https://doi.org/ 10.48047/AFJBS.6.5.2024.7715-7733

African Journal of Biological Sciences

Effect of Nano and non-Nano NPK Fertilizers on growth, Yield and Quality of Broccoli (*Brassica oleracea* var. Italica) Grown under Covered and Un Covered Conditions.

SANAA M.S. RASHEED
Sanaa.rasheed@uod.ac
Dept. of Horticulture, College of Agricultural Engineering Sciences, University of Duhok, Kurdistan Region-Iraq

Article History
Volume 6, Issue 5, 2024
Received: 15 Apr 2024
Accepted: 09 May 2024
Published : 05 Jun 2024
doi: *10.48047/AFJBS.6.5.2024 7715-7733*

Abstract

This study included the effects of two planting methods (plastic house and open field) or (covered and uncovered) conditions, three levels of nano NPK fertilizer (approximately 0, 3, 6 $g.l^{-1}$) and three levels of non-nano NPK fertilizer(0, 3, 6 $g.l^{-1}$) were included in this trial (2x3x3=18) with three replicate experimental units (54). Nano and non-nano NPK fertilizers sprayed plants after a week from transplanting and other spraying are donetwo times with an interval of 15 days between each spray. The results showed that the covered method was superior in terms of characteristics such as plant height to(64.54cm), leaf area (647.91cm^2), head weight (682.22 g), total yield (40.02 $t.ha^{-1}$ compared with uncovered method . whereas, theuncovered method showed better results for number of leaves to (22.22leaf $plant^{-1}$) and vitamin C (36.15) . In particular, nano-fertilizer at a concentration of 6 $g.l^{-1}$ significantly increased most of parameters number of leaves to (20.61leaf $plant^{-1}$), leaf area (612.66 cm), head weight (698.89 g), total yield (41.00 $t.ha^{-1}$, head diameter (32.94 cm) vitamin C (35.83) phenol content (0.83 %) fiber content (2.51%) nitrogen, phosphorus and potassium (1.994-0.861- and 1.317%) compared with control. However, significant impact of non-Nano NPK on the parameters and only the traits higher plant (62.90 cm), head diameter (35.89 cm) vitamin C (35.89) fiber content (2.13%)andnitrogen content (1.972%) compared to the control.

Key word:- Broccoli, Nano fertilizers, NPK, planting Conditions.

Introduction

Broccoli (*Brassica oleracea* var. Italica) is an edible green plant of the family Brassicaceae, with a large head eaten as a vegetable, it is found in nature along the Mediterranean Sea **(Dev, 2012)**. Its economic value increases every year **(Francisco *et al.*, 2017)**. Its flowers and buds are the parts that are consumed, while the stems and leaves are wasted after harvest **(Li *et al*., 2022a)**. Growing broccoli has a number of benefits for human health due to its high content of bioactive compounds (e.g. minerals, vitamins, fiber, glucosinolates and phenolic compounds), while also providing found anti-cancer effects **(Li *et al*,. 2022b)**.

Protected farming is the only way to increase fruit and vegetable production. Productivity and output of vegetables, fruits, and flowers are strongly affected by climatic conditions. Heavy rain, excessive solar radiation, temperature and humidity are limitations of growing vegetables in the field **(Max *et al.*, 2009)**.On occasion crop are completely vanished by external thing that could not be controlled in open area. It can be optimized thru blanketed cultivation. Insect and pest attack could be reduced in included systems which improved crop growth parameters and yield **(Prado *et al.*, 2008)**. Growing flowers constantly, without crop rotation or interruption in production as in open area manufacturing during winters, can lead to an excessive buildup of soil pathogens. for this reason, the greenhouse has developed into extra than a plant protector. **Ayas *et al.*, (2011)** found a sizeable effect structure on yield, head height; head diameter, head weight and dry rely of broccoli plant below unheated greenhouse conditions. **Karistsapol*et al.*, (2013)**, found out that the color-internet residence, improved the seedling survival, plant height and plant width, head diameter, head weight and yield of broccoli which become considerably better than complete daylight.Research by **Demchak& Smith (1990)**, highlighted the significant role of phosphorus in enhancing broccoli yield, while potassium levels also play a vital role in regulating physiological processes and ultimately affecting the growth and productivity of broccoli, as indicated by **Zaki *et al.* (2015)**.**Ying *et al.* (1997)**found that potassium played a crucial role in the yield and dry weight of broccoli. On the other hand, **Fernãndez*et al.* (2018)** discovered that using chemical fertilizers with a composition of 60 kg N, 40 kg P, and 55 kg K per hectare resulted in significantly higher total broccoli yield compared to other fertilization levels studied.

Nano fertilizers are the important tools in agriculture to improve crop growth, yield and quality parameters with increase nutrient use efficiency, reduce wastage of fertilizers and cost of cultivation. Nano fertilizers provide more surface area for different metabolic reactions in the plant which increase rate of photosynthesis and produce more dry matter and yield of the crop **(Shilpa*et al.*, 2022)**. The uptake, distribution, and accumulation of nano fertilizers in crops depend on a number of parameters, and these factors greatly depend on both internal and extrinsic factors as well as the exposure route. The two most significant inherent elements influencing the effectiveness of nanoparticle applications are particle size and surface coating **(Zulfiqar*et al.*, 2019)**. **Ajirloo*et al.*, (2015)** showed that spraying tomato plants with nano NPK fertilizers improved the quantity of fruits, weight, diameter of fruits, plant height, and stem diameterHence, the present study was conducted to examine the impact of Nano and non-Nano NPK on the growth and yield quality of broccoli (*Brassica oleracea* L. var. italica) under covered and uncovered conditions.

