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RESEARCH ARTICLE

Effect of integrated nutrient management on yield, nitrogen use efficiency and economics of sprouting broccoli, and soil health in the Terai region of West Bengal

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Abstract

A two-year field experiment was carried out to study the effect of integrated nutrient management on broccoli cultivation and soil health during the rabi season of 2016-17 and 2017-18, at the Instructional farm of Uttar Banga Krishi Viswavidyalaya, Cooch Behar, West Bengal, India. The experiment consisted of ten treatments with three replications laid in a randomized block design (RBD). The treatments consisted of different doses of vermicompost, cowdung manure, chemical fertilizer, vermiwash, and biofertilizer. The results obtained revealed that application of vermicompost 25% + cow dung manure 25% + chemical fertilizer 50%+ vermiwash + biofertilizer (T9) for sprouting broccoli gave the highest yield 17.82 t/ha, B: C ratio 2.08, and physiological nitrogen use efficiency 61.59 kg/kg. The treatment also improved the soil available nutrient content and improved the microbial count compared to the sole application of chemical fertilizer.

Keywords: Sprouting broccoli, Vermicompost, Cowdung manure, Vermiwash, Biofertilizer.

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Introduction

The unprecedented pressure on agricultural lands and natural resources to meet the food and nutritional demands of an exponentially growing population has led to the overuse of synthetic and environmentally harmful inputs in crop production systems, which have already started deteriorating soil health. This overuse or abuse of synthetic inputs is dramatic in developing countries (Mueller et al., 2012), although the average yield per unit area remains stagnant (Peng et al., 2002; Zhang et al., 2012). This clearly indicates that a large increase in synthetic inputs, such as fertilizers and pesticides, is no longer giving a corresponding yield increase. Although several scientific research papers on genetic manipulation of crops to boost the quantity of global food supply are available (Wu & Liao, 2014), the actual on-field data tell a different story. The on-field yield potential of crops is found to be one-third of what the research studies claim (Mueller et al., 2012) and it has been decreasing since the early 1990s (Brisson et al., 2010). Moreover, in many regions, this decrease is accompanied by increasing environmental degradation (Bruinsma, 2009) due to the overuse of chemicals and synthetic inputs in agriculture. Several studies have also reported an alarming decline in food quality and a decrease in nutritionally essential minerals and nutraceutical compounds in our food due to extensive use of chemicals in farming practices (Bhardwaj et al., 2024). Thus, it is high time to decrease the use of synthetic fertilizers and other chemical inputs and search for innovative and sustainable agricultural practices that can guarantee a reasonable quality yield to secure food and nutritional security while minimizing further deterioration of our environment (Foley et al., 2011).

Broccoli (*Brassica oleracea* var. *italica*), a European vegetable, is considered to be more nutritious than any other cole crop. It is not only nutritionally rich in several vitamins and minerals (Kumar et al., 2011) but also possesses antioxidant and anticarcinogenic properties (Cartea et al., 2008), which improve the body's defensive system (Carty & Mark, 2008). Several studies have established that integrated nutrient management (INM) has the potential to considerably improve crop yield while minimizing nutrient losses by managing the nutrient supply, thereby resulting in high resource-use efficiency and cost reductions (Janssen, 1993; Prasad et al., 2002; Parkinson, 2013; Zhang et al., 2012). Thus, INM can be considered an effective agricultural tool to ensure food security while improving environmental quality worldwide. INM helps in maintaining soil fertility through optimization of available resources. These studies mostly emphasise the importance of balanced used of mineral fertilizers, the role of organic manure and bio-fertilizers, use of green manure and recycling of organic wastes as supplementary practice and not as a substitute. Therefore, keeping in view previous research, the experiment was carried out to study the effect of integrated nutrient management on the increase in profitability of sprouting broccoli cultivation and soil health.

