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Influence of NPK on growth, yield and nutrient content in broccoli (*Brassica oleracea* L. var. *italica*) under drip and conventional irrigation system

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Abstract
A field trial was carried out at Vegetable Research Centre (VRC) of G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India during September to February 2021-22 and 2022-23 to find out the Influence of NPK on growth, yield and nutrient content broccoli (*Brassica oleracea* L. var. *italica*) under drip and conventional irrigation system. The experiment that uses a two factorial randomized block design (RBD) with eight treatments under two irrigation methods (drip and conventional method). T_1 consist of 100 percent of RDF NPK similarly, T_2 consist of 100 percent of RDF N_0PK, T_3 consist of 100 percent of RDF NP_0K, T_4 consist of 100 percent of RDF NPK_0, T_5 consist of 100 percent of RDF of N_0P_0K, T_6 consist of 100 percent of RDF N_0PK_0, T_7 consist of 100 percent of RDF of NP_0K_0 and T_8 control under both drip and conventional method of irrigation and replicated thrice. The outcome of the present study revealed that broccoli performance was significantly influenced under drip fertigation. Pooled data revealed that highest observation was recorded in terms of growth parameters i.e., plant height at 30, 45 and 60 days after transplanting (DAT) was recorded (53.83, 77.02 and 82.55 cm), number of leaves (18.45, 26.67 and 34.33), yield parameter i.e., total yield per hectare (163.12 q/ha) and head weight (500.94 g) and nutrient content in broccoli head i.e., nitrogen content (3.15 %), phosphorus content (0.68%) and potassium content (2.26 %) under drip fertigation. Highest observation was recorded in T_1 (fertigation with 100% RDF of NPK) in all the parameters as compared to other treatments. The outcome of the study was that fertigation of 100 percent RDF of NPK (120:60:60 kg ha^{-1}) was best treatment for broccoli.

Keywords: Broccoli, growth, yield, fertigation, NPK, nutrient content

Introduction
Broccoli (*Brassica oleraceae* L. var. *italica*) belongs to Brassicaceae family and one of the most nutritious Cole crop. It derives its name from the 'brachium' which is a Latin word meaning branch/arm/ young shoot (Boswell, 1949; Gomez-compo, 1999) [2, 8]. Broccoli is indeed native to Southern Europe and the Mediterranean region. Italy is often considered to be the primary center of origin for broccoli. There is a unique arrangement found in broccoli head, where multiple individual florets are clustered together to create what appears to be a single flower head. This crop is very healthy vegetable and also called as "crown of nutrition". Broccoli is known for its flavor, taste, and nutritive medicinal value especially with respect to vitamin C (113 IU), vitamin A (2500 IU), potassium (382 mg) and calcium (103 mg) per 100 g of edible part (Tiwari, 2010) [23]. It carries 130 times high vitamin A as compared to cauliflower and 22 times higher vitamin A compared to cabbage (Thamburaj and Singh, 2003) [22]. Per 100 g edible part of broccoli, carries 89.1% moisture, 0.3 g fat, 3.6 g protein, 5.9 g carbohydrate, 0.23 mg riboflavin, 0.10 mg thiamine, 0.6mg niacin. Now-a-days, broccoli attracted more attention due to its high nutritional value and multifarious use (Rangkadilok *et al.*, 2004) [12]. It also has the compound glucoraphanin, which has an anticancer compound sulforaphane, a compound which is associated with reducing the risk of cancer in human bodies (Aires *et al.*, 2006) [1]. In India broccoli is mainly grown in hilly areas of Himanchal Pradesh, Jammu & Kashmir, Uttarakhand, Tamil Nadu and Northern Plains. Himanchal Pradesh is leading producer in India.

In India surface irrigation such as border, check and furrow are the commonly used methods of irrigation The overall efficiency of surface irrigation is low (33%) and about 67% of water is being wasted or no use. Drip irrigation is one of the effective and efficient methods of irrigation, which having about 90% of water use efficiency.