Material& Methods

The study was conducted in the agricultural research farm (field) and plastic house (500m^2) at the College of Agricultural Engineering Sciences, University of Dohuk, Kurdistan, Iraq, during the growing season of 2021. The seeds were planted on August 20 in a greenhouse using cell plastic trays, with two seeds in each cell. All required cultural practices were implemented. The field and plastic house were properly plowed and leveled with a rotavator, and divided into rows with a spacing of 70 cm. Prior to planting, a drip irrigation system was installed.Transplanting process to the permanent field and plastic house started on September 20, with 40cm space part among plants in the same row, Agricultural practices such as weed control, Irrigation, fertilization and pest management were conducted uniformly.The experiment comprised the effect of two planting methods (plastic house and open field) or(Covered and an covered) conditions, three level of Nano NPK fertilizers (o, 3, 6 $g.l^{-1}$) and three level of non-Nano NPK fertilizers (0, 3, 6 $g.l^{-1}$) treatments were included in this trial (2×3×3=18) with three replications (54) experimental units. After a week days from seed transplanting, the initial application of two types of fertilizers was carried out. Following this, the second spray was conducted after a fifteen-day interval from the first spray. Subsequently, the third spray was administered after another fifteen days from the second spray. All sprays were conducted early in the morning. Plants were fertilized weekly through the dripsystem withcalcium nitrate and potassium nitrate and the total amount of N and Kapplied after transplanting was 110 kg ha^{-1} of each. The treatments were arranged in a split-split plot with three replications.The two planting methods (covered and uncovered) were placed in the main plots and the sub-plots were allocated to the three level of non-Nano NPK (0, 3, 6 $g.l^{-1}$) and the Nano NPK (0, 3,6, $g.l^{-1}$) in sub -sub plots and randomly arranged in a factorial experiment in a Randomized Complete Block Design (R.C.B.D.) (Al-Rawi and Khalafallah, 1980). The means were compared using the Duncan multiple rang test at a significance level of $P \leq 0.05$. Data analysis was conducted using SAS software (SAS, 2010). Five plants were randomly selected from each plot to serve as samples for vegetative, yield, and qualitative parameters. Parameters such as plant height (cm), number of leaves per plant, leaf area (cm^2), head weight (g), total yield (ton/ha), head diameter (cm), vitamin C content in curd (%), fiber content (%), nitrogen (N%), phosphorus (P%), potassium (K%), and total phenols (mg/g dry weight) were estimated following the method outlined by **Singleton & Rossi (1965)** and modified by **Gregorio *et al.*, (2020)**.

Results and Discussion

Growth Attributes

The data in (Table 1,2&3), explains that the planting conditions had a significant influence on plant high, No. of leaves and leaf area. Covered method had the highest results of plant high and leaf area which were (64.54cm and 647.91cm^2) respectively, whileuncovered methods was higher No. of leaves per plant (22.22leaf.plant^{-1}). The Non nano NPK had significantlyaffectedon growth characters, and the highest results (62.90cm plant high) had occurred in (3g.l^{-1}) non Nano fertilizer and no differs with control, But no significant effects on No. of leaves and leaf area. Nano NPK had no significant effects on characters plant high cm, but significantly increased the No. of leaves and leaf area and the highest value (20.61 leaf.plant^{-1} and 612.66 cm^2 leaf area) as compared to other treatments. As the dual interaction between treatments had significant effects on growth characters as shown in table (1,2 and 3). In the triple interaction among treatments also Significant differences were observed, the interaction among covered methods, 3g.l^{-1} non Nano fertilizers and 3g.l^{-1} Nano fertilizers had highest plant high (65.87cm), the highest No. of leaves .plant^{-1} (24.00 leaf.plant^{-1}) occurred in the interaction among un-covered methods, 3,6g.l^{-1} non Nano fertilizers and 6g.l^{-1} Nano fertilizers respectively as compared to others interaction treatments.

Table(1): Effect of Planting conditions, Non Nano, Nano NPK fertilizers and their interaction on plant high (cm) of Broccoli plant.

Planting conditions	Nano NPK g.l^{-1}	Non Nano NPK g.l^{-1}			Plantingconditions *Nano NPK	Planting conditions
		0	3	6		
Covered	0	65.10ab	64.43bc	63.67c	64.40ab	64.54a
	3	64.70abc	65.87a	64.42bc	64.99a	
	6	63.65c	64.70abc	64.30bc	64.22b	
Uncovered	0	60.77e	61.32de	60.43e	60.84c	60.22b
	3	62.27d	60.47e	55.07f	59.27d	
	6	60.77e	60.61e	60.23e	60.54c	
Non Nano NPK g.l^{-1}		62.88a	62.90a	61.35b	Nano NPK g.l^{-1}	
Plantingconditions *Non Nano NPK	Covered	64.48ab	65.00a	64.13b		
	Uncovered	61.27c	60.80c	58.58d		
Nano NPK * Non Nano NPK	0	62.93abc	62.87abc	62.05c	0	62.62a
	3	63.48a	63.17ab	59.75d	3	62.13a
	6	62.21bc	62.66abc	62.27bc	6	62.38a

*Means with same letter for each interaction are not significantly different at 5% level based on Duncan Multiple Rang Test.

