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Effect of Nano Fertilizer on Growth, Yield and Quality of Broccoli (*Brassica oleracea* var. italica)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The experiment was conducted in the Horticulture Research Farm, Department of Horticulture, Naini Agricultural Institute, Sam Higgin bottom, University of Agriculture, Technology and Sciences, Prayagraj (UP) during October 2021 to february 2022. The experiment was laid out in randomized block design (R.B.D.) with 10 treatments with 3 replications. From the observations it was found that T_2 (Soil application of 50% recommended dose of fertilizers as conventional fertilizer + 50% recommended dose of nano N as foliar application nano P&K as soil application) had the best impact on the growth and yield and quality parameters like plant height 65.27 cm, number of leaves per plant 27.14, leaf length 55cm, leaf width 21.83cm, leaf area at harvesting stage 725.00 cm^2, days to head initiation 45.42 days, days to harvest 55.67, head diameter 21.16cm, head weight 461.47 gm, head yield per plot 2.77 Kg, head yield per hectare16.95t, TSS 9.76 Brix. The highest cost benefit ratio 3.55 was also observed in T_2.

Keywords: Broccoli; nano fertilizer; brassicaceae.

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1. INTRODUCTION

Broccoli (*Brassica oleracea* L. var. italica) is a cool season vegetable of family Braassicaceae. Broccoli commonly known as Hari Gobi in Hindi. It was a rare Cole crop in India but now it is gaining popularity. In the world market about 40 percent is marketed as fresh and remaining 60 percent as frozen. Since the time of the Roman Empire, broccoli has been considered a uniquely valuable food among Italians. Broccoli was brought to England from Antwerp in the mid-18th century by Peter Scheemakers. Broccoli was first introduced to the United States by Southern Italian immigrants [1], but did not become widely popular until the 1920s. In India the cultivation of broccoli was initially restricted to hill areas of Jammu and Kashmir, Himachal Pradesh and Uttar Pradesh but now is successfully grown under North Indian plain conditions. It is classified into two types, heading and sprouting. Sprouting broccoli is more popular in India. Broccoli is a rich source of vitamins, minerals, proteins etc. It has about 130 times higher content of Vitamin A than cauliflower and 22 times more than cabbage. The nutritive value of broccoli per 100g is moisture 89.3 g, energy 141 kg, carbohydrates 6.64 g, sugar 1.7 g, dietary fibber 2.6 g, fat 0.37 g, protein 2.82 g, calcium 47 mg, iron 0.73 mg, phosphorous 66 mg, thiamine 0.071 mg, riboflavin 0.117 mg, niacin 0.639 mg, vit C 89.2 mg [2]. Broccoli has anticarcinogenic properties and reduce the risk of prostate cancer by up to 45 percent.

The use of excess of chemical fertilizer for increasing crop yield causes serious environmental problems, (for e.g. eutrophication of waters [3], loss of biodiversity, global warming and stratospheric ozone depletion), soil and plant health problems as some fertilizers also contains heavy metals, excess use of which leads fertilizer to enter the food chain via absorption from soil. Thus, fertilization often leads to water, soil and air pollution and it has been observed that the soil fertility is declined. Unscientific application of conventional chemical fertilizer leads to deterioration of ground water quality increases the salinity of the soil, reduce profit margins, induce deficiency of other elements, interfere with metabolic processes and restrict yield and quality of broccoli.

Nano fertilizers are synthesized or modified form of traditional fertilizers, fertilizers bulk materials or extracted from different vegetative or reproductive parts of the plant by different chemical, physical, mechanical or biological methods with the help of nanotechnology and are used to improve soil fertility, productivity and quality of agricultural produce. Nano fertilizers are being prepared by encapsulating plant nutrients into nanomaterials, employing thin coating of nanomaterials on plant nutrients, and delivering in the form of nano-sized emulsions. Nanotechnology refers to the application of molecules and compounds whose size does not exceed 100 nm [4]. This technique depends on reducing the particle to a size equal to one billionth of a meter (10-9 m) and then using the new material. The nano fertilizer allows incorporating nutrients onto a nano dimensional adsorbent. Therefore, this approach leads to the controlled release of active ingredients for a long time and prevents the leaching of nutrients into groundwater, thus reducing the amount of fertilizer used [5]. It is estimated that the amount of nano formulations needed for plants is only equivalent to 20% of conventional fertilizers [6]. Nanotechnology is a new perspective of precision farming, which maximizes the output from crops while minimizing the inputs such as fertilizers, pesticides, fungicides and herbicides.

