RESEARCH ARTICLE

Effect of integrated nutrient management on the economic production of sprouting broccoli and its qualitative characteristics (*Brassica oleracea* L. var. *italica* Plenck)

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An experiment was conducted during Rabi season 2018-2019 to 2019-2020 to evaluate the effect of integrated nutrient management for yield, quality traits and economic production of sprouting broccoli variety F_1 hybrid 'Green Magic' in Kanpur condition having high sub-tropical humid with hot summer and cold winter. Results revealed that the application of vermicompost@ 5 t ha^{-1}+*Azotobacter*), performed better with respect to quality parameters and economic production of sprouting broccoli after harvesting. The treatments significantly affected various quality traits and economics parameters *viz.* quality characters namely total soluble solids content (8.65°Brix), ascorbic acid content (86.90 mg/100 g), reducing sugars content (3.59%), non-reducing sugars content (0.80%) and total sugar content (4.04%) and economic parameters such as Benefit cost ratio (2.66), gross returns (Rs.1,58,941.5/ha), and net returns (Rs.99,323.5/ha) were better after using vermicompost and bio-fertilizer significantly enhanced various crop yield quality traits and economics parameters, at the same time they reduced the time taken for head initiation, improved quality traits and economic production.

Key Words: *Sprouting broccoli; Quality; Economics; INM; Gross return; Net return*

INTRODUCTION

Vegetables are high in protein, carbs, fibre, minerals, and vitamins. As a result, they are regarded as a protective food that is essential for human health. Sprouting broccoli is derived from the Italian word 'brocco,' which means shoot, and refers to the development of a young flower bud that is used as a vegetable. It may be eaten alone or combined with potatoes in salads, curries, soups, pickles, and other dishes [1]. Broccoli sprouts have excellent organoleptic properties and are a delicious vegetable.

It has the highest nutritive value of any Cole crop, with high levels of vitamin-C (137 mg/100 g), vitamin-A (9000 IU/100 g), thiamine (33 mg/100 g), vitamin-B2 (0.12 mg/100 g), protein (3.3%), iron (205 mg/100 g), and calcium (0.80 mg/100 g) [2]. Broccoli contains anticancer compounds such as sulforaphane, indoles, beta-carotene, and phytochemicals. Broccoli's chemical components include glucoraphanin, glucoibrin, vitamins, and myrosinase. It contains a variety of nutrients, including Di Indolyl Methane (DIM) and a trace of selenium. Additionally, it is thought to contain therapeutic qualities that can treat diabetes and heart problems. Goitrogens, which are naturally occurring chemicals that might affect thyroid gland function, are also present in sprouting broccoli [3].

Consuming more than one serving of sprouting broccoli per week lowers the risk of prostate cancer by up to 45 percent [4]. It contains glucosinolates, a powerful anti-cancer compound that protects against bowl cancer [5]. The overuse of chemicals on vegetable crops has reduced the population of beneficial microorganisms in the soil, particularly those that control insect pests and improve soil fertility [6].Through the optimization of all available biotic, inorganic, and organic resources in an integrated manner that is appropriate to each cropping system and farming situation with its associated ecological, social, and economic ramifications, integrated nutrient management considers improving and maintaining soil fertility for sustainable crop productivity.

MATERIALS AND METHODS

A field experiment was conducted during 2018-2019 and 2019-2020 both the year same time at Vegetable Research Farm, Department of Vegetable Science, Chandra Shekhar Azad University of Agriculture and Technology, Kalyanpur, Kanpur situated at longitude ranging between 25.28° to 28.50° north and 79.31° to 84.34° east at elevation of 125.90 m above mean sea level. Three replications were used in the randomized block design of the experiment. Nutrient status of experimental plot was estimated before planting of sprouting broccoli. The pH was determined by electric pH meter and available nitrogen was determined by alkaline permagnate method as reported by Piper [7] and available phosphorus and potash by Olsen's method and Flame photometer method respectively. The E.C was determined by Conductivity Bridge as described by Jackson [8]. The status of soil organic matter (0.78%, 0.82%), available nitrogen (210.50 kg/ha, 204.32 kg/ha), available phosphorus (45.50 kg/ha, 41.80 kg/ha), available potash (195.40 kg/ha, 185.65 kg/ha), pH range (7.68, 7.63) and E.C (0.28 m mhos, 0.26 m mhos) determined by different methods suggested above in the two-year data 2018-2019 and 2019-2020, respectively.

