil nutrient levels compared to the seaweed liquid fertilizer derived from the green algae *Caulerpa peltata.* This could be attributed to the presence of both macro and micronutrients, leading to an enhanced yield. An experiment conducted by Huda et al. [50] reported that foliar spray of seaweed *(Gracilaria tenuistipitata var. Liui* at the rate of 20% recorded maximum number of branches per plant and stated that the seaweed extract demonstrated a 23.04% higher count of branches per plant when utilizing a 20% concentration in comparison to the recommended fertilizer doses. Whereas its application led to a 50% rise in the number of pods per mungbean plant compared to untreated conditions, 4.36% increase in seeds per pod and seed yield by 93.14% in comparison to control condition. The growth-regulating substances (seaweed oligosaccharides) prompted the synthesis of hormones such as abscissic acid, cytokinin, and auxin in treated plants, which can enhance crop growth whereas the increase in crop yield might also be linked to specific nutritional elements, particularly iron, zinc, and manganese from compost, as well as potassium, calcium, magnesium, sulfur, and iron from the seaweed extracts we employed. This correlation is supported by Zodape et al. [51], who noted a boost in green gram yield with the application of *Gracilaria* extracts. Seaweed extracts (SWEs) offer a superior alternative by minimizing the reliance on synthetic fertilizers and agrochemicals in agricultural systems. Additionally, seaweed extracts (SWEs) improve plant health by affecting the microbial community in the rhizosphere, making them a feasible eco-friendly method for sustainable agriculture and a potential component in organic cultivation of agricultural crops [13,51].

5.5 Vermiwash

Vermiwash refers to a liquid obtained by filtering water through a bed of earthworms, comprising their excretions, mucus, and micronutrients derived from organic matter in the soil. It serves as an effective foliar spray. Vermiwash are enriched with enzymes and secretions from earthworms has the capacity to stimulate crop growth and enhance yields [52]. It comprises a mixture of different enzymes, including protease, amylase, urease, and phosphatase. Moreover, analysis of vermiwash's microbial content has revealed the presence of nitrogen-fixing bacteria like *Azotobacter sp., Agrobacterium sp., and Rhizobium sp*., as well as phosphate-solubilizing bacteria [53]. The application of vermiwash as a foliar spray notably enhanced the growth, yield, and quality of the crops [54]. The quality of vermiwash generated by earthworms is impacted by the composition of the raw materials used in vermicompost preparation [55]. Vermiwash consists of 0.01-0.001% Nitrogen, 1.70% Phosphorous, 26ppm Potassium, 8ppm sodium, 3ppm calcium, 0.01 ppm Copper, 0.06 ppm Iron, 160 ppm Magnesium, 0.60 ppm Manganese and 0.02ppm Zinc. When combined with a 10% solution of cow urine or extracts from neem or garlic and sprayed, it acts as a biopesticide [56]. The vermiwash obtained from municipal solid waste contains organic materials, plant nutrients, and soluble salts, all of which contribute to increasing soil nutrient levels and moisture retention [57].

5.6 Effect of Vermiwash on Crop Production

Vermiwash assists in effectively managing market wastes for profit and can be utilized for crop production through foliar and soil applications. At present, foliar application is the prevailing method for sustainable crop production, aiming to meet production goals while minimizing the use of fertilizers**.** According to a study conducted by Rajasooriya and Karunarathna [58] it was observed that application of vermiwash at the rate of 75% at 6th and 8th weeks after planting recorded highest number of pods per plant, number of seeds per pod, 100 seed weight and total yield per plant in greengram. The utilization of vermiwash led to yield enhancements of 2.3 and 2.5 times in greengram compared to the control treatment.