Materials and Methods

Experimental site description

Two-year experiments were conducted at the Instructional Farm, Uttar Banga Krishi Viswavidyalaya, Cooch Behar, West Bengal, India, which comes under the Terai zone of West Bengal and is located at $26^{0}19'86''$ N latitude and $89^{0}23'53''$ E Longitude, at an elevation of 43 meters above mean sea level (MSL). The average rainfall ranges from 2100 to 3300 mm, and the temperature varies from a minimum of 7 to 8°C to a maximum of 24 to 33.2°C. The experimental plot has been used specifically to conduct research work on vegetable production for more than twenty years by the university. The previous crop grown on the experimental plot was ridge gourd, which was cultivated by using organic manure only, without any chemical inputs. The soil of the experimental plot was sandy loam with a low pH (5.20). The initial soil nutrient content recorded was- available nitrogen: 169.97 kg/ha, available phosphorus: 20.16 kg/ha, available potassium: 98.56 kg/ha and organic carbon: 0.70%. The total area of the experimental plot was around 330 $m^{2,}$ in which seeds were first sown in pots and then transplanted into the prepared beds of 2.5 × 4 m size at a spacing of 50 cm x 50 cm. Each plot accommodated 40 plants.

Experimental design

The experiment was conducted during the rabi season of 2016-17 and 2017-18. It was laid in Randomized Block Design with three replications and ten treatments: T_1-No nutrient application, T_2-Chemical fertilizer$_{100\%}$, T_3-Vermicompost$_{100\%}$, T_4- Cow Dung Manure$_{100\%}$, T_5-Vermicompost$_{50\%}$ + Chemical Fertilizer$_{50\%}$, T_6-Cow Dung Manure$_{50\%}$ + Chemical Fertilizer$_{50\%}$, T_7-Vermicompost$_{50\%}$ +Cow Dung Manure$_{50\%}$, T_8-Vermicompost$_{25\%}$ +Cow Dung Manure$_{25\%}$ +Chemical Fertilizer$_{25\%}$, T_9-Vermicompost$_{25\%}$ + Cow Dung Manure$_{25\%}$+ Chemical Fertilizer$_{25\%}$+ Vermiwash + Biofertilizer, T_{10}-Vermicompost$_{50\%}$ + Cow Dung Manure$_{50\%}$ + Vermiwash + biofertilizer.

Materials used

The nutrients were applied as per the treatments. The recommended dose of nutrients for sprouting broccoli was N: P_2O_5:K_2O @ 150:50:50 kg/ha. For chemical fertilizers, urea, murate of potash (MOP), and single super phosphate (SSP) were used. Full dose of P_2O_5 and K_2O, and 1/3rd of nitrogen was applied during land preparation. The remaining nitrogen was applied in two split doses at 3 weeks and 6 weeks after transplanting. The recommended dose of vermicompost was 10 t/ha, which was calculated on 100% recommended N equivalent basis. Vermiwash was applied @ 650 l/ha. *Azophos* was collected from the Department of Plant Pathology, Uttar Banga Krishi Viswavidyalaya, Pundibari. It is a microbial inoculant containing *Azotobacter* and *Acinetobacter sp.* It was thoroughly mixed with decomposed organic manure (Cow Dung Manure and Vermicompost) @ 10 g/kg of organic manure and stored in shade conditions for twenty days. The mixture was kept moist by covering it with a gunny bag and regular sprinkling of water. The seeds of a locally popular spouting broccoli variety, Green Magic (F_1 Hybrid), were purchased from a local shop and sown in seed bed during early November.

Data collection and analysis

The yield of broccoli was measured manually after harvesting it at a fully developed but still green and unopened bud stage. To calculate nitrogen use efficiency (NUE), nitrogen uptake by the plant was measured by using the Micro-Kjeldhal method given by Jackson (1967), and was calculated by using the following equation:

$$NUE = \frac{\text{Crop yield (kg/ha)}}{\text{Total N uptake (kg/ha)}}$$

Agronomic nitrogen use efficiency (NUE-AE) was calculated using the equation:

$$NUE\text{-}AE = (Y_f\text{-}Y_o)/P$$

Where Y_f implies the yield of fertilized crops, Y_o implies the yield of unfertilized crops and P is the rate of fertilizer applied.

