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Algae-Agro Culture: Integrating Algae-Based Organic Farming for Sustainable Agriculture in the East Nimar Region of Khandwa, Madhya Pradesh

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Abstract
The present investigation was carried out at the Rishi Parashar School of Agriculture Science from November 2024 to February 2025 to assess the performance of Chlorophyceae algae, specifically those collected from the Tapti River in Bhuranpur. The study examined the impacts of microalgae applications on three major crops: barley, mustard, and maize. Thirteen experimental treatments were implemented, including various combinations of algae with organic amendments and control groups: T-1 (Algae + vermiwash), T-2 (Algae + poultry manure), T-3 (Algae + vermicompost), T-4 (Algae + NADEP compost), T-5 (Algae + vermiwash + poultry manure), T-6 (Algae + vermiwash + vermicompost), T-7 (Algae + vermiwash + NADEP), T-8 (Algae alone), T-9 (Vermiwash alone), T-10 (Poultry manure alone), T-11 (Vermicompost alone), T-12 (NADEP alone), and T-13 (Control). Throughout the course of the experiment, both growth and yield parameters were systematically evaluated. The study evaluated the effects of algae-based organic amendments, in combination with vermiwash, poultry manure, vermicompost, and NADEP compost, on the growth and yield performance of maize, barley, and mustard. Results revealed significant differences among treatments across all crops. In maize, the integrated treatment Algae + Vermiwash + Poultry Manure (T-5) recorded the maximum plant height (195.66 cm), cob weight (258.33 g), and green cob yield (148.56 q ha^{-1}), nearly doubling productivity compared to the control (78.22 q ha^{-1}). In barley, the same treatment (T-5) produced the tallest plants (98.25 cm), highest grain number per spike (40.11), and maximum grain yield (26.66 q ha^{-1}), while control plots had the lowest yield (12.66 q ha^{-1}). Similarly, in mustard, T-5 achieved the maximum plant height (131.33 cm), siliqua number per plant (90.66), seeds per siliqua (18.33), and seed yield (21.33 q ha^{-1}), outperforming the control (11.88 q ha^{-1}). Across all crops, stover or straw yield also followed the same trend, with integrated treatments showing nearly 100% yield advantage over control. The findings demonstrate that the combined application of algae with vermiwash and organic manures, particularly poultry manure, vermicompost, and NADEP compost, substantially enhances plant growth, yield attributes, and productivity. This integrated approach provides a sustainable and eco-friendly alternative to improve crop performance while maintaining soil health.

Keywords: Algae, algae-agro-culture, chlorophyceae, organic manure, natural farming

Introduction

Algae-based organic farming, or Algae-Agro culture, represents a promising direction in the quest for sustainable agriculture. With the escalating concerns over soil degradation, excessive use of synthetic fertilizers, and environmental pollution, microalgae and cyanobacteria are emerging as eco-friendly alternatives that bolster soil health while improving crop productivity and resilience. These photosynthetic organisms serve as biofertilizers, biostimulants, and biopesticides, contributing significantly to nutrient recycling, soil structure improvement, and reduced dependency on chemical inputs.

The integration of algae into agricultural systems not only reduces the environmental footprint by minimizing chemical fertilizer and pesticide usage but also enhances carbon sequestration and water management, making it highly relevant in regions facing resource limitations and climate change pressures. Innovations such as open ponds, photobioreactors, and vertical farming have made large-scale algae cultivation feasible, allowing for year-round production with optimized resource use. Furthermore, advances in biotechnology are enabling the development of genetically robust algal strains that deliver improved yields and nutrient profiles.

The urgent need to enhance agricultural productivity while maintaining ecological balance has led to the exploration of innovative, sustainable farming practices. Conventional agriculture, though successful in meeting global food demands, has been increasingly criticized for its reliance on chemical fertilizers and pesticides, which contribute to soil degradation, biodiversity loss, and greenhouse gas emissions (Foley *et al.*, 2011; Tilman *et al.*, 2017) [6, 21]. In this context, algae-based organic farming, often referred to as algae-agro culture, has emerged as a promising alternative approach that integrates biological resources into modern farming systems.