Table 2. Effect of various organic fertilizers on yield and yield attributes of greengram

Sl. No.	Treatments	Number of pods per plant	Number of seeds per pod	Seed yield (kg ha^{-1})	Reference
1.	12 kg ha^{-1} humic acid	13	10	1312.7	
	9 kg ha^{-1} humic acid	11	9	826.7	[36]
2.	Control	12.67	9.87	6.04	
	Seaweed 20%	20	10.30	11.66	[50]
3.	Control 6th WAP	23	9	12.68 ± 0.53	
	Control 8th WAP	21	9	11.58 ± 0.63	
	Vermiwash 75% 6th WAP	35	11	29.02 ± 1.66	[58]
	Vermiwash 75% 8th WAP	35	11	29.02 ± 0.33	
4.	Panchagavya + S1 Every 10 days	28.40	10.85	870	
	Jeevamruth + S1 Every 10 days	27.65	9.22	850	[73]
	Cow urine + S1 Every 10 days	23.70	9.32	840	
5.	Control	19.10	7.5	748.5	
	RDF+ Vermicompost + Rhizobium+ Jeevamrutam	31.35	12.2	1242.5	[77]

It may be due to increased concentration of vermiwash which increased the number of pods per plant and number of seeds per pod according to Bhalero et al. [59]. Application of Basal FYM 750kg/ha + 1% Vermiwash spray @30,45 DAS recorded significantly higher seed yield [60]. These conclusions is consistent with the research conducted by Hatti et al. [61] who found that the use of vermiwash spray resulted in increased growth parameters and total biomass of greengram. Vermiwash, acknowledged as an environmentally safe spray solution by Sinha et al. [62] demonstrated its effectiveness by acting as a source of nutrients and promoting growth, resulting in the cultivation of healthy green gram plants and increased seed production. Vermiwash, produced through the decomposition of organic matter by earthworms, is additionally recognized as a valuable liquid fertilizer, playing a significant role in enhancing crop development and productivity when applied as a foliar spray [63].

5.7 Panchagavya

In Sanskrit, the term "Panchagavya" denotes a mixture comprising of five products obtained from cow. When mixed appropriately and utilized, these components demonstrate extraordinary effects. Panchagavya is employed in diverse ways, such as foliar spraying, incorporating into the soil with irrigation water, and treating it with seeds or seedlings [64]. In organic farming, Panchgavya plays a pivotal role as the most favored organic fertilizer for agricultural fields, ensuring the complete elimination of harmful synthetic fertilizers, pesticides, insecticides, and antibiotics. Panchgavya stands out as the most cost-effective and beneficial fertilizer option. It enhances soil fertility, improves earthworm quality, and boosts crop health as an organic fertilizer [65,66]. Panchagavya consists of growth regulators such as Indole acetic acid, Gibberellic acid, and cytokinin, as well as important plant nutrients and beneficial microorganisms like lactic acid bacteria, yeast, and actinomycetes [67].

5.8 Effect of Panchagavya on Crop Production

Panchgavya aids in producing food without the use of synthetic pesticides, facilitating the shift from conventional to organic farming, while also sustaining and enhancing crop yields, as well as improving the flavour and longevity of fruits, grains, and vegetables. Additionally, it speeds up crop maturation by 15 days and decreases production costs by minimizing expenditures on chemicals, ultimately leading to increased profits [68]. Yadav Prakash and Tripathi [69] found that utilizing foliar spray of Panchagavya at the concentration of 3 percent without additional requirement of fertilizers was the most cost-effective method for enhancing the seed yield of greengram. As per study conducted by Krishnaprabhu [70] it was revealed that foliar spray of Panchagavya (5%) resulted in a significant increase in both grain yield and yield parameters of greengram. The considerable boost in yield observed with application of panchagavya can be mainly attributed to the significant improvement in both the number of pods per plant and the test weight. The application of a 3 percent foliar spray of Panchagavya at intervals of 15, 25, 40, and 50 days after sowing (DAS) without any fertilizers proved to be the most efficient and economical technique for increasing the grain yield of greengram [71]. A field experiment conducted by Sagar et al. [72] reported that foliar application of combination of Panchagavya + in every 10 days recorded significantly higher higher number of pods per plant, number of seeds per pod, seed yield and stover yield respectively. The increase in yield and its characteristics could be a result of stimulated root growth due to inorganic nutrients, alongside enhanced absorption of water and nutrients attributed to the effects of panchagavya post-fermentation, thereby promoting higher yields. Bhargavi et al. [73] concluded panchagavya applied at the rate of 3 percent with 10 days interval recorded higher yield and yield attributes such as number of pods per plant, number of seeds per pods and seed yield. This could be attributed to the enhanced availability of nearly all vital nutrients to the plants, leading to enhanced vegetative growth, heightened photosynthetic activity, and subsequently, the efficient movement and accumulation of photosynthates in the economically valuable parts of the plant.