Physiological nitrogen use efficiency (NUE-PE) was calculated by using the equation:

$$NEU\text{-}PE=(Y_f-Y_o)/(P_{uf}-P_{uo})$$

Where, Y_f is the yield of fertilized crops, Y_o is the yield of unfertilized crops, P is the rate of fertilizer applied,

P_{uf} is N uptake in fertilized crops and P_{uo} is N uptake in unfertilized crops.

The economics of cultivation was worked out on the basis of the expenditures incurred during cultivation and finally, the benefit-cost ratio was estimated by calculating the ratio of net return and cost of cultivation.

Soil sample analysis

Soil samples from the multiple locations of the plots were collected from 0-15 cm depth before and after the experiment. The soil pH which was determined using potentiometric method given by Jackson (1967), for soil organic carbon content estimation rapid titrimetric wet oxidation method by Walkley & Black (1934) was followed, available Nitrogen content of soil was estimated by modified Macro Kjeldal method (Jackson, 1967), available phosphorus was determined by following Bray's No. 1 method (Jackson, 1967), available potassium content was determined using flame photometric method (Jackson, 1973). The most probable number (MPN) technique given by Alexandre (1982) was followed to estimate the microbial population in a test sample. It is based on the theory of probability of the number of observed positive growth responses to a standard dilution series of sample inoculums placed into a set number of culture media tubes.

Statistical analysis

All the recorded data were subjected to standard statistical analysis of variance for Randomized Block Design formulated by Panse & Sukhatme (1985) using SPSS Statistics 17.0.0 (IBM Analytics, USA). The test for significance in variation among the treatments was tested by the F test (Cochran & Cox, 1958). For determining the critical difference at 5% level of significance, Fisher & Yates (1963) table was consulted. Pooled analysis of the data was done following the method suggested by Gomez & Gomez (1984).

Results and Discussion

Effect of Integrated nutrient management on yield and economics of sprouting broccoli

Integrated nutrient management significantly affected the yield parameters of sprouting broccoli. The recorded data revealed that among different treatments, T_9 (Vermicompost$_{25\%}$ + Cow Dung Manure$_{25\%}$ + Chemical Fertilizer$_{50\%}$ +Vermiwash + biofertilizer) had a significantly higher head weight (561.36 g) as well as yield per hectare (17.82 t/ha), which was statistically at par with T_2 for both the parameters. The head weight of broccoli for T_9 was increased by 111.78% than T_1(control), 49.92% than T_4, 37.19% than T_7, 26.52% than T_3, 26.04% than T_6, 19.88% than T_{10}, 14.24% than T_5, 10.24% than T_8 and 1.73% than T_2. Similarly, the increase in yield per hectare for T_9 was 108.67, 34.69, 24.96, 24.79, 18.56, 12.36, 8.79 and 0.11% than T_1 (control), T_4, T_7, T_6, T_3, T_{10}, T_5, T_8 and T_2, respectively. Several studies on integrated nutrient management have already shown that using organic manure in combination with inorganic manure enhances the yield as well as the profitability of the crop (Meena & Reddy, 2021). Vermicompost is known to contain most of the plant nutrients in available forms such as nitrates, phosphates, calcium, potassium, magnesium, etc. (Garg & Gupta, 2009) along with plant growth regulators *viz*., auxins, gibberellic acid, cytokinins, humic substances, etc. (Zhang et al., 2014) and enhance enzymatic activity in plants (Subler et al., 1998). Further application of vermiwash, which contains several enzymes, plant growth hormones (IAA, Cytokinin, GA_3), Vitamins, macro and micro nutrients (Buckerfield et al., 1999), growth promoters such as auxin and cytokinin (Patil et al., 2007), enzymes such as protease, amylase, urease and nitrogen fixing bacteria like *Azotobacter sp*., *Agrobacterium sp*., *Rhizobium sp*., and some phosphate solubilizing bacteria (Zambare et al., 2008). In addition to vermiwash, the applied biofertilizer might have made the nutrients more available to the plant. All these might have helped in better nutrient absorption by plants, which resulted in higher yield. Sole organic manure could not meet the nutritional needs of the crop. The combined application of organic manure and inorganic fertilizer is more effective because of better nutrient uptake by broccoli. Similar results were reported by Bahadur et al. (2003) and Chatterjee et al. (2005).