Drip irrigation method provides an efficient method for water and fertilizer delivery and also allows precise timing and the uniform distribution of nutrients and water application (Debbarma, 2019). It is not only increase the production but also increase water use efficiency (Rawat *et al.,* 2023) [14]. Traditional methods of applying fertilizers often result in inefficient utilization by crops. Fertigation, on the other hand, involves applying nutrients directly through emitters into the zone where the plant's roots are most active. This method can lead to improved efficiency in fertilizer use compared to conventional application techniques. By applying nutrients frequently through drip irrigation, the efficiency of fertilizer use is enhanced Malik *et al.* (1994) [10]. For implementing drip fertigation over traditional methods in broccoli cultivation can offer several advantages in terms of water and nutrient management.

Hence the objective of the present study was to optimize the utilization of fertilizers and irrigation techniques (drip and conventional) to maximize the yield and quality of the broccoli crop. The present research work was undertaken to analyze the response of varying levels of NPK under drip and conventional method on the yield, growth and quality of broccoli.

Materials and Methods

Pantnagar is indeed located in the humid subtropical zone and is situated in the Tarai region at the foothills of the Shivalik range of the Himalayas. This location is situated at 29°N latitude and 79.30°E longitude, with an altitude of 243.84 meters above mean sea level. Here the maximum temperatures in summer ranging from 32°C to 44°C (89.6°F to 111.2°F) with a minimum temperature of 4.4°C (39.9°F) in winter. The investigation that took place at the Vegetable Research Center (VRC) of the G.B. Pant University of Agriculture and Technology in Pantnagar, Uttarakhand, during the *rabi* (winter) season for two consecutive years during September to February 2021-22 and 2022-23 in two factorial RBD with three replications. First factor is the irrigation method (drip and conventional) whereas, the second factor is the NPK application. Of the second factor different treatments were T_1: recommended dose of NPK, T_2: recommended dose of PK only (N_0PK), T_3: NK only (NP_0K), T_4: NP only (NPK_0), T_5: K alone (N_0P_0K), T_6: P only (N_0PK_0), T_7: N only (NP_0K_0) and T_8: no application of NPK (absolute control) The seeds of Paraiso variety were grown in the nursery and after 25 to 30 days, seedlings were ready to transplanting. Healthy seedlings (10–15cm) of consistent shape and size were planted in the main field. Each plot has dimensions of $20m^2$. The spacing between seedlings during transplantation was 60 x 50 cm. 15 days after transplanting fertigation was given to the plants according to the treatments. Water-soluble fertilizers are often used for fertigation, which is the process of applying fertilizers through irrigation water while for conventional method commercial practice was applied for fertilizer application.

To meet the NPK requirement under drip fertigation, urea, mono ammonium phosphate and potassium nitrate were used. Under conventional method fertilizer application involves the use of specific fertilizers like urea, single super phosphate, and muriate of potash. In this method entire dose of phosphorus and potassium and one third dose of nitrogen were applied as basal dose. The remaining nitrogen dose was applied in 2 splits at 20, 40 DAT, respectively. Five plants were selected randomly from each treatment and marked to record the data on yield, growth, quality attributes and nutrient content in broccoli head. Harvesting was done when the flower buds became compact and firm. The observations were recorded for plant height and number of leaves at 30, 45 and 60 DAT.