5.9 Jeevamruth

Jeevamrutam, an organic fertilizer, is composed of a combination of cow dung, cow urine, pulse flour, jaggery, and a small amount of soil, with the intention of promoting microbial populations.It acts as a potent plant growth enhancer, enhances the biological effectiveness of crops while also activating soil, defending plants from diseases, and improving the nutritional value of fruits and vegetables Devakumar et al. [74].

Jeevamruth is hailed as a natural farming marvel due to its simple preparation and rich composition of macro and micro nutrients. It contains beneficial microorganisms, including bacteria, actinomycetes, and some fungi, which boost the activity of nitrogen-fixers, phosphorus solubilizers, and other helpful microorganisms which are beneficial to plants [75]. Applying jeevamrut to acidic soil raises its pH level, while in alkaline soil, it lowers the pH. This practice leads to sustainable increases in crop yield and eliminates the need for chemical fertilizers, thereby enhancing soil health. Jeevamrut exhibits acidity with a pH level of 4.93 and acts as a valuable reservoir of essential macro and micro nutrients, comprising nitrogen (1.97%), phosphorus (0.172%), potassium (0.29%), manganese (47 ppm), and copper (50 ppm). Jeevamrut consists of high concentration of microbial populations, with peak levels typically occurring between the 8th and 13th days after its preparation. Additionally, it promotes the growth of nitrogen-fixing bacteria in locally available materials such as farmyard manure, compost, and biogas slurry [76].

5.10 Effect of Jeevamruth on Crop Production

The combined organic nutrient formulations exhibit a synergistic effect and have demonstrated favorable outcomes in enhancing crop production. According to a study conducted by Kumari et al. [77] it was revealed that application of RDF + Vermicompost + Rhizobium + Jeevamrutam recorded higher number of pods per plant, test weight, grain yield, Straw yield as compaired to control treatment. Similar findings were recorded by Verma et al. [78] and Marko et al. [79]. Jeevamrit promotes soil microbial activity, leading to enhanced soil fertility [80]. Jeevamruth reportedly hosts a significant population of microorganisms capable of nitrogen fixation, phosphate solubilization, and siderophore production [81]. The organic liquid fertilizer is formulated for a fermentation process that generates beneficial live soil microorganisms, enhancing plant growth, productivity, and nutrient supply. These fertilizers offer cost-effective and environmentally friendly bioinoculants, with promising potential to boost agricultural production sustainably. Using Jeevamrut can decrease the over-reliance on chemical fertilizers, which leads to diminished soil fertility, making it an optimal substitute for chemical fertilizers [82].

6. ADVANTAGES OF USING ORGANIC FERTILIZERS

Organic fertilizers demonstrate effectiveness in fostering environmental sustainability and enhancing plant growth over extended periods [83]. Moreover, the amalgamation of irrigation and fertilization methods has the potential to boost the efficiency of nutrient usage while diminishing the risk of nutrient leaching. Additionally, unique constituents present in liquid organic fertilizers, such as chitin, humic and fulvic acids, and other biopolymers, serve as plant biostimulants which helps in increasing productivity of crops. Several studies have indicated that the use of organic fertilizers on the soil surface can provide a substantial nutrient supply for microorganisms, resulting in a notable enhancement in both the composition and diversity of microbial communities compared to situations where such application is not present [84]. Organic fertilizers meet the biological needs of plants and also help control the populations of plant pests [85]. Organic fertilizers furnish plants with nitrogen in a form that promotes growth without the risk of root burn or harm to beneficial soil microorganisms. Additionally, by fulfilling the plants' nutritional needs and boosting their tolerance, organic fertilizers help prevent diseases, thereby alleviating a significant source of stress [86,87,88].

7. CONCLUSION

Organic fertilizer sources such as humic acid, seaweed extract, vermiwash, panchagavya and jeevamruth formulations have significant potential in increasing productivity in greengram and as such products should be encouraged in farming practices. Moreover utilizing organic fertilizers and amendments is environmentally friendly and holds a distinct advantage over synthetic, inorganic fertilizers which can lead to environmental pollution and potentially result in soil accumulation, posing risks to human health. Thus the purpose of this review is to enlightened the useful benefits of organic fertilizers and to incorporate it into the existing farming practices so as to increase the productivity of greengram while maintaining sustainable agriculture production.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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