Table(2): Effect of Planting conditions, Non Nano, Nano NPK fertilizers and their interaction on Number of leaves (No.plant^{-1}) of Broccoli plant.

Planting conditions	Nano NPK g.l^{-1}	Non Nano NPK g.l^{-1}			Planting conditions * Nano NPK	Planting conditions
		0	3	6		
Covered	0	16.33de	16.67de	15.33e	16.11e	16.67b
	3	16.33de	16.33de	16.67de	16.44e	
	6	17.67d	17.00de	17.67d	17.44d	
Uncovered	0	20.33c	20.67c	20.67c	20.56c	22.22a
	3	21.33bc	22.67ab	23.00a	22.33b	
	6	23.33a	24.00a	24.00a	23.78a	
Non Nano NPK g.l^{-1}		19.22a	19.56a	19.56a	Nano NPK g.l^{-1}	
Planting conditions * Non Nano NPK	Covered	16.78b	16.67b	16.56b		
	Uncovered	21.67a	22.44a	22.56a		
Nano NPK * Non Nano NPK	0	18.33e	18.67de	18.00e	0	18.33c
	3	18.83cde	19.50bcd	19.83abc	3	19.39b
	6	20.50ab	20.50ab	20.83a	6	20.61a

*Means with same letter for each interaction are not significantly different at 5% level based on Duncan Multiple Rang Test.

Table(3): Effect of Planting conditions, Non Nano, Nano NPK fertilizers and their interaction on leaf area (cm^2) of Broccoli plant.

Planting conditions	Nano NPK	Non Nano NPK $g.l^{-1}$			Planting conditions * Nano NPK	Planting conditions
		0	3	6		
Covered	0	663.87a	457.97b	663.83a	595.22ab	647.91a
	3	666.47a	673.27a	676.83a	672.19a	
	6	680.67a	670.30a	678.00a	676.32a	
Uncovered	0	448.10b	448.87b	455.70b	450.89d	496.71b
	3	455.90b	530.17ab	484.63b	490.23cd	
	6	545.63ab	545.17ab	556.20ab	549.00bc	
Non Nano NPK $g.l^{-1}$		576.77a	554.29a	585.87a	Nano NPK $g.l^{-1}$	
Planting conditions * Non Nano NPK	Covered	670.33a	600.51a	672.89a		
	Uncovered	483.21b	508.07b	498.84b		
Nano NPK * Non Nano NPK	0	555.98a	453.42b	559.77a	0	523.06b
	3	561.18a	601.72a	580.73a	3	581.21a
	6	613.15a	607.73a	617.10a	6	612.66a

*Means with same letter for each interaction are not significantly different at 5% level based on Duncan Multiple Rang Test.

The growth of plants can be significantly influenced by various structures such as poly houses, shade net houses, low tunnels, or raw covers, which create favorable climatic conditions. According to **Prado et al., (2008)**, plants cultivated under two or three layer shading nets exhibited early maturity, increased leaf count, and taller plants during heading and harvesting stages. Additionally, the utilization of plastic houses and naturally ventilated net-cum-poly houses in broccoli cultivation can lead to the production of taller plants, larger heads, and ultimately, earlier and higher yields **(Ayais*et al.*, 2011)**.The enhancing effect of nano-fertilizers on these studied parameters can be attributed to the fact that nano-fertilizer helps build larger cells and increases the number of cells and then increases the overall growth of the plant. , which is a sign of increased vegetative growth. In addition to the efficient absorption and permeability of nano-fertilizer into plant tissues through stomatal holes with ion sizes smaller than the diameter of stomatal and cell wall holes **(Eichert *et al*., 2008; Pérez-de-Luque, 2017)**. In addition, the recommendation of fertilizer and its effect on the plant's access to important nutrients, including nitrogen, which is important for the formation of amino acids and proteins, cell division and elongation **(Fadhil *et al*., 2021)**.Availability of available nitrogen leads to early growth, promotes the consumption of other nutrients including potassium and phosphorus, and promotes overall plant growth **(Bloom, 2015&Hemerly, 2016)** and potassium, which is important for plant establishment. Enzymes important for growth **(Mirza *et al.*, 2018)** and finally phosphorus important for the formation of energy compounds, which increases vegetative growth. **Kanjana (2020)** reported that nano-fertilizers increased the height of plants at square shape stage (45 DAS) and harvest stage as a common micronutrient source and control. Similar results were obtained from the findings of **(Sohair*et al.*, 2018)**.