Plant nutrition is one of the most important factors that increase plant production. Usage of nano fertilizer might enhance the production by increasing the yield by target specific action, with proper nutrient use efficiency [7,8] etc. and also application of it will not harm the soil health and also minimize the pollution hazard. Nano fertilizers, which have the greater role in enhancing crop production this will reduce the cost of fertilizer for crop production. However, very scarce information is reported regarding the effect of Nano fertilizers. Therefore, the aim of this work was to study about the effect of nano fertilizers on growth, yield and quality of Broccoli (*Brassica oleracea* var. italica).

2. MATERIALS AND METHODS

The experiment was conducted at Experimental Research Field, Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology & Sciences, Prayagraj (UP) during 2021-2022 during Rabi season in India.

The experiment material consists of Broccoli F_1, Hybrid Green Magic The soil of the experiment field was alkaline, sandy loam and pH of 7.2. The experiment was laid out in randomized block design with three replications consisting of 10

treatments. Broccoli was planted in the field at a spacing of 0.45 x 0.60 m in plot of 1m x 2m size. The observation were recorded for leaf length (cm), leaf width(cm), plant height(cm), days taken to head initiation, Days for harvest, head weight(gm), head yield per plot (kg), head yield per hectare (tonnes), head diameter (cm), TSS (total soluble solids) (^{0}Brix), Vitamin C content (mg/100 gm).

2.1 Statistical Analysis

The data were analysed in randomized block design as per procedure of Cochran and Cox (1959). Interpretation of results was made on the basis of "F" test and critical difference at 0.05 probability calculated to compare the treatments.

2.2 Source of Fertilizers

2.2.1 Nano fertilizer

Nano N: IFFCO: It contains 4.0% total nitrogen (w/v) evenly dispersed in water. Nano nitrogen particles size varies from 20-50 nm.

Nano P: Tropical Agro: Nano Phos is an innovative, first of its kind product that combines gluconated phosphorus fertilizer and Indian Council of Agricultural Research (ICAR) '4G' Nano nutrient technologies.Tag Nano Phos is a unique proteino-lacto-gluconate formulation that helps to prevent and correct Phosphorus deficiency in the cultivated crops.

Nano K: Tropical Agro: The given product is precisely formulated using acids and 4G Nano nutrient technology. Nano Potash is a unique proteino-lacto-gluconate formulation, formulated with organic acids based chelated Potash, vitamins and probiotics.

2.2.2 Conventional fertilizer

Source of Nitrogen: Urea (46% N)

Source of Phosphorus: Single Super Phosphate (SSP)- (16%P_2O_5)

Source of Potassium: Muriate of Potash (MOP) – (60% K_2O).

2.3 Application Dosage of Fertilizer

(Recommended N: P: K dosage for Broccoli: 120:80:80 kg/ha). (PAU 2021)

RDF of Nano Liquid formulation (NPK): 4 ml/lit. (Recommended by IFFCO)

RDF of Nano Granular formulation (P&K): 15 - 20 Kg / acre. (Recommended by Tropical Agro).

Treatment details:

Treatment	Conventional fertilizer	Nano fertilizer	
		Foliar application	Soil application
T_1	75%NPK	25%N	25%PK
T_2	50%NPK	50%N	50%PK
T_3	25%NPK	75%N	75%PK
T_4	75%NPK	25%NPK	-
T_5	50%NPK	50%NPK	-
T_6	25%NPK	75%NPK	-
T_7	100%NPK	-	-
T_8	-	100%N	100%PK
T_9	-	100%NPK	-
T_{10}	-	-	-

3. RESULTS AND DISCUSSION

3.1 Growth Attributes

The maximum plant height (27.95) at 20 DAT (days after transplanting) was found in T_2 and minimum (21.29 cm) was found in T_{10} (Absolute control). The maximum plant height (55.00 cm) at 40 DAT was found in T_2, followed by T_5 (54.76cm) and T_1 (53.62 cm) which are also statistically at par value while the minimum(42.67 cm) was found in T_{10}. At 60 DAT, the highest plant height was found in T_2 (65.27 cm), followed by T_5 (64.40 cm) while the minimum (48.67 cm) was found in T_{10}.

