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Effect of different organic and bio fertilizer on growth, yield and quality of Kale [*Brassica oleracea* var. 'Acephala']

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Abstract
A field experiment was conducted during the Rabi season of 2024-25 at SHUATS, Prayagraj, to assess the influence of organic manures and biofertilizers on Kale (*Brassica oleracea var.* acephala). The trial included nine treatments: various combinations of vermicompost, compost, mustard cake, Azospirillum, and arbuscular mycorrhizal fungi (AMF), laid out in a Randomized Block Design with three replications. The work revealed that treatment T_8 (Mustard cake + Azospirillum + AMF) significantly outperformed all others in plant height (62.26 cm), number of leaves (40.80), leaf area (337.59 cm²), and yield (245.17 q/ha). It also showed the highest chlorophyll (106.37 mg/g), ascorbic acid (1.45 mg/100g), TSS (10.0 °Brix), and the best economic return (₹4, 19, 653.20/ha) with a B:C ratio of 5.94. The study concludes that integrated application of organic manures and biofertilizers not only improves growth, yield, and nutritional quality of Kale but also offers economic and environmental benefits, supporting sustainable vegetable cultivation.

Keywords: Kale, organic fertilizer, Azospirillum, AMF, mustard cake, growth, yield, quality, B:C ratio, sustainable agriculture

Introduction
Kale (*Brassica oleracea var*. acephala) is a hardy, cool-season leafy vegetable widely grown for its tender and highly nutritious foliage. Commonly referred to as ―borecoles,‖ a term derived from the Dutch word Borenkool, Kale is known for its resilience to harsh climates, surviving temperatures as low as -10 °C to -15 °C Fadigas *et al.*, 2010 [7]. Its increasing global popularity is largely due to its high concentration of essential vitamins particularly vitamin C and provitamin A as well as calcium, iron, magnesium, and other micronutrients. Additionally, Kale provides potent antioxidants, dietary fiber, and a broad spectrum of amino acids such as leucine, arginine, lysine, and histidine, which are crucial for human health and metabolism (Ahmad & Beigh, 2009) [2].

Kale belongs to the Brassicaceae family and is considered among the earliest cultivated brassicas. It shares characteristics with wild cabbage and was widely grown in ancient Greece and other parts of Europe as a staple winter vegetable (Nieuwhof, 1969) [13]. Agronomically, Kale is grown as an annual for leaf production and as a biennial for seed generation. It adapts well to temperate climates and tolerates both drought and frost conditions, making it suitable for a range of agroecological zones. The crop displays morphological diversity with curly or smooth leaves that range in color from green to purplish hues. Kale is recognized as a ―superfood‖ because of its nutritional profile it is exceptionally rich in vitamins A, C, and K, antioxidants such as beta-carotene, and phytochemicals like glucosinolates. Studies show that Kale possesses higher concentrations of protein, sugars, and essential amino acids compared to other cole crops like cabbage and cauliflower (Ahluwalia *et al.*, 1979) [1]. Moreover, its vitamin C retention remains high even after cooking, making it suitable for health-conscious consumers (Coa & Sopic, 1996) [6].

As the global agricultural paradigm shifts toward sustainability, organic farming is gaining momentum as a viable alternative to conventional chemical-based systems. Organic fertilizers such as compost, farmyard manure (FYM), and vermicompost are known to enhance soil structure, nutrient retention, microbial activity, and long- term fertility. In particular, vermicompost produced by earthworm-mediated decomposition has shown improved nutrient profiles and microbial biomass, with benefits extending to plant growth, soil porosity, water-holding capacity, and pH stabilization (Fadigas *et al.*, 2010) [7]. Biofertilizers like Azospirillum and Arbuscular Mycorrhizal Fungi (AMF) are crucial components of organic nutrient systems. Azospirillum, a diazotrophic bacterium, colonizes the rhizosphere and fixes atmospheric nitrogen. It produces phytohormones such as indole-3-acetic acid (IAA), gibberellins, and cytokinins, which promote root elongation, nutrient uptake, and resistance to abiotic stresses (Kulkarni *et al.*, 2004) [9]. AMF, on the other hand, form mutualistic associations with plant roots, significantly enhancing the uptake of phosphorus and other immobile micronutrients. Their role in improving plant tolerance to drought, salinity, and pathogens is well documented (Bahadur *et al.*, 2009) [4].