Yield Attributes

Head weigh(g)

Through Tables (4,5 and 6), we note that the planting conditions significantly affected yield characters and the covered methods had the heist results of (head weight g, total yield $t.ha^{-1}$ and head diameter cm) than un-covered which was (682.22g, 40.02 $t.h^{-1}$ and 34.78cm) respectively. As the treatment of nano-fertilizer 6 $g.L^{-1}$ nano-fertilizer significantly affected most of the studied traits, including (head weight, total yield $t.h^{-1}$ and head diameter and had highest value (698.89g, 41.00 $t.h^{-1}$&32.94cm) respectively. Non Nano NPK had no significant effect on the head weight g and total yield $t.h^{-1}$,while significantly affected the head diameter cm, the $6g.l^{-1}$ non nano had the highest value (32.94cm) as compared to others.The results in same table, indicated that the interaction positively affected all the studied traits, the interaction among covered methods, 6 $g.l^{-1}$ nano NPK and control treatments had the highest results (head wight 790.00g and total yield 46.35 $t.h^{-1}$), while the interact among covered method, $6g.l^{-1}$ nano NPK and $6g.l^{-1}$ non nano NPK had the highest head diameter (35.67cm).

Table(4): Effect of Planting conditions, Non Nano, Nano NPK fertilizers and their interaction on Head Weight (g) of Broccoli plant.

Planting conditions	Nano NPK	Non Nano NPK g.l^{-1}			Planting conditions * Nano NPK	Planting conditions
		0	3	6		
Covered	0	625.00abc	646.67abc	610.00abc	627.22bc	682.22a
	3	661.67abc	733.33ab	533.33c	642.78b	
	6	790.00a	780.00a	760.00a	776.67a	
Uncovered	0	510.00c	536.67c	550.00bc	532.22c	594.44b
	3	626.67abc	653.33abc	610.00abc	630.00bc	
	6	600.00abc	646.67abc	616.67abc	621.11bc	
Non Nano NPK g.l^{-1}		635.56a	666.11a	613.33a	Nano NPK g.l^{-1}	
Planting conditions * Non Nano NPK	Covered	692.22ab	720.00a	634.44abc		
	Uncovered	578.89c	612.22cb	592.22cb		
Nano NPK * Non Nano NPK	0	567.50b	591.67ab	580.00b	0	579.72b
	3	644.17ab	693.33ab	571.67b	3	636.39ab
	6	695.00ab	713.33a	688.33ab	6	698.89a

*Means with same letter for each interaction are not significantly different at 5% level based on Duncan Multiple Rang Test.

Table(5): Effect of Planting Conditions, Non Nano, Nano NPK fertilizers and their interaction on Total yield (t.ha^{-1}) of Broccoli plant.

Planting conditions	Nano NPK	Non Nano NPK			Planting conditions * Nano NPK	Planting conditions
		0	3	6		
Plastic house	0	36.67abc	37.94abc	35.79abc	36.80bc	40.02a
	3	38.82abc	43.02ab	31.29c	37.71b	
	6	46.35a	45.76a	44.59a	45.56a	
Open field	0	29.92c	31.48c	32.27bc	31.22c	34.87b
	3	36.76abc	38.33abc	35.79abc	36.96bc	
	6	35.20abc	37.94abc	36.18abc	36.44bc	
Non Nano NPK		37.29a	39.08a	35.98a	Nano NPK	
Planting conditions * Non Nano NPK	Plastic house	40.61ab	42.24a	37.22abc		
	Open field	33.96c	35.92bc	34.74bc		
Nano NPK * Non Nano NPK	0	33.29b	34.71ab	34.03b	0	34.01b
	3	37.79ab	40.68ab	33.54b	3	37.33ab
	6	40.77ab	41.85a	40.38ab	6	41.00a

*Means with same letter for each interaction are not significantly different at 5% level based on Duncan Multiple Rang Test.

Table(6): Effect of Planting conditions, Non Nano, Nano NPK fertilizers and their interaction on head diameter (cm) of Broccoli plant.

Planting conditions	Nano NPK	Non Nano NPK 0	Non Nano NPK 3	Non Nano NPK 6	Planting conditions * Nano NPK	Planting conditions
Plastic house	0	34.67ab	33.00bc	35.00ab	34.22a	34.78a
	3	35.00ab	34.33ab	35.33ab	34.89a	
	6	35.00ab	35.00ab	35.67a	35.22a	
Open field	0	25.17g	27.17g	29.33def	27.22c	29.33b
	3	28.67ef	30.33de	31.33cd	30.11b	
	6	30.33de	30.67cde	31.00cde	30.67b	
Non Nano NPK		31.47b	31.75b	32.94a	Nano NPK	
Planting conditions * Non Nano NPK	Plastic house	34.89a	34.11a	35.33a		
	Open field	28.06c	29.39b	30.56b		
Nano NPK * Non Nano NPK	0	29.92b	30.08b	32.17a	0	30.72b
	3	31.83a	32.33a	33.33a	3	32.50a
	6	32.67a	32.83a	33.33a	6	32.94a

*Means with same letter for each interaction are not significantly different at 5% level based on Duncan Multiple Rang Test.