The maximum Number of leaves (10.8) at 20 DAT was found in T_2, followed by T_5 (10.63) and T_1(10.43) which are also statistically at par value while minimum was found in T_{10} (Absolute control) which was 7.31. The maximum Number of leaves (17.14) at 40 DAT was found in T_2, followed by T_5 (16.11) which are also statistically at par value while the minimum (13.91) was found in T_{10}. At 60 DAT, the maximum number of leaves (65.27) was found in T2 and the minimum was found in T_{10} (48.67).

The maximum leaf width (10.8 cm) at 20 DAT was found in T_2, followed by T_5 (10.63 cm) and T_1 (10.43 cm) which are also statistically at par value while minimum (7.31 cm) was found in T_{10}. The maximum leaf width at 40 DAT was found in T_2 (17.14 cm), followed by T_5 (16.11 cm) and the minimum (12.83 cm) was found in T_{10}. The maximum Leaf Width (21.83) at 60 DAT was found in T_2, followed by T_5 (21.66 cm) and the minimum leaf width (19.23 cm) was found in T_{10}.

The maximum Leaf length at 20 DAT was found in T_2 (18.16) followed by T_5 (18.06), and minimum leaf Length was found in T_{10} (16.46). The maximum Leaf length at 40 DAT was found in T_2 (35.00) followed by T_5 (34.81 cm) and the minimum was found in T_{10} (31.90cm). At 60 DAT, the maximum leaf length was found in T_2 (55 cm) followed by T_5 (52.1) and the minimum leaf length (39.19cm) was found in T_{10}.

The Maximum Leaf area at harvest was found in T_2 (725.00$cm^{2)}$ and minimum leaf area at harvest (546.39 cm^2) was found in T_{10} (Absolute control).

The Minimum days to head initiation (45.42) was found in T_2 followed by T_5 (49.15 days). While the maximum Days to Head initiation was found in T_{10} (59). The minimum Days to Harvest (55.67) was found in T_2. And maximum Days to Harvest (72.00) was found in T_{10}.

Nano-fertilizer helps in building larger cells, as well as an increase in the number of cells, and then an increase in the general growth of the plant, which is an indication of increased vegetative growth. In addition to the efficient absorption and permeability of the nano-fertilizer into the plant tissues through the stomata holes, whose ions size are smaller than the diameter of the stomata and cell wall holes. In addition of the fertilizer recommendation and its effect on providing the plant with important nutrients, including nitrogen, which is important in amino acids and proteins formation, cell division and elongation (Hakim et al. [9]. The presence of nitrogen in the available form leads to early growth, it promotes absorption of other nutrients including potassium and phosphorus and promotes total plant growth [10,11] (Hemerly, 2016). as well as potassium, which is important in the formation of important enzymes for growth (Mirsa et al. [12]), and finally phosphorous, which is important in the formation of energy compounds, thus increasing vegetative growth.

Kanjana et al. [13] reported that nano fertilizers increased the plant height at square formation (45 days after sowing) and harvest stage of the crop than normal source of micronutrients and control. Also similar results were obtained in the findings of Sohair et al. [14], showed that significant increase in the sympodial branches was achieved with the application of 50% RFD of nano NPK fertilizers. Significant increase in the height of the plant and the highest increase is has been achieved when the fertigation of the combination of nano NPK fertilizers (53.43 cm) and the traditional fertilizer NPK of (44.33 cm) compared with the comparison treatment, good potato productivity can be achieved through the adoption of fertigation combined with nano N, P and K fertilizers and good irrigation management using dripping irrigation according to the study conducted by Hayyawi et al. [15]. Nofal et al. [16] found that plant fresh weight, leaf area, head fresh weight and head size of lettuce significantly increased by the application of nano N, P and K fertilizers. Moreover, the highest obtained values were recorded with nano nitrogen at the rate of 50% compared to other nano treatments and NPK conventional fertilizers (control). Abdel Aziz et al. [17] found that nano NPK increased the growth of leaves in wheat,which was obtained by enhanced availability of nutrients by easy penetration of nanoformulation of NPK through stomata of leaves via gas uptake.

3.2 Yield Attributes

Statically at par value and minimum head diameter was found in T_{10} (14.16). The maximum head weight (461.47gm) was found in T_2 followed by T_5 (453.51) which is statically at par value and minimum head weight was found in T_{10} (210.55).