Algae, comprising both microalgae and macroalgae, are photosynthetic organisms capable of producing a wide array of bioactive compounds, organic matter, and phytonutrients. Their use in agriculture is not entirely new; seaweed extracts have long been employed as biofertilizers and soil conditioners in coastal regions (Khan *et al.*, 2009) [9]. Recent research, however, highlights their broader potential in improving soil fertility, enhancing plant growth, suppressing plant pathogens, and contributing to carbon sequestration (Singh *et al.*, 2016; Renuka *et al.*, 2018) [14, 15]. Moreover, algae cultivation requires minimal arable land, can thrive on wastewater, and recycles nutrients, making it an ecologically efficient practice aligned with circular economy principles (Chojnacka *et al.*, 2015) [4].

The integration of algae into farming systems thus addresses multiple dimensions of sustainability. Beyond supplying organic fertilizers, algal biomass can be incorporated into integrated nutrient management (INM), reducing dependence on synthetic inputs while maintaining crop productivity (Ronga *et al.*, 2019) [16]. Additionally, algal applications can improve soil microbial diversity, enhance water retention capacity, and mitigate abiotic stresses such as drought and salinity, which are major challenges under climate change scenarios (Renuka *et al.*, 2016; Rani *et al.*, 2021) [16, 12].

Given the pressing need to transition toward sustainable agriculture, algae-agro culture represents a frontier in organic farming practices that can simultaneously ensure food security and environmental resilience. This article examines the cultivation of algae for agricultural applications, its role as a biofertilizer and soil amendment, and its potential to transform conventional farming systems into sustainable, eco-friendly models.

The objectives of the study were to systematically assess the effects of NADEP compost, algae, vermiwash, vermicompost, and poultry manure on the growth and yield of barley, mustard, and maize when cultivated as individual crops, as well as to identify the most effective combination of these organic amendments for optimizing crop productivity. By comparing the distinct and synergistic impacts of each input and their combinations, the research aimed to pinpoint organic management practices that enhance soil fertility and maximize agricultural output for these staple crops.

Materials and Methods

The field experiment was conducted from November 2024 to February 2025 at the Rishi Parashar School of Agriculture Science to evaluate the effects of Chlorophyceae algae, collected from the Tapti River, Bhuranpur, on barley, mustard, and maize crops. The study adopted three replication with plot size 3X3 m in a randomized complete block design (RCBD) with thirteen treatments: T-1 (algae + vermiwash), T-2 (algae + poultry manure), T-3 (algae + vermicompost), T-4 (algae + NADEP), T-5 (algae + vermiwash + poultry manure), T-6 (algae + vermiwash + vermicompost), T-7 (algae + vermiwash + NADEP), T-8 (algae alone), T-9 (vermiwash alone), T-10 (poultry manure alone), T-11 (vermicompost alone), T-12 (NADEP alone), and T-13 (control). Algae were cultured under controlled conditions and applied to experimental plots either in combination with or separately from vermiwash, poultry manure, vermicompost, and NADEP compost. Standard agronomic practices were maintained for all plots, and treatments were applied at sowing as soil amendments or as irrigated solutions according to treatment requirements. Data on growth parameters (plant height, number of leaves, biomass) and yield attributes (number of grains or pods, grain/pod weight, total yield per plot) of each crop were collected at key developmental stages and at harvest. Statistical analysis was performed to compare the treatments and determine significant differences in crop performance.

Table 1: details of Treatments

S.No.	Treatment	Treatment Description
1.	T-1	Algae + vermiwash
2.	T-2	Algae+ Poultry manure
3.	T-3	Algae + Vermi compost
4.	T-4	Algae+ NADEP
5.	T-5	Algae+Vermiwash+ Poultry Manure
6.	T-6	Algae+ vermiwash+vermicompost
7.	T-7	Algae + Vermiwash+ NADEP
8.	T-8	Algae
9.	T-9	Vermi wash
10.	T-10	Poultry manure
11.	T-11	Vermi compost
12.	T-12	NADEP,
13.	T-13	Control