Result and Discussion

1. Growth parameters

Pooled data of two years of study showed that at 30 DAT, 45 DAT and 60 DAT maximum plant height were observed in T_1 (fertigation with RDF of NPK) under drip fertigation *i.e.* 53.83, 77.02 and 82.55 cm, respectively and was *at par* with T_3 (fertigation of NP_0K) with a plant height of 52.85, 72.74 and 81.57 cm. Minimum values for plant height were observed under T_8 (control). Similarly under conventional method at 30, 45 and 60 DAT lowest plant height was observed under T_8 42.97, 63.43 and 69.89 cm while maximum plant height was observed in T_1 49.59, 73.16 and 77.882 respectively. As far as number of leaves are concerned, pooled data in Table 2 show that number of leaves in broccoli plants were significantly influenced by drip fertigation. The interaction of fertilizer application and irrigation method was also found non significant during the investigation. Under drip fertigation maximum number of leaves per plant was observed in T_1 (fertigation with 100 % RDF of NPK) 18.45, 26.67 and 34.33 followed by T_3 (fertigation with 100 % of NP_0K) 17.03, 25.22 and 32.89, while the minimum values were observed in T_8 (control). At 60 DAT under commercial method lowest leaves per plant was observed under T_8 (25.06) while higher number of leaves per plant was observed in T_1 (31.00).

Plant height increased as a result of improved nutrient utilization, higher uptake of nutrients, and a better nutritional environment in both the root zone and the plant system. This indicates that the plants were able to efficiently absorb and utilize nutrients from the soil, leading to healthier growth and development. Besides, it may be due to fertilizer availability enhance photosynthesis, nitrogen metabolism, formation of chlorophyll, auxin, mobilization and complete solubility of nutrients and their availability at regular interval in a required quantity due to split utilization of nutrients which ultimately improved the plant growth. Similar findings were revealed by Debbarma *et al.* (2021) [5], Singh *et al.*, 2004 [18], and Mal *et al.*, 2005 [9].

Increased in number of leaves with fertilizer application may be due to the better nutrient utilization together with higher nutrients uptake that leads to increase in photosynthesis and metabolites in plant system. These results were similar to the results of Debbarma *et al.* (2022) [6], Rawat *et al.* (2023) [14] and Surve *et al.* (2002) [21].

Table 1: Influence of NPK levels on plants height at 30, 45 and 60 DAT under drip and conventional irrigation system (Pooled data)

S. N.	Treatments	Plant height (cm) (30 DAT) Pooled (2021-23)			Plant height (cm) (45 DAT) Pooled (2021-23)			Plant height (cm) (60 DAT) Pooled (2021-23)		
		Drip		Conventional	Drip		Conventional	Drip		Conventional
1.	T_1 (NPK)	53.83		49.59	77.02		73.16	82.55		77.82
2.	T_2 (N_0PK)	49.28		43.78	67.65		64.37	77.46		72.76
3.	T_3 (NP_0K)	52.85		49.11	72.74		71.16	81.57		76.37
4.	T_4 (NPK$_0$)	52.36		49.06	72.73		70.35	80.66		75.54
5.	T_5 (N_0P_0K)	46.60		43.28	66.44		64.06	73.07		70.76
6.	T_6 (N_0PK$_0$)	46.66		43.78	68.17		66.15	74.56		72.67
7.	T_7 (NP_0K$_0$)	51.53		48.42	71.25		69.63	80.60		75.32
8.	T_8 (control)	45.83		42.97	66.19		63.43	72.19		69.89
		I	T	I x T	I	T	I x T	I	T	I x T
S.Em. ±		0.96	0.54	0.76	0.29	0.81	1.15	0.26	0.72	1.03
CD at 5 %		0.54	1.53	N/S	0.81	2.29	N/ S	0.73	2.05	N/ S

I-irrigation, T-treatment

Table 2: Influence of NPK on number of leaves per plant at 30 DAT, 45 DAT and 60 DAT under drip and conventional irrigation system (Pooled data)