The broccoli was cultivated using covered methods to provide lower light intensity, lower temperature, and higher relative humidity compared to uncovered methods, which likely contributed to increased growth and yield. This study's findings align with **Kanthaswamy*et al.*, (2000)** research on the impact of planting methods on broccoli plants, showing that curd yield was higher in naturally ventilated poly houses compared to full sunlight. These results suggest that covered methods can be effective in shielding sensitive plants from adverse environmental conditions, in agreement with the current study. **Ayas*et al.*, (2011)** observed a notable impact on yield, head height, head diameter, head weight, and dry matter under unheated greenhouse conditions. **Thapa*et al.*, (2013)** similarly concluded that plants grown in poly houses outperformed those grown in open fields, with the highest quality marketable curd yield achieved in polyhouse conditions. **Thakur *et al.*,(2016)** found that curd yield, plant spread, and stem diameter were greater in a naturally ventilated poly house compared to an open field. **Yasoda*et al.*, (2017)**observed a significant impact on curd weight, curd diameter, and curd circumference of cauliflower grown under varying levels of shade.

Nano fertilizers facilitate the transport and delivery of nutrients through the nano-sized channels called plasmodesmata, leading to higher Nutrient Use Efficiency (NUE) and reduced nutrient losses. The increased efficiency leads to higher productivity (6-17%) and improved nutritional quality of vegetable crops **(Pérez-de-Luque, 2017)**. An optimal level of nitrogen enhances processes like photosynthesis, cell division, and cell enlargement. A larger leaf area results in more photosynthetic surface, leading to higher accumulation of photosynthetic and therefore higher yield **(Shashidhara, 2000)**. The maximum diameter, length, and area of leaves in a cultivar affect the translocation of photosynthetic products to the fruit, promoting head growth **(Singh, 2004)**. In addition, potassium is crucial for enzyme formation and phosphorous is essential for energy compound formation, both promoting root development and vegetative growth, ultimately impacting yield positively **(Abdel-Aziz *et al.*, 2016)**.

Quality Attribute

From Table (7, 8, 9, 10, 11&12) we notice that the covered methods significantly increased the vitamin C and N percent in curd, while no differences obtained in other characters. As theaddition ofnano-fertilizer significantly affected thepercentage of vitamin C, phenol, fiber and NPK in curd.Where the treatmentof 6 $g.L^{-1}$ nano fertilizer gave the best results inthe content of curd of vitamin C, phenol, fiber and NPK, which were (3583, 0.83, 2.51, 1.994, 0.861 and 1.317 %) respectively. The treatmentof 6 $g.L^{-1}$ of non-Nano fertilizer gave the bestsignificant positive effect on the content of curdof vitamin C (35.89%) and N% (1.972), while no significant effect on characters (phenols, P and K). The dual and triple interaction among all treatments significantly affected most of the studied traits, including (vitamin C, phenol, fiber and NPK %)in cured.

Table (7): Effect of Planting conditions, Non Nano, Nano NPK fertilizers and their interaction on vitamin C of Broccoli plant.

Planting conditions	Nano NPK	Non Nano NPK			Planting conditions * Nano NPK	Planting conditions
		0	3	6		
Plastic house	0	26.00k	28.33j	36.33b-e	30.22d	32.22b
	3	31.67hi	32.00hi	36.00cde	33.22c	
	6	32.33hi	34.67efg	32.67ghi	33.22c	
Open field	0	30.67i	33.33fgh	35.00def	33.00c	36.15a
	3	37.33a-d	37.33a-d	36.33b-e	37.00b	
	6	38.67ab	37.67abc	39.00a	38.44a	
Non Nano NPK		32.78c	33.89b	35.89a	Nano NPK	
Planting conditions * Non Nano NPK	Plastic house	30.00d	31.67c	35.00b		
	Open field	35.56ab	36.11ab	36.78a		
Nano NPK * Non Nano NPK	0	28.33c	30.83b	35.67a	0	31.61b
	3	34.50a	34.67a	36.17a	3	35.11a
	6	35.50a	36.17a	35.83a	6	35.83a

*Means with same letter for each interaction are not significantly different at 5% level based on Duncan Multiple Rang Test.

Table(8): Effect of Planting conditions, Non Nano, Nano NPK fertilizers and their interaction on Phenol % in curdof Broccoli plant.

Planting conditions	Nano NPK	Non Nano NPK			Planting conditions * Nano NPK	Planting conditions
		0	3	6		
Plastic house	0	0.63c	0.63c	0.73abc	0.67c	0.74a
	3	0.77abc	0.77abc	0.70bc	0.74bc	
	6	0.73abc	0.83ab	0.83ab	0.80ab	
Open field	0	0.63c	0.70ab	0.83ab	0.72bc	0.78a
	3	0.77abc	0.73abc	0.77abc	0.76bc	
	6	0.87ab	0.90a	0.80abc	0.86a	
Non Nano NPK		0.73a	0.76a	0.78a	Nano NPK	
Planting conditions * Non Nano NPK	Plastic house	0.71a	0.74a	0.76a		
	Open field	0.76a	0.78a	0.80a		
Nano NPK * Non Nano NPK	0	0.63d	0.67cd	0.78abc	0	0.69b
	3	0.77abc	0.75a-d	0.73bcd	3	0.75b
	6	0.80ab	0.87a	0.82ab	6	0.83a

*Means with same letter for each interaction are not significantly different at 5% level based on Duncan Multiple Rang Test.