Algae: 1.5 to 2 million liters ha^{-1}
Vermiwash: 80 liters ha^{-1}
Poultry manure: 10 Tones'ha^{-1}
Vermi compost: 10 Tones'ha^{-1}
NADEP: 10 Tones'ha^{-1}

Results and Discussion

The results of the maize experiment in table 2 revealed significant differences among treatments in terms of growth and yield attributes. The maximum plant height (195.66 cm) was recorded under T-5 (Algae + Vermiwash + Poultry manure), followed by T-6 (Algae + Vermiwash + Vermicompost, 180.56 cm) and T-7 (Algae + Vermiwash + NADEP, 175.55 cm). The lowest plant height (138.66 cm) was observed in the control (T-13), highlighting the beneficial role of organic amendments. In terms of cob number per plant, the highest value (4.11) was recorded under T-5, while the control showed the minimum (1.22). Similarly, cob weight was also superior in T-5 (258.33 g), closely followed by T-6 (245.66 g) and T-7 (239.66 g), and whereas the lowest weight (150.66 g) was found in the control.

Cob length and diameter also showed marked variations across treatments. The longest cob length (25.23 cm) was observed in T-5, while T-6 (24.25 cm) and T-7 (24.66 cm) were statistically close. Control produced the shortest cobs (15.22 cm). The maximum cob diameter (9.86 cm) was found in T-7, followed by T-5 (9.66 cm) and T-6 (9.25 cm), whereas the lowest cob diameter (6.25 cm) occurred under control.

Green cob yield per hectare also followed a similar trend. The highest yield was recorded under T-5 (148.56 q ha^{-1}), followed by T-6 (146.28 q ha^{-1}) and T-7 (145.33 q ha^{-1}), showing clear superiority of integrated treatments combining algae with vermiwash and organic manures. In contrast, the control treatment resulted in the lowest yield (78.22 q ha⁻¹), which was almost half of the best-performing treatment. These findings clearly indicate that combining algae with vermiwash and organic manures, particularly poultry manure, significantly enhances growth, yield components, and productivity of maize compared to sole applications or control.

The present study clearly demonstrated that the combined application of algae with organic manures and biostimulants significantly improved growth, yield attributes, and green cob yield of maize compared to sole applications or the control. Treatments such as Algae + Vermiwash + Poultry manure (T-5), Algae + Vermiwash + Vermicompost (T-6), and Algae + Vermiwash + NADEP (T-7) consistently outperformed other treatments, which can be attributed to the synergistic effect of organic nutrient sources and bio-stimulatory compounds present in algae and vermiwash.

Algal extracts are well-documented for their role in enhancing plant growth through bioactive compounds such as growth-promoting hormones, amino acids, and micronutrients (Khan *et al.*, 2009; Ronga *et al.*, 2019) [9, 16]. The increased plant height and cob length observed in the present study under integrated treatments can be linked to the stimulation of cell division and elongation by cytokinins and auxins present in algal formulations. Similarly, vermiwash, a liquid extract derived from vermicomposting units, contains enzymes, vitamins, and plant growth hormones that improve physiological activity and nutrient uptake efficiency (Ismail, 2005; Jat & Ameta, 2017) [7, 8].

The significant improvement in cob weight and diameter under T-5 and T-6 might be due to the enhanced availability of readily decomposable organic matter from poultry manure and vermicompost, which improve soil fertility, microbial activity, and nutrient cycling (Rathore *et al.*, 2018; Choudhary *et al.*, 2020) [13, 5]. Poultry manure is particularly rich in nitrogen, phosphorus, and potassium, which directly contribute to higher biomass accumulation and yield (Adediran *et al.*, 2003) [1]. The synergistic effect of combining algae, vermiwash, and organic manures ensured balanced nutrition, leading to improved cob yield.

The highest green cob yield (148.56 q ha⁻¹) in T-5 was nearly double that of the control (78.22 q ha⁻¹), underscoring the potential of integrated nutrient management through algae-based organics. Similar findings were reported by Singh *et al.* (2024) [2], who observed that combining organic manures with biostimulants improved maize productivity while reducing dependence on chemical fertilizers. Likewise, Shukla and Sharma (2025) [18] highlighted that integrated use of organic amendments not only improved crop yield but also enhanced soil health and profitability.