The experimental site experienced hot, muggy summers and chilly, muggy winters. The highest temperature ranged from 24 to 46 degrees Celsius and the minimum from 7.0 to 24.8 degrees Celsius during the growth season. The maximum relative humidity ranged from 86% to 98% while the minimum humidity ranged from 33% to 68%. Over the course of the broccoli production period, 800 to 880 mm of total rainfall were observed. The experimental site's soil had a sandy loam texture, was low in organic carbon, and had medium levels of readily available nitrogen, phosphate, and potassium. The combination consisted of 12 treatments, T_0-Control; T_1-100% RDF (120: 80: 60 N P K/ha), T_2-FYM@25 tons/ha, T_3-vermicompost @ 5 tons/ha, T_4-*Azotobacter*@2 kg/ha,T_5-100% RDF+FYM@25 tons/ha T_6-100% RDF+vermicompost@5 tons/ha, T_7: 100% RDF+*Azotobacter*@2 kg/ha, T_8-vermicompost@5 tons/ha+*Azotobacter*, T_9-100% RDF+FYM@25tons/ha+*Azotobacter*@2 kg/ha, T_{10}-100% RDF+vermicompost@5 tons/ha+Azotobacter@2 kg/ha and T_{11}-100% RDF+FYM@12.5 tons/ha+vermicompost@2.5 tons/ha+*Azotobacter*@ 1 kg/ha. The seed of F_1 hybrid variety Green magic was sown on 2nd October 2018-19 and 2019-20 same time and transplanted on 30th October both year in a randomized block design with twelve treatment combinations in three replications. A spacing of 60 cm × 45 cm with plot size of 2.40 m × 1.35 m was used for experimental purpose. 25 t/ha FYM applied in experimental plot (Table 1).

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Nitrogen was applied at a rate of 120 kg/ha, potassium at a rate of 60 kg/ha, and phosphorus at a rate of 80 kg/ha. N was applied in two separate doses. The remaining nitrogen was applied in two split doses, the first 30 days after transplanting and the second before head initiation. The treatments included farmyard manure, vermicompost and either RDF or biofertilizers (*Azotobactor*). The observations were made for various yield, quality, and economic parameters. It led to improved growth development and earlier head initiation. From the 15th of January 2018-19 to the 21st of January 2019-20, the crop was harvested by cutting the entire plant at ground level (Table 2).

TABLE 1

Effect of integrated nutrient management on the economic production of sprouting broccoli and its qualitative characteristics (*Brassica oleracea* L. var. *italica* Planck), on the basis of two year pooled data

Treatments	T.S.S (°Brix)	Ascorbic acid (mg/100 g)	Reducing sugar content (%)	Non-reducing sugar content (%)	Total sugar content (%)
T_0	5.65	78.42	1.23	0.37	1.74
T_1	7.73	84.68	2.33	0.43	2.86
T_2	7.87	79.27	2.55	0.71	2.67
T_3	8.11	83.02	2.38	0.66	2.87
T_4	7.95	84.07	2.77	0.59	3.34
T_5	7.81	84.42	2.57	0.57	3.44
T_6	7.94	80.86	2.22	0.43	2.47
T_7	8.08	83.49	3.23	0.45	3.23
T_8	8.65	86.92	3.59	0.81	4.04
T_9	8.49	84.26	3.33	0.72	3.55
T_{10}	8.36	85.55	3.19	0.43	2.84
T_{11}	8.21	85.89	3.49	0.78	3.69
SE (m) ±	0.074	0.214	0.053	0.013	0.058
CD (P=0.05)	0.211	0.608	0.151	0.036	0.164

TABLE 2

Effect of integrated nutrient management on the economic production of sprouting broccoli and its qualitative characteristics (*Brassica oleracea* L. var. *italica* Plenck), estimated on the basis of yield per hectare 2018-19 and 2019-20 on the basis of two years (Pooled data)