Table(9): Effect of Planting conditions, Non Nano, Nano NPK fertilizers and their interaction on Fiber % of Broccoli plant.

Planting conditions	Nano NPK	Non Nano NPK			Planting conditions * Nano NPK	Planting conditions
		0	3	6		
Plastic house	0	1.33g	1.77ef	1.73ef	1.61d	2.04a
	3	2.07de	1.93ef	2.40bcd	2.13c	
	6	2.43bcd	2.63ab	2.07de	2.38b	
Open field	0	1.63fg	1.80ef	1.63fg	1.69d	2.14a
	3	1.87ef	2.10cde	2.33bcd	2.10c	
	6	2.47abc	2.83a	2.63ab	2.64a	
Non Nano NPK		1.97b	2.18a	2.13a	Nano NPK	
Planting conditions * Non Nano NPK	Plastic house	1.94c	2.11abc	2.07abc		
	Open field	1.99bc	2.24a	2.20ab		
Nano NPK * Non Nano NPK	0	1.48e	1.78cd	1.68de	0	1.65c
	3	1.97cd	2.02c	2.37b	3	2.12b
	6	2.45b	2.73a	2.35b	6	2.51a

*Means with same letter for each interaction are not significantly different at 5% level based on Duncan Multiple Rang Test.

Table(10): Effect of Planting conditions, Non Nano, Nano NPK fertilizers and their interaction on N%of Broccoli plant.

Planting conditions	Nano NPK	Non Nano NPK			Planting conditions * Nano NPK	Planting conditions
		0	3	6		
Plastic house	0	1.600cd	1.900abc	2.200a	1.900b	1.956a
	3	1.900abc	1.800bcd	1.900abc	1.867bc	
	6	2.067ab	2.200a	2.033ab	2.100a	
Open field	0	1.533d	1.800bcd	1.867bc	1.733c	1.844b
	3	1.900abc	1.933ab	1.900abc	1.911b	
	6	1.867bc	1.867bc	1.933ab	1.889bc	
Non Nano NPK		1.811b	1.917ab	1.972a	Nano NPK	
Planting conditions * Non Nano NPK	Plastic house	1.856bc	1.967ab	2.044a		
	Open field	1.767c	1.867bc	1.900abc		
Nano NPK * Non Nano NPK	0	1.567b	1.850a	2.033a	0	1.817b
	3	1.900a	1.867a	1.900a	3	1.889ab
	6	1.967a	2.033a	1.983a	6	1.994a

*Means with same letter for each interaction are not significantly different at 5% level based on Duncan Multiple Rang Test.

Table(11): Effect of Planting conditions, Non Nano, Nano NPK fertilizers and their interaction on P%of Broccoli plant.

Planting conditions	Nano NPK	Non Nano NPK			Planting conditions * Nano NPK	Planting conditions
		0	3	6		
Plastic house	0	0.467f	0.667cde	0.600def	0.578c	0.722a
	3	0.667cde	0.767a-e	0.800a-d	0.744bc	
	6	0.767a-e	0.867abc	0.900ab	0.844ab	
Open field	0	0.567ef	0.700b-e	0.767a-e	0.678c	0.770a
	3	0.800a-d	0.733b-e	0.733b-e	0.756bc	
	6	0.967a	0.867abc	0.800a-d	0.878a	
Non Nano NPK		0.706a	0.767a	0.767a	Nano NPK	
Planting conditions * Non Nano NPK	Plastic house	0.633b	0.767a	0.767a		
	Open field	0.778a	0.767a	0.767a		
Nano NPK * Non Nano NPK	0	0.517c	0.683b	0.683b	0	0.628c
	3	0.733ab	0.750ab	0.767ab	3	0.750b
	6	0.867a	0.867a	0.850a	6	0.861a

*Means with same letter for each interaction are not significantly different at 5% level based on Duncan Multiple Rang Test.

Table(12): Effect of Planting conditions, Non Nano, Nano NPK fertilizers and their interaction on K%of Broccoli plant.

Planting conditions	Nano NPK	Non Nano NPK			Planting conditions * Nano NPK	Planting conditions
		0	3	6		
Plastic house	0	0.733	0.833	0.800	0.789c	1.048a
	3	0.833	0.800	0.967	0.867c	
	6	1.400	1.500	1.567	1.489a	
Open field	0	0.733	0.800	0.933	0.822c	1.026a
	3	0.900	1.267	1.167	1.111b	
	6	1.167	1.233	1.033	1.144b	
Non Nano NPK		0.961a	1.072a	1.078a	Nano NPK	
Planting conditions * Non Nano NPK	Plastic house	0.989a	1.044a	1.111a		
	Open field	0.933a	1.100a	1.044a		
Nano NPK * Non Nano NPK	0	0.733d	0.817cd	0.867bcd	0	0.806c
	3	0.867bcd	1.033bc	1.067b	3	0.989b
	6	1.283a	1.367a	1.300a	6	1.317a

*Means with same letter for each interaction are not significantly different at 5% level based on Duncan Multiple Rang Test.