This significant effect on yield directly impacted the economics of cultivation and the highest benefit: cost ratio of 2.08 was obtained for T_9 (Vermicompost$_{25\%}$ + Cow Dung Manure$_{25\%}$ + Chemical Fertilizer$_{50\%}$ +Vermiwash + biofertilizer). Similar results were obtained by Singh et al. (2021).

Effect of integrated nutrient management on N-uptake, agronomic nitrogen use efficiency and physiological nitrogen use efficiency by sprouting broccoli

As shown in Table 1, integrated nutrient management had a significant effect on N-uptake, agronomic nitrogen use efficiency and physiological nitrogen use efficiency by sprouting broccoli. Among all the treatments application sprouting broccoli planted in T_2 (Chemical Fertilizers$_{100\%}$) showed the significantly highest N-uptake. Application of chemical fertilizers$_{100\%}$(T_2) increased the N-uptake by 327.52, 66.45, 57.23, 42.97, 41.72, 30.26, 24.73, 23.10 and 2.98% than T_1, T_4, T_7, T_6, T_{10}, T_3, T_5, T_8 and T_9, respectively.

Table 1: Effect of integrated nutrient management on yield, economics, N-uptake, N-use efficiency, soil residual nutrient and soil microbial count of sprouting broccoli cultivation.

Treatment	Head weight (g)	Yield per ha (t)	B:C	Plant N-Uptake (kg/ha)	Agronomic Nitrogen Use Efficiency (kg/kg)	Physiological Nitrogen Use Efficiency (kg/kg)	Available soil nitrogen (kg/ha)	Available soil phosphorus (kg/ha)	Available soil potassium (kg/ha)	PSB Microbial count (cfu/g)	Azotobacter Microbial count (cfu/g)
T_1	265.07^{g}	8.54^{g}	1.11	45.45^{f}	0.00	0	119.90^{f}	14.92^{f}	93.71^{f}	4.023^{c}	4.19^{d}
T_2	551.82^{a}	17.80^{a}	1.71	194.31^{a}	60.68^{a}	66.04^{abc}	169.61^{cd}	15.64^{f}	105.28^{ef}	4.500^{b}	4.42^{cd}
T_3	443.69^{d}	14.28^{d}	0.93	149.17^{bc}	38.49^{d}	60.67^{bc}	177.18^{c}	17.10^{e}	186.85^{a}	4.446^{b}	4.52^{cd}
T_4	374.44^{f}	12.03^{f}	1.38	116.74^{e}	23.03^{f}	43.31^{d}	171.49^{cd}	19.19^{bc}	128.24^{cd}	4.559^{b}	4.36^{d}
T_5	491.39^{cb}	15.86^{cb}	1.70	155.79^{b}	47.86^{bc}	70.76^{ab}	191.66^{b}	19.56^{bc}	159.97^{b}	4.446^{b}	4.38^{cd}
T_6	445.40^{d}	14.26^{d}	2.02	135.91^{c}	37.49^{d}	67.89^{abc}	196.57^{ab}	17.77^{de}	113.12^{de}	4.273^{bc}	4.38^{cd}
T_7	409.19^{e}	13.23^{e}	1.13	123.58^{c}	31.02^{e}	58.67^{c}	156.28^{e}	18.37^{cd}	98.75^{ef}	4.523^{b}	4.09^{d}
T_8	509.23^{b}	16.38^{b}	1.98	157.85^{b}	50.98^{b}	73.96^{a}	194.64^{b}	19.14^{bc}	141.68^{c}	4.446^{b}	4.86^{c}
T_9	561.36^{a}	17.82^{a}	2.08	188.68^{a}	61.59^{a}	69.97^{abc}	206.98^{a}	22.32^{a}	165.20^{b}	5.399^{a}	5.50^{b}
T_{10}	468.25^{dc}	15.03d^{c}	1.24	137.11^{bc}	42.40^{cd}	76.56^{a}	164.33^{de}	19.87^{b}	102.85^{ef}	5.290^{a}	6.34^{a}
S.Em.	9.82	0.31		5.94	1.998	3.563	3.75	0.388	5.643	0.130	0.15
CD (P=0.05)	28.18	0.91		17.05	7.754	10.218	10.76	1.113	16.184	0.374	0.43