Treatment details	Selling rate (Rs./ quintal)	Yield (quintal/ ha) (Pooled)	Gross returns (Rs./ ha)	Treatment cost (Rs./ ha)	Total cost (Rs./ ha)	Net return (Rs./ ha)	B:C ratio
T_0	850	106.91	90890.5	-	43421	47472.5	02:09
T_1	850	132.85	112922.5	4718	48148	64785.5	02:34
T_2	850	137.93	117240.5	10012	53425	63821.5	02:19
T_3	850	145.78	123828	15023	5842	65418.2	02:13
T_4	850	139.26	118286	1242	44622	73667.4	0.128472
T_5	850	143.64	122102.5	14168	57627	64485.5	02:12
T_6	850	159.68	135677	19189	62626	73062.3	02:17
T_7	850	152.74	129803.5	5395	48818	80984.5	0.127778
T_8	850	186.99	158941.5	16221	59622	99323.5	0.129167
T_9	850	172.49	146531.5	15398	58825	87714.5	02:48
T_{10}	850	171.42	145605	20375	63819	81788.4	02:29
T_{11}	850	159.79	135821.5	17297	60717	75104.5	02:24
85.89	85.89	85.89	85.89	85.89	85.89	85.89	85.89
85.89	85.89	85.89	85.89	85.89	85.89	85.89	85.89

The quality parameters *viz*. total soluble solids were measured by using Erma Hand Refractometer (0-32°Brix) ERMA, Japan. Ascorbic acid content in head was estimated by volumetric method, was determined titrimetrically using 2,6 dichlorophenol indophenol dye as per method suggested by Ranganna [9].

$$\frac{1}{T} \times V \times V_1 / V_2 \times \frac{100}{W} = Vita\min - C(\frac{mg}{100g})$$

Total sugars, Non-reducing sugars and Reducing sugars were estimated by volumetric method, suggested by Ranganna [9].

$$\textbf{Factor for Fehlings Solution} = \frac{\textbf{Titre (Burette reading)} \times \textbf{2.5 (g of invert sugar)}}{1000}$$

Total sugar as invert sugar=Calculated as % reducing sugar making use of the titre value obtained in determination of total sugar after inversion.

$$\textbf{Non-reducing sugar } \% = (Total\ invert\ sugar\ \% - Reducing\ sugar\ \%\ originally\ present) \times 0.95$$

$$Total\ sugar\ \% = (Reducing\ sugar\ \% + Non-reducing\ sugar\ \%)$$

(10 ml of Fehling solution=0.05 g of sugar).

$$Reducing\ sugar\ \% = \frac{Mg\ of\ invert\ sugar \times Dilution \times 100}{Titre \times water\ volume\ of\ the\ sample \times 100}$$

To determine the most economic treatment, the economics of each treatment under examination were calculated based on the current market pricing of the produce and inputs. Benefit cost ratios (B:C) for each treatment were determined after calculating gross and net returns. Gross returns (Rs/ha) were calculated by multiplying total output (yield) by the relevant market prices at the time.

Net returns (Rs/ha)

$$Net\ returns = Gross\ returns - cost\ of\ cultivation$$

Benefit cost ratio

The benefit cost ratio from each treatment was calculated using the following formula:

$$Benefit\ cost\ ratio = (Gross\ return) / (Cost\ of\ cultivation)$$

Utilizing the OPSTAT software for Windows, *version* 1.0, statistical analysis was performed. Data obtained during the experiment was analyzed using normal statistical techniques. Microsoft Excel was used for statistical analysis, and the analysis of variance method was used to calculate the data [10]. To evaluate whether there was a significant difference between the treatments, the Critical Difference (CD) at the 5% level was utilized.

RESULTS AND DISCUSSION

Qualitative parameters of sprouting broccoli

Effect of integrated nutrient management on the qualitative parameters of sprouting broccoli revealed significant effects of various treatments could be recorded after harvesting in a laboratory during both years of the study. The qualitative parameters of sprouting broccoli, including total soluble solids content (°Brix), ascorbic acid content (mg/100 g), reducing sugars content (%), non-reducing sugars content (%), and total sucralose content, were measured. The data showed that the maximum amount of total soluble solids in the case of T_8 (vermicompost@ 5 tons/ha+*Azotobacter*@ 2 kg/ha) was 8.65°Brix. Total soluble solids content was lowest in the control group at 5.65°Brix, while ascorbic acid content was highest when vermicompost @ 5 t/ha+*Azotobacter*@ 2 kg/ha was applied (T_8).

In the case of the control, the vitamin C level was at least 78.42 mg/100 g (T_0). According to a study on vitamin C content, the amount of ascorbic acid in the cranium considerably dropped when more nutrients were consumed.

More vegetative development results in a larger surface area for photosynthesis and transpiration, which causes water to move upward from the root zones to the top regions of the plants and decreased vitamin-C concentration at higher nutritional levels.

According to Upadhyay et al., [11] organically maintained crops typically have higher vitamin-C levels than conventionally fertilized crops.