Materials and Methods

The present investigation done to understand the plant growth, leaf yield and quality of Kale. The investigation was carried out at Horticultural Research Farm (HRF), Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj during the *Rabi* season of 2024-25. The experiment was laid out in RBD with 9 treatments each replicated thrice. The treatment combinations are T_0 - (Control (No input)), T_1 - (Vermicompost + Azospirillum (10:7)), T_2 - (Vermicompost + AMF (10:8)), T_3 - (Vermicompost + Azospirillum + AMF (10:7:5)), T_4 - (Compost + Azospirillum (10:7)), T_5 - (AMF + Azospirillum (10:7)), T_6 (Compost + Azospirillum + AMF (10:7:5)), T_7 - (Mustard Cake + AMF (10:5)), T_8 - (Mustard Cake + Azospirillum + AMF (10:7:5). Observations were recorded at different stages of growth for parameters like plant height, number of leaves, leaf length, average leaf weight, yield per plot and quality parameters like TSS and vitamin C content. The data were statistically analysed by the method suggested by Fisher and Yates, 1936.

Results and Discussion

Growth parameters

Plant height

The plant height data of Kale recorded at 20, 40, and 60 Days After Sowing (DAS) revealed noticeable variations across the different treatment combinations of organic and biofertilizers. At 20 DAS, the differences were statistically non-significant, indicating uniform early germination and seedling vigor regardless of treatment. However, as the crop advanced to 40 and 60 DAS, the influence of treatments became apparent and statistically significant at the 5% level (CD = 0.50). The highest plant height at 60 DAS was observed in T_8 (Mustard cake + Azospirillum + AMF) with 62.26 cm, followed by T_6 (61.51 cm) and T_3 (60.56 cm). This result indicates that the integrated application of slow-releasing organic nitrogen (from mustard cake) and biofertilizers (*Azospirillum* for nitrogen fixation and AMF for phosphorus uptake) synergistically promoted vegetative growth and elongation. The minimum plant height was recorded in the control plot (T_0) with 52.27 cm, indicating that nutrient deficiency and lack of microbial assistance restricted plant development.

This finding aligns with the reports by Bahadur *et al.*, (2009) [4], who found significant improvements in plant height in lettuce following the application of *Azospirillum* and AMF. Kulkarni *et al.* (2004) [9] similarly reported increased plant height due to the production of indole- 3-acetic acid (IAA) and gibberellins by *Azospirillum*. Mahato *et al.*, (2021) [11] also observed increased vegetative parameters in Kale under biofertilizer inoculation, which enhanced nutrient mobilization and water absorption. Overall, the superior height in treatments T_8, T_6, and T_3 highlights the importance of combining organic and biofertilizer sources for optimal growth performance in Kale.

Number of Leaves per Plant

The number of leaves per plant is a key morphological trait that reflects the vegetative vigor and biomass accumulation in leafy vegetables like Kale. Shows that there were progressive increases in the number of leaves from 20 DAS to 60 DAS across all treatments, with statistically significant differences recorded at each stage. The control treatment (T_0) consistently recorded the lowest number of leaves, with only 31.30 leaves at 60 DAS. In contrast, the maximum number of leaves at the final stage was observed in T_8 (Mustard cake + Azospirillum + AMF) with 40.80 leaves/plant, followed by T_6 (39.84) and T_3 (39.09)

These findings are consistent with those reported by Meena *et al.*, (2016) [12], who demonstrated increased leaf count in Kale under integrated use of biofertilizers. Bahadur *et al.*, (2009) [4] also observed significant improvements in the number of functional leaves in lettuce and other leafy crops under the influence of AMF and Azospirillum. The results reinforce that the combined use of organic manures and microbial inoculants leads to improved vegetative architecture and enhanced leaf production, which directly contributes to higher yields in Kale.