The climate surrounding the plant is crucial for crop production and can only be altered through protected cultivation (**Sojitra *et al*., 2023)**. Protected structures change microclimatic parameters, which in turn affect crop water requirements and enhance crop quality in comparison to open field cultivation**(Santosh, 2021)**. Nanomaterials offer several advantages over traditional fertilizers due to their high efficiency and ability to retain nutrients for longer periods, resulting in increased plant absorption and usefulness. **(Ditta&Arshad, 2013; Naderi&Shahraki, 2015)**.The cause of this outcome could also be a physical and chemical characteristics of the culture medium had a major impact on how readily available air, nutrients, and water are to plants. As a result, the physical characteristics of the medium were crucial to increase plant development and output, two of the most vital nutrients for crop production are nitrogen and calcium carbonate due to their chemical characteristics, which play crucial roles in plant cell architecture and metabolism and affect both the quantity and quality of secondary metabolites **(Hassan, 2012)**. Nutrition plays a key role in plant growth and development; increases nutrients will stimulate plants to grow and increase their yield **(Zheljazkov et al., 2011)**. The results of present study agreed with results when compared to previous studies. (**Ajirloo*et al.*, 2015)** on Tomato plant, (Muhemed&mijwel, 2020) on cucumber plants, and **(Abdulhameed*et al.*, 2021)** on cabbage plants.

Conclusion

Nowadays, it is increasingly difficult to maintain sustainability in traditional farming due to the global population growth and rapid urban development. To increase the production of fruits and vegetables, protected cultivation is essential. Research has demonstrated that plastic greenhouses have a significant impact on the growth and yield of plants. Additionally, studies have shown that Nano fertilizers can positively affect various plant traits, highlighting their crucial role in enhancing growth indicators.

References.

Abdel-Aziz, H. M., Hasaneen, M. N., & Omer, A. M. (2016). Nano chitosan-NPKfertilizer enhances the growth and productivity of wheat plants grown in sandy soil. Spanish Journal of Agricultural Research, 14(1), e0902–e0902

Ajirloo, A. R., Shaaban, M., &Motlagh, Z. R. (2015).Effect of K nano-fertilizer and N bio-fertilizer on yield and yield components of tomato (Lycopersiconesculentum L.). Int. J. Adv. Biol. Biom. Res., 3(1), 138-143.

Al-Rawi K.M. &Khalafallah A.M. (1980).Design and Analysis of Agricultural Experiments.College of Agriculture and Forestry.Mussel University.pp.361-363. (In Arabic).

Ayas, S.; Orta, H. and Yazgan, S. (2011). Deficit irrigation effects on broccoli (*Brassica oleracea* L.var. Monet) yield in unheated greenhouse condition. Bulgarian Journal of AgriculturalScience, 17(4): 551-559.

cauliflower var. Snowball-16 under cold Arid Region of ladakh. Haryana- Journal-ofHorticulturalSciences. 33(1/2): 127-129.

Demchak, K. T. and Smith. C. B. (1990). Yield responses and nutrient uptake of broccoli as affected by time type and fertilizer. Amer. soc. Hort. Sci115 (5): 737-740.

DEV, H (2012) 'Standardization of planting time and spacing in broccoli cv Green Head for lower hills of Northern India', International Journal of Farm Sciences, 2(1), pp. 36-42.

Ditta, A. and Arshad.M. (2015).Applications andperspectives of using nanomaterials for sustainableplant nutrition, Nanotechnology Reviews.Dio: https://dio.Org/10.1515/ntrev-2015-0060.

Eichert, T., Kurtz, A., Steiner, U., & Goldbach, H. E. (2008). Size exclusion limits and lateral heterogeneity of the stomatal foliar uptake pathway for aqueous solutes and water suspended nanoparticles. PhysiologiaPlantarum, 134(1), 151–160.

Fabek S.; Toth N.;Redovnikovic I.R.;Custic M.H.; Benko B. &Zutic I. (2012).The effect of nitrogen fertilization on nitrate accumulation.and the content of minerals and glucosinolates in broccoli cultivars. Food Tech. Biotech.; 50(2): 183-6.

Fadhil J.K.; Hakim R.T. andMijwel A.K. (2021).Response of tomato, eggplant, and pepper to nano fertilizers and the method of their addition.Plant Archives Vol. 21, Supplement 1, 2021 pp. 55-58.Journal homepage: http://www.plantarchives.orgdoilink : https://doi.org/10.51470/PLANTARCHIVES.2021.v21.S1.011

Fernãndez, J.L.; Orozco L.F.O. and Orozco L.F.M. (2018).Effect of nitrogen,phosphorus and potassium fertilization on the yield of broccoli cultivars. Rev. Fac. Nac. Agron.Medellin, 71(1), 8375-8386.

Francisco M, Tortosa M, Martínez-Ballesta MC,Velasco P, García-Viguera C, D.A. Moreno DA. (2017). Nutritional and phytochemical value ofBrassica crops from the agri-food perspective.Ann. Appl. Biol., 170, 273-285.