These results emphasize that algae-based organic inputs, when used in combination with vermiwash and farm-derived manures, can serve as a sustainable strategy for maize cultivation. Beyond yield improvement, such practices contribute to long-term soil fertility, microbial diversity, and ecological sustainability, aligning with the principles of organic and climate-smart agriculture (Basavarajappa *et al.*, 2021) [3].

Table 2: Effects on various treatment in maize

Name of Treatments	Name Of crop	Average Plant Height(cm)	Number of cob	Cob Weight (g)	Length of cob (cm)	Diameter of cob (cm)	Green cob yield (q ha⁻¹)
T-1 Algae + vermiwash	Maize	152.23	2.66	165.67	22.26	8.25	142.55
T-2 Algae+ Poultry manure		155.29	3.15	169.33	23.29	8.21	144.25
T-3 Algae + Vermi compost		154.55	2.66	187.33	22.26	8.66	143.22
T-4 Algae+ NADEP		153.97	2.22	183.33	22.66	8.33	141.33
T-5 Algae+Vermiwash+ Poultry Manure		195.66	4.11	258.33	25.23	9.66	148.56
T-6 Algae+ vermiwash+vermicompost		180.56	3.66	245.66	24.25	9.25	146.28
T-7 Algae + Vermiwash+ NADEP		175.55	3.55	239.66	24.66	9.86	145.33
T-8 Algae		150.25	2.11	150.33	21.22	8.11	128.45
T-9 Vermi wash		151.22	2.59	159.66	20.22	8.09	125.22
T-10 Poultry manure		165.22	3.66	169.66	21.26	8.91	138.24
T-11 Vermi compost		169.66	2.66	166.66	21.25	8.55	136.58
T-12 NADEP		149.99	2.23	158.84	21.22	8.91	134.22
T-13 Control		138.66	1.22	150.66	15.22	6.25	78.22
CD (p=0.05)		4.701	2.912	5.161	1.121	0.981	4.841
S.Em (±)		1.567	0.913	1.687	0.354	0.327	1.597

The results of the study on barley in table 3 revealed that growth and yield attributes varied significantly across treatments. The tallest plants (98.25 cm) were observed in T-5 (Algae + Vermiwash + Poultry Manure), followed by T-7 (Algae + Vermiwash + NADEP, 96.33 cm) and T-6 (Algae + Vermiwash + Vermicompost, 91.91 cm). The lowest plant height (75.22 cm) was recorded in the control (T-13). The number of grains per spike was also highest under T-5 (40.11), while the minimum was recorded in the control (22.22). Similarly, awn length was maximized in T-5 (20.66 cm), followed by T-7 (19.33 cm), whereas the shortest awns were produced under the control (12.55 cm).

Grain weight per spike was highest in T-7 (17.88 g), closely followed by T-5 (17.81 g), while the control treatment produced the lowest (9.66 g). Grain yield showed a similar trend, with the maximum recorded in T-5 (26.66 q ha⁻¹), followed by T-7 (25.22 q ha⁻¹) and T-6 (24.55 q ha⁻¹). In contrast, the lowest yield was observed in the control (12.66 q ha⁻¹), indicating nearly a 100% yield advantage in integrated treatments over no treatment. Straw yield was also superior in T-5 (54.22 q ha⁻¹), followed by T-7 (52.33 q ha⁻¹) and T-6 (50.66 q ha⁻¹), compared to the minimum in the control (28.22 q ha⁻¹).

The synergistic effect of combined organics especially the use of vermiwash and poultry manure was evident in increases in plant height, grain number per spike, and spikelet development. Previous work has shown that organic fertilizers, including farmyard manure, poultry manure, and vermicompost, significantly enhance barley growth and yield components, including tiller number, spike length, grain weight, and total biomass (Yimer, 2021) [22]. This is attributed to better nutrient supply, improved microbial activity, and increased soil fertility that result from their application (Khyalia *et al.*, 2024) [10].