Maximum value of non-reducing sugar 0.80% in case of T_8 (application of vermicompost@ 5 t/ha+*Azotobacter*), minimum value of non-reducing sugar 0.37% in case of control (T_0), maximum value of reducing sugar 3.59% in case of T_8 (application of vermicompost@ 5 tons/ha+*Azotobacter*@ 2 kg/ha), maximum value of reducing sugar 1.23% in case of control (T_0), and both of these values were measured in terms of (T_0). Furthermore, T_8 (vermicompost@ 5 tons/ha+*Azotobacter*@ 2 kg/ha) has a maximum total sugar content of 4.04%. In the case of the control, the minimum amount of total sugar was 1.74 percent (T_0). These conclusions are quite similar to those made by Raghav and Kamal [12], Yadav et al., [13], Sharma et al., [14], and Tiwari et al., [15]. Highest concentration of T.S.S. (10.15°Brix), titratable acidity (0.49%), and vitamin-C (82.11 mg/100 g). Similar to this, treatment T_{11} had the lowest concentration of sugars (T_0) and the greatest total sugar (3.16%), reducing sugar (2.75%), and non-reducing sugar (0.43%) in control.

These result corroborated with the findings of Meena et al., [5] in broccoli and Qureshi et al., [16] in kale. Not only higher production but also the high quality produce is essential for healthy and wholesome living.

In general, appropriate crop nutrition regulates the quality of the produce. When the most organic manures were used, highest amounts of ascorbic acid, reducing sugar, and total sugar were produced when different nutrients were administered. When organic manures like vermicompost and farmyard manure were combined with bio fertilizers, the highest concentrations of these quality metrics were detected. However, 100% NPK treatments using biofertilizers and organic manures also maintained their parity with those using only organic manures. In the presence of biofertilizers, the application of only organic manures facilitated the availability of several nutrients that aid in the development of ascorbic acid and sugars (reducing and total sugar), consequently enhancing the quality of the head. The results corroborate the findings of Chatterjee et al., [17] and Raghav and Kamal [12] in broccoli.

Economic parameters of sprouting broccoli

The effect of integrated nutrient management on economic parameters of sprouting broccoli showed significant effects of different treatments could be recorded after harvesting during both years on the basis of pooled data revealed that economic parameters of sprouting broccoli *viz*. gross returns (Rs/ha), net returns (Rs/ha), and total returns (Rs/ha) could be recorded after harvesting during both years. With the application of 100% RDF+vermicompost@ 5 tons/ha+*Azotobacter*@ 2 kg/ha, the maximum total cost of cultivation (Rs. 6,3819/ha), the maximum gross return (Rs. 1,58,941.5/ha), and the greatest net profit (Rs. 9,9323.5/ha) were recorded, resulting in the maximum benefit cost ratio (2.66). Since sprouting broccoli is a heavy feeder crop that responds well to nutrient management and has a high cultivation cost, proper management strategies were necessary to produce better results. Cost economics calculations are required in order to come to a reliable conclusion. Singh and Singh et al., [18], Sharma et al., [14], Srichandan et al., [19], and others have all reported similar findings. A higher uptake of nutrients by the crop under various treatments that were impacted by integrated nutrient management strategies led to higher recoveries. Not only do optimal nutrient dosages outperform poor doses, but also single integration of bio inoculants outperforms single application of organic manures, and primarily integration of bio inoculant and organic manures with inorganic nutrients increases nutrient recoveries. Integrated nutrient management practices not only yielded higher with quality produce but also generated sizable income from the crop (Rs.168047 profit/ha for an investment of Rs 41188/ha with benefit: cost ratio of 5.08:1) [20-26].

CONCLUSION

On the basis of results, it may be concluded that integrating several organic nutrients and biofertilizers *viz*. Farm yard manure, Vermicompost and *Azotobactor* with inorganic fertilizers, higher yield and quality traits improvement in sprouting broccoli is achievable such treatments not only reduce the application of nitrogen but also proved profitable by giving cost: benefit ratio of more than 2.0. From the study, it was found that application of Vermicompost@ 5 tons/ha+*Azotobactor*@ 2 kg/ha being cheap and readily available at farm, reduced input cost of all the treatments and maximized net profits. Since maximum cost: benefit ratio of 2:66 was obtained in T_8 (Vermicompost@ 5tons/ha+*Azotobactor*@ 2 kg/ha), hence it can be recommended to the farmers of the region for successful cultivation of sprouting broccoli under Central Uttar Pradesh conditions.

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