The maximum Head Yield per plot (2.77kg) was found in T_2 followed by T_5 (2.72) and minimum Head yield per plot was found in T_{10} (1.26kg) respectively. The maximum Head Yield per hectare was found in T_2 (16.95 t) followed by T_5 (16.6 t), and minimum Head yield per hectare was found in T_{10} (7.68 t).

Table 1. Effect of Nano Fertilizer on growth traits of broccoli

Treatment no	Plant height (cm)	Number of leaves per plant	Leaf width (cm)	Leaf length (cm)	Leaf area at harvest (cm^2)	Days for head initiation	Days for harvest
T_1	62.97	26.01	21.03	52.00	700.14	45.42	55.67
T_2	65.27	27.14	21.83	55.00	725.00	41.77	52.67
T_3	58.80	25.59	20.70	47.45	630.98	48.44	60.67
T_4	62.10	25.90	20.86	50.33	634.82	48.33	60.00
T_5	64.40	26.11	21.66	52.10	702.00	43.75	53.00
T_6	54.26	25.48	20.5	47.44	621.53	48.77	62.00
T_7	53.91	25.33	20.26	46.17	600.01	49.15	62.33
T_8	53.73	24.77	20.23	43.96	593.25	51.1	62.67
T_9	50.53	24.63	19.26	43.35	560.28	52.33	63.00
T_{10}	48.67	24.27	19.23	39.19	546.39	55	65.00
F-Test	S	S	S	S	S	S	S
S.Ed.	1.97	0.47	1.58	1.58	0.31	4.59	1.90
C.D. at 0.5	4.10	0.98	3.28	3.28	2.08	3.13	3.95
CV	5.06	2.72	4.88	4.88	4.78	4.59	4.70

Table 2. Effect of Nano fertilizer on yield and quality traits of broccoli

Treatment no	Yield traits				Quality traits	
	Head Diameter (cm)	Head weight (gm)	Head yield per plot(Kg)	Head yield tones/ha	TSS(^{0}Brix)	Vitamin –C Content (mg/100gm)
T_1	20.33	430.22	2.58	15.84	9.26	97.66
T_2	21.16	461.47	2.77	16.95	9.76	102.66
T_3	19.13	400.44	2.40	14.71	8.63	92.28
T_4	19.9	421.98	2.53	15.5	8.84	92.51
T_5	21.03	453.51	2.72	16.66	9.47	101.5
T_6	18.56	392.99	2.36	14.45	8.06	86.44
T_7	18.16	373.51	2.24	13.72	7.95	86.12
T_8	17.6	350.24	2.10	12.81	7.82	78.68
T_9	15.66	320.12	1.92	11.75	7.63	78.36
T_{10}	14.16	210.55	1.26	7.68	7.6	76.04
F-Test	S	S	S	S	S	S
S.Ed.	0.44	8.07	0.04	0.29	0.29	1.72
C.D. at 0.5	0.91	16.74	0.10	0.62	0.60	3.57
CV	3.50	3.11	3.11	3.14	5.05	2.83

Nano fertilizers have higher transport and delivery of nutrients through plasmodesmata, which are nano sized (50–60 nm) channels between cells. The higher NUE (nutrient-use efficiency) and significantly lesser nutrient losses of nano fertilizers lead to higher productivity (6–17%) and nutritional quality of vegetable crops. The adequate amounts of nitrogen enhance photosynthesis, cell division and cell enlargement. The higher the leaf area the higher will be the photosynthetic surface, higher the photosynthetic surface and higher will be the photosynthetic accumulation hence resulting in higher yield (Shashidhara et al.) [18]. The maximum diameter, maximum leaf length and maximum leaf area of the cultivar and the translocation of the photosynthetic products to the fruit (sink) which is head (Singh et al., [19].). As well as potassium, which is important in the formation of important enzymes for growth, and finally phosphorous, which is important in the formation of energy compounds, thus increasing roots formation and increasing vegetative growth. Thus, it reflects positively on yield.

Abd El-Azeim et al. [20] observed the superiority of yield parameters following foliar application of nano fertilizers attributed to increased availability of nutrients by foliar application due to quick absorption of NPK nano fertilizers by stomatal

tissues. Also, nutrients uptake may have increased as a result of increased photosynthesis rate, fresh and dry weights of potato and consequently improved overall growth parameters of potato plants. Mishra et al. [21] observed in experiments carried in tomato using nano fertilizer, that the interaction between nanoparticle and fertilization resulted in increased concentrations of nitrogen and phosphorous elements in the fruits. Therefore, this reflected positively on the increase in growth and yield, and the improvement of overall production and quality. In study conducted by Helaly et al. [22] it was found that the high rate of nano nitrogen (50%) significantly increased the vegetative growth expressed as plant fresh weight, leaf area head fresh weight, head size, firmness, total yield and marketable yield.