The effectiveness of combinations such as vermiwash and composts can be traced to their ability to supply both readily available nutrients and gradual nutrient release via microbial mineralization, resulting in continuous nutrient support throughout crop development. Bio-stimulant properties of inputs like vermiwash further enhance growth by promoting the synthesis and activity of plant hormones, amplifying cell division, and facilitating better root and shoot growth (Khyalia *et al.*, 2024) [10]. These positive effects ultimately promote greater translocation of photosynthates to the developing grains and improve both grain and straw yields.

The results confirm that integrated nutrient management with organics nearly doubled the grain yield compared to the control, emphasizing the importance of diversified sources of fertility for barley. Recent research reports similar yield improvements from combining composts, vermicompost, and biofertilizers, which enhance nutrient use efficiency, sustain soil productivity, and contribute to environmentally sound barley production (Yimer, 2021; Khyalia *et al.*, 2024) [22, 10].

Table 3: Effects of various treatments in Barley.

Name of Treatments	Name Of crop	Average Plant Height(cm)	Number of grains spike^{-1}	Awn Length (cm)	Weight of grain Spike^{-1} (g)	Grain Yield (q ha^{-1})	Straw yield (q ha^{-1})
T-1 Algae + vermiwash	Barley	88.55	35.22	16.33	16.22	21.22	44.25
T-2 Algae+ Poultry manure		89.25	34.55	17.22	15.66	22.66	46.33
T-3 Algae + Vermi compost		86.66	33.66	16.66	14.22	23.22	48.22
T-4 Algae+ NADEP		83.33	32.11	16.32	13.55	23.66	47.55
T-5 Algae+Vermiwash+ Poultry Manure		98.25	40.11	20.66	17.81	26.66	54.22
T-6 Algae+ vermiwash+vermicompost		91.91	38.22	18.55	16.32	24.55	50.66
T-7 Algae + Vermiwash+ NADEP		96.33	37.66	19.33	17.88	25.22	52.33
T-8 Algae		82.52	28.22	14.33	12.55	20.33	41.22
T-9 Vermi wash		89.22	27.22	14.66	11.22	19.33	40.22
T-10 Poultry manure		84.22	28.88	13.28	12.66	20.22	42.55
T-11 Vermi compost		86.28	28.91	14.22	11.22	21.22	44.66
T-12 NADEP		85.66	28.55	13.55	12.55	20.55	42.66
T-13 Control		75.22	22.22	12.55	9.66	12.66	28.22
CD (p=0.05)		4.725	2.681	1.984	1.165	1.079	2.961
S.Em (±)		1.567	0.889	0.662	0.356	0.346	0.987

The study on mustard in table 4 revealed clear variations in growth, yield attributes, and productivity under different organic treatments. Plant height was significantly influenced, with the maximum height (131.33 cm) recorded under T-5 (Algae + Vermiwash + Poultry Manure), followed by T-6 (Algae + Vermiwash + Vermicompost, 125.66 cm) and T-7 (Algae + Vermiwash + NADEP, 120.66 cm). The minimum plant height (90.22 cm) was observed in the control (T-13).

The number of siliqua per plant was highest in T-5 (90.66), followed by T-6 (88.56) and T-7 (88.33), while the control treatment recorded the lowest (50.22). Siliqua length was also enhanced under integrated treatments, with the longest siliqua (4.55 cm) observed in T-5, followed by T-6 (4.21 cm) and T-7 (4.33 cm), whereas the shortest siliqua (3.11 cm) was found in the control.

Seeds per siliqua were maximized under T-5 (18.33) and T-6 (17.55), whereas the lowest seed count (10.22) was recorded in the control. The seed yield was significantly improved under integrated nutrient management, with the maximum yield obtained in T-7 (21.66 q ha^{-1}) and T-5 (21.33 q ha^{-1}), followed by T-6 (20.66 q ha^{-1}). By contrast, the lowest seed yield (11.88 q ha^{-1}) was recorded in the control, reflecting nearly a 100% yield increase under the best-performing treatments.

Stover yield also followed a similar pattern, with the highest value (44.66 q ha^{-1}) in T-7, followed closely by T-5 (44.33 q ha^{-1}) and T-6 (42.33 q ha^{-1}), while the lowest stover yield (26.33 q ha^{-1}) was noted in the control.