Table 1: Effect of different organic and bio fertilizers on plant height and number of leaves of Kale

	Plant height (cm)			No of leaves/ plant		
Treatment	**20 DAS**	**40 DAS**	**60 DAS**	**20 DAS**	**40 DAS**	**60 DAS**
T_0	13.49	32.88	52.27	28.11	29.60	31.30
T_1	16.00	35.39	54.78	28.28	30.10	32.50
T_2	19.51	38.90	58.29	28.99	33.33	34.80
T_3	21.78	41.17	60.56	29.30	38.08	39.09
T_4	16.79	36.18	55.57	28.50	31.09	33.03
T_5	20.34	9.73	9.12	29.00	35.46	34.90
$_6$	22.73	42.12	61.51	29.88	38.55	39.84
T_7	20.45	39.84	59.23	29.01	36.91	37.50
T_8	23.48	42.87	62.26	30.00	39.30	40.80
F-test: NS (20 DAS), S (40 & 60 DAS); CD (5%) = 0.50				F-test: S; CD (5%) = 0.10 (20 DAS), 0.57 (40 DAS), 0.52 (60 DAS)		

Leaf Morphological Traits

Significant differences were observed in leaf length, width, area, and weight across treatments. T_8 exhibited the longest leaves (22.21 cm), widest leaves (15.20 cm), and largest leaf area (337.59 cm²). The results suggest a synergistic effect of organic and bio inputs on cell elongation and expansion. Leaf morphological characteristics such as length, width, and area play a vital role in determining the photosynthetic efficiency, canopy development, and marketability of leafy vegetables like Kale. presents the impact of different organic and biofertilizer Leaf Width (cm) combinations on these traits, showing statistically significant differences among treatments.

The results indicate that the maximum leaf length (22.21 cm) and leaf width (15.20 cm) were recorded in T_8 (Mustard cake + Azospirillum + AMF), which also led to the highest calculated leaf area of 337.59 cm² followed closely by T_6 (305.09 cm²) and T_3 (280.43 cm²), confirming the superiority of integrated nutrient application over the control and single-input treatments.

The improved leaf morphology in these treatments is attributed to enhanced nitrogen availability from Azospirillum, which promotes cell division and elongation; phosphorus uptake through AMF, which supports chlorophyll formation and energy transfer; and the slow but sustained nutrient release from mustard cake or compost, ensuring continuous vegetative growth. A broader leaf blade and larger leaf surface area allow for greater interception of light and photosynthetic activity, ultimately contributing to increased biomass production. Alongside leaf area, average leaf weight followed a similar trend, with T_8 showing the heaviest leaves (8.63 g), indicating robust vegetative health and commercial potential. Control treatment T_0, on the other hand, showed the smallest leaf area (201.99 cm²) and lowest average leaf weight (4.70 g), reaffirming the importance of nutrient management in foliage development. These findings are supported by earlier studies such as Rani *et al.*, (2015), who reported that vermicompost and organic manure application significantly improved leaf dimensions in broccoli. Similar results were observed by Mahato *et al.*, (2021) [11] in Kale, where the integrated use of AMF and Azospirillum led to better leaf expansion, higher chlorophyll content, and improved leaf biomass. The outcome of the present study highlights that the synergistic action of organics and beneficial microbes not only improves growth parameters but also enhances the functional leaf traits essential for photosynthesis and yield.

Leaf yield attributes in Kale

The Leaf yield-related parameters were significantly influenced by the application of organic and biofertilizer combinations. The highest leaf yield per hectare was recorded in T_8 (Mustard cake + Azospirillum + AMF) with 245.17 q/ha, followed closely by T_6 (244.50 q/ha) and T_3 (231.25 q/ha). These treatments also recorded superior performance in terms of leaf yield per plant (1.52 g in T_8) and per plot yield (13.12 kg in T_8).

The control treatment (T_0) showed the lowest values across all yield metrics, including 158.82 q/ha, highlighting the inadequacy of natural soil fertility in supporting high-yielding Kale production. Treatments like T_4 and T_5 also performed reasonably well, suggesting that even dual combinations of compost with Azospirillum or AMF can enhance productivity over untreated soil.