Note: T_1-No nutrient application, T_2-Chemical fertilizer$_{100\%}$, T_3-Vermicompost$_{100\%}$, T_4- Cow Dung Manure$_{100\%}$, T_5- Vermicompost$_{50\%}$ + Chemical Fertilizer$_{50\%}$, T_6-Cow Dung Manure$_{50\%}$ + Chemical Fertilizer$_{50\%}$, T_7-Vermicompost$_{50\%}$ +Cow Dung Manure$_{50\%}$, T_8-Vermicompost$_{25\%}$ +Cow Dung Manure$_{25\%}$ +Chemical Fertilizer$_{25\%}$, T_9-Vermicompost$_{25\%}$ + Cow Dung Manure$_{25\%}$ + Chemical Fertilizer$_{25\%}$+ Vermiwash + Biofertilizer, T_{10}-Vermicompost$_{50\%}$ + Cow Dung Manure$_{50\%}$ + Vermiwash + Biofertilizer.

The highest agronomic nitrogen use efficiency (NUE-AE) of 61.59 kg/kg was recorded for T_9 (Vermicompost$_{25\%}$ + Cow Dung Manure$_{25\%}$ + Chemical Fertilizer$_{50\%}$ +Vermiwash + biofertilizer) (Table 1), which was 167.43, 98.55, 64.28, 60.02, 45.26, 28.69, 20.81, 1.50% higher than T_4, T_7, T_6, T_3, T_{10}, T_5, T_8, and T_2, respectively. Whereas, the highest physiological nitrogen use efficiency (NUE-PE) of 76.56 kg/kg was recorded highest for T_{10} (Vermicompost$_{50\%}$ + Cow Dung Manure$_{50\%}$ + Vermiwash + Biofertilizer), which was 76.77, 30.49, 26.19, 15.93, 12.77, 9.42, 8.20 and 3.52% higher than T_4, T_7, T_3, T_2, T_6, T_9, T_5 and T_8, respectively. The humic substance in vermicompost and vermiwash is reported to improve fertilizer use efficiency (Gomes et al., 2019) as organic manure provides a regulated supply of N (Sharma, 2002) than inorganic fertilizer. Findings of the present study are in corroboration with those of Chaudhary et al. (2004) and Balasubramanian (2013).