3.3 Quality Attribute

The maximum TSS Brix (9.76) was found in $_{T2}$ followed by $_{T5}$ (9.47) and minimum TSS Brix was found in $_{T10}$ (Absolute control) which was 7.6. The maximum Vitamin C Content (mg / 100 g) was found in $_{T2}$ (102.66) followed by T_5 (101.5) and minimum Vitamin C Content (mg / 100 g) was found in $_{T10}$ (76.04).

TSS Increased due to increased chlorophyll and photosynthesis. Likewise, increasing firmness could be associated to superior accumulation of some osmoles and increase potassium concentrations in cells. Abdel et al. [23] observed the positive effect of nano fertilizers NPK on chemical composition of plant yield such as total soluble solids (T.S.S), dry matter, may be attributed to the presence of macro nutrients suggesting that nano-engineered N, P, K fertilizers appeared to enhance the uptake and use efficiency of nutrients by plants. Nano fertilizers has a main role in sugars accumulate in fruit tissues leading to increase TSS. The result observed in experiment carried out by Aman et al. [24] revealed that spray treatment with a concentration of 1.5 ml L^{-1} nano NPK was superior in increasing the chlorophyll content, TSS. Increased potassium fertilization markedly increased Vitamin C content (Nagy [25]). Abdel Aziz et al. observed the positive effect of nano fertilizers NPK on chemical composition of lettuce plants such as ascorbic acid, sugars, phosphorus and potassium content may be attributed to the presence of macro nutrients suggesting that nano-engineered N, P, K fertilizers appeared to enhance the uptake and use efficiency of nutrients by plants.

The study revealed that among the 10 treatment combinations, T_2 gave better yield. This might be due the fact that the basal dose fertilizer requirement of the broccoli plant was met with the supply of conventional fertilizer, this contributed to the vigor growth of the plant initially and the requirement of the nutrients at later stages were met with the application of nano fertilizers. With high nutrient use efficiency nano fertilizer was able to enhance the later growth of the plant development effectively. The nanostructured formulation with nano N particle having size varying from 20-50nm can easily penetrate into the stomatal pores and augment the nutrient absorption and stored in plasmodesmata. Also, with the soil application of nano P&K fertilizer the nutrients are released into the soil in a controlled and gradual manner which enhance better nutrient supply to the plant, also the microbial population and enzyme activity in the soil might have increased due to the reduced impact of the nano fertilizers to the soil.

Table 3.

Treatments	Cost of Cultivation (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	B:C Ratio
T_1	1,15,784	396000	2,80,216	3.42
T_2	1,19,162	423750	3,04,589	3.55
T_3	1,22,538	367750	2,45,212	3.00
T4	1,17,269	387500	2,70,231	3.30
T_5	1,22,094	416500	2,94,407	3.41
T_6	1,25,688	361250	2,35,562	2.87
T_7	1,11,055	343000	2,31,945	3.08
T_8	1,25,916	320250	1,94,334	2.54
T_9	1,31,780	293750	1,61,970	2.22
T_{10}	1,07,000	192000	85,000	1.79

3.4 Economics

The maximum cost of Rs. 1,31,780/ha was incurred in T_9. Whereas the minimum cost of Rs. 1,07,000 was incurred in $T_{10.}$ Highest gross income of Rs. 4,23,750/ha were obtained in T_2, whereas the lowest of Rs. 1,92,000/ha were obtained in T_{10}. Similarly, highest net return of Rs.3,04,589/ha were obtained in T_2, and the minimum Rs. 85,000/ha were obtained in T_{10}. Highest B:C ratio (3.55) was observed in T_2 and the minimum B:C ratio (1.79) was observed in T_{10}.

4. CONCLUSION

Based on the result of experiment, it can be concluded that T2 - Soil application of 50% RDF as Traditional fertilizer + 50% recommended dose of Nano N as foliar application, P&K as soil application was recorded the best among all combinations of Traditional fertilizer NPK and Nano NPK in term of growth, yield attribute and quality parameters and highest benefit cost ratio (3.55) was also recorded in T2.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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