These results corroborate the findings of Phookan *et al.*, (2016) and Patel *et al.*, (2018), who observed increased yields in cabbage and broccoli with enriched compost and biofertilizer application. Similarly, Ansari *et al.*, (2020) demonstrated that integrated nutrient management involving mustard cake and biofertilizers significantly increased Kale leaf yield by improving nutrient uptake efficiency and maintaining soil microbial balance. The findings of this study thus confirm that combining organics with microbial inoculants leads to a cumulative effect on biomass production, ensuring higher leaf yield in Kale under sustainable cultivation practices.

Leaf Quality Attributes

The best quality traits were also recorded in T_8, which had the highest ascorbic acid (1.45 mg/100g), chlorophyll content (106.37 mg/g), and TSS (10.0 °Brix). The combined application of mustard cake, Azospirillum, and AMF proved most effective in enhancing nutrient density and photosynthetic pigments. Leaf Quality attributes such as ascorbic acid (Vitamin C), chlorophyll content, total soluble solids (TSS), and acidity are vital indicators of the nutritional and sensory appeal of leafy vegetables like Kale. Table 5 clearly reveals that these parameters were significantly influenced by the application of organic and biofertilizer treatments.

The highest ascorbic acid content (1.45 mg/100g) was recorded in treatment T_8 (Mustard cake + Azospirillum + AMF), followed by T_6 (1.40 mg/100g) and T_3 (1.37 mg/100g). This increase in vitamin C content can be attributed to the enhanced uptake of micronutrients and improved physiological metabolism induced by microbial inoculants and organic inputs. Vitamin C plays a vital role in boosting the antioxidant profile of Kale and is considered a key nutritional quality trait.

Similarly, chlorophyll content, which reflects the photosynthetic potential and visual appeal of the crop, was highest in T_8 (106.37 mg/g), followed by T_6 (105.20 mg/g) and T_3 (104.29 mg/g). The enhanced chlorophyll synthesis in these treatments is likely due to improved nitrogen and magnesium availability, both essential for chlorophyll biosynthesis. The role of Azospirillum in promoting nitrogen assimilation and of AMF in enhancing phosphorus and magnesium availability is well-documented.

Total Soluble Solids (TSS), an indicator of sugars and other dissolved solids, also showed the highest value in T_8 (10.0 °Brix), indicating improved sweetness and flavor. The lowest TSS was recorded in T_0 (8.8 °Brix). Higher TSS may result from increased carbohydrate synthesis due to improved photosynthetic efficiency under biofertilizer-supported treatments.

The observed trends in this study align well with those of Chatterjee *et al.*, 2019, who noted improvements in ascorbic acid and chlorophyll content in cabbage under organic fertilization. Likewise, Mahato *et al.*, 2021 [11] confirmed that AMF and Azospirillum inoculation significantly improved the nutritional quality of leafy vegetables by enhancing both macro- and micronutrient absorption and metabolic efficiency. The results of the current study underscore the fact that integrated organic and biofertilizer treatments not only improve Kale yield but also elevate its nutritional and market value.

Table 2: Effect of different organic and bio fertilizers Leaf Morphological Traits and leaf yield and quality of kale

Leaf Morphology				Leaf yield			Quality		
Treatment	Leaf Length (cm)	Leaf Width (cm)	Leaf Area (cm²)	Leaf Weight (g)	Yield/ Plant (g)	Yield/ Ha (q)	TSS (°Brix)	Chlorophyll (mg/g)	AscorbicAcid (mg/100g)
T_0	18.28	11.05	201.99	4.70	0.65	158.82	8.80	99.65	1.20
T_1	19.65	12.15	238.75	5.07	1.15	186.66	8.90	100.40	1.23
T_2	20.23	12.23	247.41	6.65	1.23	213.26	9.20	102.23	1.29
T_3	20.85	13.45	280.43	7.01	1.37	231.25	9.60	104.29	1.37
T_4	20.29	12.76	258.90	6.54	1.18	211.86	9.10	101.32	1.25
T_5	20.42	13.12	267.91	6.71	1.29	228.09	9.30	102.45	1.32
T_6	21.35	14.29	305.09	7.27	1.49	244.50	9.80	105.20	1.40
T_7	20.78	13.37	277.83	6.78	1.35	228.56	9.50	103.35	1.35
T_8	22.21	15.20	337.59	8.63	1.52	245.17	10.00	106.37	1.45
F-test: S; CD (5%) = 0.20 (Length), 0.22 (Width), 7.08 (Area)				F-test: S; CD (5%) = 0.17 (Weight), 0.04 (Plant), 4.23 (Ha)			F-test: S; CD (5%) = 0.06 (TSS), 0.33 (Chlorophyll), 0.01 (Ascorbic acid)		