Gregorio, I.P. P.; Mario A. R.; Juan F. Z. N.; CarlosÁ. M.; Lucia B. R.; (2020). Antioxidant Capacity andAntigenotoxic Extract of Hibiscus sabdaria L.Extracts Obtained with UltrasoundAssistedExtraction Process. Appl. Sci., 10(560): 1-13.

Kanjana D. (2020).Evaluation of Foliar Application of Different Types of Nanofertilizers on Growth, Yield and Quality Parameters and Nutrient Concentration of Cotton under Irrigated Condition. International Journal of Current Microbiology and Applied Sciences ISSN: 2319-7706. 2020;9:7.

Karistsapol, N.;Quanchit, S. and Sompong, T. C. (2013).Effect of shading and variety on thegrowth and yield of broccoli during the dry season in Southern Thailand. InternationalJournal of Plant, Animal and Environmental Sciences, 3(2): 111-115.

Li H; Xia Y; Liu HY; Guo H; He XQ; Liu Y;WuDT;Mai YH; Li HB; Zou L; Ren-You and Gan RY.(2022a). Nutritional values, beneficial effects,and food applications of broccoli (*Brassica oleracea* var. italicaPlenck). Trends in FoodScience & Technology, 119, 288-308.https://doi.org/10.1016/j.tifs.2021.12.015.

Li L, Sun Y, Liu H, Shuhui Song S (2022b). Theincrease of antioxidant capacity of broccolisprouts subject to slightly acidic electrolyzedwater. Food Bioscience, 49, 101856.https://doi.org/10.1016/j.fbio.2022.101856.

Max, J.F.J.; Horst, W.J.;Mutwiwa, U.N. and Tantau, H.J. (2009).Effects of greenhouse coolingmethod on growth, fruit yield and quality of tomato (*Solanumlycopersicum* L.) in a tropicalclimate. Scientific Horticulture, 122(2): 179-186.

Mirza H.; Bhuyan, M.H.M.; Nahar, K.; Hossain, M.D. S.; JubayerA.l.& Hossen, M.D.& Fujita, M. (2018). Potassium: A Vital Regulator of Plant Responses and Tolerance to Abiotic Stresses. Agronomy. 8. 10.3390/agronomy8030031.

Naderi, M.R. and Danesh-Shahraki, A. (2013). Nanofertilizers and their roles insustainable agriculture, Intl.J. of Agri. Crop Sci., 5(19): 2229-2232.

Pérez-de-Luque, A. (2017). Interaction of nanomaterials with plants: What do we need for real applications in agriculture? Frontiers in Environmental Science, 5, 12.

Prado, J. C.; Raga-as, M. and Inosantos, J. N. (2008).Growth and yield of broccoli (*Brassica oleracea* L inn.) as influenced by different layers of shading nets. Philippine Journal of CropScience (Philippines), 37-38.

Santosh, D. T. (2021). Response of horticultural crops under variable microclimatic conditions of differentprotected cultivation structures. International Journal of Agricultural Sciences, 17(2), 515-521.

Shashidhara, G. B. (2000). Integrated nutrient management for chilli (*Capsicum annuum*L.) in Alfisops of Northern Transition Zone of Karnataka. M. Sc. (Agri.) Thesis, Univ.Agric. Sci., Dharwad, Karnataka, India.

Shilpa, R. S., Kant, C., &Prashar, N. (2022).Role of nano fertilizers in horticulture.In Pharma Innovation Journal, 11(6), 831-836.

Singh, (2004) Effect of nano nitrogen and nano phosphorus on growth and curd yield of

Sohair.E.E.D; Abdall, A. and Hossain, H.(2018). Evaluation of Nitrogen, Phosphorus and Potassium NanoFertilizers on Yield, Yield Components and Fiber Properties of Egyptian Cotton (*Gossypium Barbadense* L.) Journal of Plant Sciences and Crop Protection; 2018. ISSN: 2639-3336.

Sojitra, M. A.;Satasiya, R. M.; Rank, H. D.; Chauhan, P. M.; Parmar, H. V., & Patel, D. V. (2023). Study theMicro Climatic Parameter in Protected Structure. Environment and Ecology, 41(2A), 953-960.)

Ying, W.G.;Zheng, Z.C. and Fushan, Z. (1997).Effect of nitrogen, phosphorus and potassium fertilizer on the yield and physiology target of broccoli. China Veg. 1: 14-17[CITED FROM HORT. ABSTR., 68(7): 5849, 1998].

Zaki, M.F.;Saleh S.A.; Tantawy A.S. and El-DewinyC. Y. (2015) 'Effect of Different Rates of Potassium Fertilizer on the Growth, Productivity and Quality of Some Broccoli Cultivars under New Reclaimed Soil Conditions', International Journal of ChemTech Research, 8(12), pp. 28-39 [Online].Availableat:http://sphinxsai.com/2015/ch_vol8_no12/1/(2839)%20V8N12CT.pdf (Accessed: 18th June 2018).

Zulfiqara, F., Muhammad, M. N., Aisha, A. N., &Munné-Boschbf, A. S. (2019).Nanofertilizer use for sustainable agriculture: Advantages and limitations. Sciencedirect.Plant Science, (289), 110270.