Effect of integrated nutrient management on residual soil nutrient content and soil microbial count

The data presented in Table 1 show that the soil residual nutrient contents, such as available soil nitrogen, available soil phosphorus, and available soil potassium, were significantly affected by the integrated nutrient management for sprouting broccoli cultivation. Among all the treatments the highest available soil nitrogen (206.98 kg/ha) as well as available soil phosphorus (22.32 kg/ha) was recorded for T_9 (Vermicompost$_{25\%}$ + Cow Dung Manure$_{25\%}$ + Chemical Fertilizer$_{50\%}$ + Vermiwash + biofertilizer), whereas the highest available soil potassium (186.85 kg/ha) was recorded for T_3 (Vermicompost$_{100\%}$). The fulvic acid and humic acid present in vermicompost and vermiwash dissolve insoluble minerals in organic matter (OM) (Singh et al., 2008), improve soil aggregate stability, have a high affinity for organic and inorganic ions, and can form complexes with cations and inorganic phosphorus, preventing leaching and promoting availability. Vermiwash is reported to revitalize the soil quality (Gopal et al., 2010) and is considered a liquid biofertilizer that is rich in several primary nutrients (Nath et al., 2009; Palanichamy et al., 2011). The findings of this experiment are in confirmation with the findings of Kumar et al. (2017), Sharma et al. (2018), and Gupta et al. (2019).

As per the recorded data highest population count for *Phosphate Solubilizing Bacteria* (5.399 cfu/g) was recorded for T_9 (Vermicompost$_{25\%}$ + Cow Dung Manure$_{25\%}$ + Chemical Fertilizer$_{50\%}$ + Vermiwash + Biofertilizer), which was statistically at par with T_{10} and the highest population count for *Azotobacter* (6.34 cfu/g) was recorded for T_{10} (Vermicompost$_{50\%}$ + Cow Dung Manure$_{50\%}$ + Vermiwash + Biofertilizer). Vermicompost promotes beneficial microbes and their diversity in the soil. Organic manures enhance soil biodiversity by supporting valuable microbes (Lazcano & Domínguez, 2011). Further, application of biofertilizers might have improved the population of microorganisms in the soil along with vermicompost and cow dung.

Conclusion

Based on the present findings of two years, it can be concluded that adopting the application of vermicompost 25% + cow dung manure 25% + chemical fertilizer 50%+ vermiwash + biofertilizer for sprouting broccoli can be an option to improve its yield and profitability, along with improvement in soil health in the Terai region of West Bengal.

Disclosure Statement

No potential conflict of interest was reported by the author(s).

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सारांश

उत्तर बंगाल कृषि विश्वविद्यालय, कूचबिहार, पश्चिम बंगाल, भारत के शैक्षणिक खेत में 2016-17 एवं 2017-18 के रबी मौसम के दौरान ब्रोकली की खेती एवं मृदा गुणवत्ता पर एकीकृत पोषक तत्व प्रबंधन के प्रभावों का अध्ययन किया गया। इस प्रयोग में विभिन्न जैविक खाद जैसे वर्मीकम्पोस्ट, वर्मीवॉश, गोबर खाद, जैव उर्वरक एवं रासायनिक उर्वरकों को विभिन्न अनुपातों में मिलाकर दस उपचारों का निर्माण किया गया। इन दस उपचारों को यादृच्छिक खंड डिजाइन में रखा गया एवं तीन बार उनकी पुनरावृत्ति की गई। अध्ययन के दौरान लिए गए अवलोकनों से यह पाया गया कि 25 प्रतिशत वर्मीकम्पोस्ट + 25 प्रतिशत गोबर खाद + 50 प्रतिशत रासायनिक उर्वरक + वर्मीवॉश + जैव उर्वरक वाले उपचार से ब्रोकली में सबसे अधिक उपज (17.82 टन/हेक्टेयर) एवं लाभ (2.08 लाभ-लागत अनुपात) की प्राप्ति हुई, तथा सबसे अधिक फिजियोलॉजिकल नाइट्रोजन उपयोग दक्षता (61.59 किग्रा/किग्रा) भी पाई गई। इस उपचार के फलस्वरूप मृदा गुणवत्ता जैसे मृदा में उपलब्ध पोषक तत्वों की मात्रा एवं मृदा के सूक्ष्मजीवों की जनसंख्या में भी वृद्धि पाई गई।