Economical analysis

Economic evaluation revealed that treatment T_8 provided the highest net return of Rs. 4, 19, 653.20/ha and a B:C ratio of 5.94, followed by T_6 and T_5. The increase in yield under integrated nutrient management justified the slight increase in cost of cultivation.

Among all treatments, T_8 (Mustard cake + Azospirillum + AMF) recorded the highest net return of Rs.4, 19, 653.20/ha, followed by T_6 (Rs.3, 98, 305.40/ha) and T_5 (Rs. 3, 86, 139.40/ha). Correspondingly, the Benefit-Cost Ratio (B:C) was also maximum in T_8 (5.94), showing that for every Rs.1 invested, there was a return of B:C ratio 5.94, which confirms superior profitability. This indicates that although T_8 had a slightly higher input cost (Rs.70, 690/ha), the investment was well-compensated through higher yield and better quality produce.

On the other hand, the control plot (T_0) recorded the lowest gross return (Rs.3, 17, 640/ha) and net return (Rs.2, 52, 550/ha), with a B:C ratio of only 3.88. This clearly illustrates the inefficiency of relying solely on natural soil fertility without nutrient supplementation.

Table 3: Effect of different organic and bio fertilizers Economical analysis of kale

Treatment	Yield (q/ha)	Selling Price (Rs)	Cost of Cultivation (Rs/ha)	Net Return (Rs/ha)	B:C Ratio
T_0	158.82	2000	65, 090	2, 52, 550	3.88
T_1	186.65	2000	69, 090	3, 04, 210	4.40
T_2	201.86	2000	69, 890	3, 33, 825	4.78
T_3	221.25	2000	70, 440	3, 72, 068.20	5.28
T_4	213.26	2000	69, 640	3, 56, 887.80	5.12
T_5	228.09	2000	70, 040	3, 86, 139.40	5.51
T_6	234.50	2000	70, 690	3, 98, 305.40	5.63
T_7	228.56	2000	70, 290	3, 86, 827.00	5.50
T_8	245.17	2000	70, 690	4, 19, 653.20	5.94

The profitability of treatments such as T_5 and T_6 also remained high due to the relatively moderate cost of cultivation paired with substantial yield increases, suggesting that even partial integration of organic and microbial inputs can be economically rewarding. These economic gains are not only a result of higher yield but also enhanced quality (vitamin C, TSS, chlorophyll), which can attract premium pricing in health- conscious markets.

The present findings are consistent with Jha *et al.*, (2017) [8] and Thakur & Sharma (2020) [17], who demonstrated that organic and integrated nutrient management practices in cole crops, including cabbage and Kale, resulted in higher B:C ratios than conventional systems. Similarly, Kumari & Singh (2023) [10] highlighted that organic Kale cultivation improved farmer income due to reduced input costs, increased soil fertility, and premium market opportunities. The current study therefore supports the conclusion that integrating mustard cake, Azospirillum, and AMF is not only agronomically effective but also economically sustainable for commercial Kale production.

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Conclusion

The findings of the present investigation clearly indicate that the integrated use of organic fertilizers and biofertilizers significantly enhances the growth, yield, and quality of Kale compared to untreated control and sole input applications. Among the various treatment combinations tested, T_8 (Mustard cake + Azospirillum + AMF) emerged as the most effective in promoting superior vegetative development, nutrient uptake, and biochemical quality traits. This treatment recorded the highest values for plant height, number of leaves, leaf area, chlorophyll content, ascorbic acid concentration, and total soluble solids, while also yielding the highest leaf biomass per hectare. Moreover, T_8 also proved to be the most profitable, achieving the highest net return and benefit-cost ratio, thereby offering strong evidence for its adoption in commercial organic Kale production.

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