Overall, the results clearly indicated that integrated application of algae with vermiwash and organic manures (particularly poultry manure, vermicompost, and NADEP compost) significantly enhanced plant growth, yield attributes, seed yield, and stover yield of mustard compared to sole applications or control.

The pronounced increases in plant height and siliqua development with poultry manure and vermiwash are corroborated by recent research, which found that poultry manure (2 t/ha) combined with liquid organics like Panchagavya or vermiwash produced significantly higher plant height, siliqua per plant, siliqua length, seed yield, and stover yield compared to control or sole applications (Banerjee *et al.*, 2024). This improvement is attributed to the rich nutrient content and growth-promoting substances available in poultry manure and vermiwash, leading to better nutrient uptake and distribution throughout the plant (Banerjee *et al.*, 2024).

Integrated nutrient management (INM) with a combination of solid and liquid organic fertilizers enhances availability and uptake of macro- and micronutrients, optimizes soil properties, and supports sustained growth and seed setting in mustard. Studies further confirm that such combinations enhance not only growth and yield metrics like plant height, number of siliqua, and seed yield, but also product quality attributes such as protein and oil content, emphasizing their superior effectiveness over traditional control practices (Mohamed *et al.*, 2010; Banerjee *et al.*, 2024) [11, 2].

Table 4: Effects of various treatments in Mustard.

Name of Treatments	Name of crop	Average Plant Height(cm)	Number of siliqua plant-1	Siliqua Length (cm)	Seeds per siliqua	Seed yield (q ha-1)	Stover yield (q ha-1)
T-1 Algae + vermiwash	Mustard	110.55	82.99	3.99	15.33	19.33	40.66
T-2 Algae+ Poultry manure		112.33	83.66	4.01	16.33	19.66	41.33
T-3 Algae + Vermi compost		119.66	82.66	4.11	15.66	18.66	38.66
T-4 Algae+ NADEP		119.66	81.22	4.09	16.99	19.33	41.22
T-5 Algae+Vermiwash+ Poultry Manure		131.33	90.66	4.55	18.33	21.33	44.33
T-6-Algae+ vermiwash+vermicompost		125.66	88.56	4.21	17.55	20.66	42.33
T-7 Algae + Vermiwash+ NADEP		120.66	88.33	4.33	16.33	21.66	44.66
T-8 Algae		94.33	70.25	3.33	14.33	15.66	32.55
T-9 Vermi wash		92.99	75.22	3.66	14.11	14.66	31.22
T-10 Poultry manure		105.33	77.22	3.22	13.22	17.33	36.33
T-11 Vermi compost		110.22	76.22	3.49	14.66	17.88	36.99
T-12 NADEP		111.22	75.22	3.88	15.33	16.22	34.55
T-13 Control		90.22	50.22	3.11	10.22	11.88	26.33
CD (p=0.05)		4.812	3.411	1.614	2.412	2.121	2.714
S.Em (+)		1.591	1.112	0.512	0.789	0.689	0.889

Conclusion

The results across maize, barley, and mustard experiments clearly demonstrated that integrated application of algae with vermiwash and organic manures significantly improved growth, yield attributes, and productivity compared to sole applications or control. In all three crops, the combination of Algae + Vermiwash + Poultry Manure (T-5) consistently produced the tallest plants, highest yield components, and maximum grain or seed yields, followed closely by treatments involving vermicompost (T-6) and NADEP compost (T-7). In maize, this integration nearly doubled cob yield compared to control, while in barley, grain yield and straw yield were enhanced by almost 100% under the best-performing treatments. Similarly, in mustard, integrated treatments produced the highest number of siliquae, seeds per siliqua, seed yield, and stover yield, with yields nearly twice that of the untreated control. These results highlight the synergistic effects of algae, vermiwash, and organic manures, which together enhance nutrient availability, stimulate growth through bioactive compounds, and improve soil fertility. Therefore, the integration of algae-based inputs with traditional organic amendments presents a sustainable and eco-friendly strategy for boosting crop productivity while maintaining soil health.

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