S.N.	Treatment	Number of leaves per plant (30 DAT) Pooled (2021-23)			Number of leaves per plant (45 DAT) Pooled (2021-23)			Number of leaves per plant (60 DAT) Pooled (2021-23)		
		Drip		Conventional	Drip		Conventional	Drip		Conventional
1.	T_1 (NPK)	18.45		15.11	26.67		24.28	34.33		31.00
2.	T_2 (N_0PK)	14.61		12.00	21.33		19.44	29.67		25.67
3.	T_3 (NP_0K)	17.03		13.83	25.22		22.62	32.89		30.44
4.	T_4 (NPK$_0$)	16.78		13.67	24.00		22.44	32.67		29.89
5.	T_5 (N_0P_0K)	15.11		12.00	21.56		19.42	30.67		25.61
6.	T_6 (N_0PK$_0$)	14.56		11.56	21.17		19.28	29.33		25.26
7.	T_7 (NP_0K$_0$)	16.56		13.38	23.00		22.11	30.89		29.00
8.	T_8 (control)	14.39		11.39	21.06		17.89	29.22		25.06
		I	T	I x T	I	T	I x T	I	T	I x T
S.Em. ±		0.08	0.24	0.33	0.11	0.32	0.45	0.18	0.50	0.71
CD at 5 %		0.24	0.67	N/S	0.32	0.90	N/ S	0.51	1.43	N/ S

I-irrigation, T-treatment

2. Yield parameters

The net head weight of broccoli seems to have been influenced by two factors: the irrigation method and the levels of NPK (Nitrogen, Phosphorus, and Potassium) applied, while the interaction of these two factors also observed to be significant. The results showed positive effect of fertigation with NPK on weight of curd. Maximum weight of curd was observed in pooled data under T_1 (fertigation with NPK) that is 500.94 g which was significantly higher than T_4 (466.90 g), while minimum curd weight was recorded in control (T_8) 250.75g under drip fertigation. Under conventional method net head weight measured 439.93g in T_1 and minimum net head weight was observed in T_8 (162.55g). Pooled analysis data revealed that maximum yield 163.12 qha^{-1} of yield per hectare was observed with fertigation with NPK (T_1), followed by T_4 (144.53 qha^{-1}) while, the minimum total yield per hectare was recorded in control (T_8) 77.74 qha^{-1} under drip fertigation. Under conventional method minimum yield was observed under T_8 48.39 qha^{-1} while maximum yield per hectare was observed in T_1 122.85 qha^{-1} (Table 2, fig. 1).

The combination of uniform nutrient distribution and the proper balance of NPK nutrients in root zone through fertigation likely contribute to the observed positive effects on crop growth and yield, leading to better head development. The conventional method of fertilizer application has shown to result in minimum head weight due to leaching losses of nutrients. This occurs because poor root development leads to restricted uptake of nutrients, ultimately leading to poor plant growth and smaller curd formation. Similar outcome were also observed by Shinde *et al*. (2006) [16], Singh *et al.* (2014) [19] and Debbarma *et al.* (2021) [5].

Increase in head yield under fertigation at 100 % of RDF of NPK might be due to the availability of optimum soil moisture and adequate nutrients in the root zone. Thereby higher nutrient uptake by heads which may lead to larger size and heavier heads. The increase in yield observed under drip fertigation can indeed be attributed to several factors, including the maintenance of a favorable soil water regime in the root zone which helps plants to utilize nutrients and water more efficiently from the wetted area.

The low minimum yield observed with the conventional method of fertilizer application can be attributed to several factors working in combination such as water stress at the time of critical growth period, along with aeration problem. When there is an then there is less availability of nutrients for crop growth due to high weed infestation between the crops and leaching of nutrients. Similar outcome were also reported by Singh *et al.*, (2002) [17], Pattanaik *et al.*, (2003) [11], Bhatt *et al.* (2005) [3], Shinde *et al*. (2006) [16] and Rawat *et al.* (2023) [14].

Table 3: Influence of NPK on head weight and total yield under drip and conventional irrigation system. (Pooled data)

S.N.	Treatment	Head weight (g) Pooled (2021-23)			Total yield (qha^{-1}) Pooled (2021-23)		
		Drip		Conventional	Drip		Conventional
1.	T_1 (NPK)	500.94		439.93	163.12		122.85
2.	T_2 (N_0PK)	451.07		362.39	140.08		102.34
3.	T_3 (NP$_0$K)	454.70		370.30	141.16		104.79
4.	T_4 (NPK$_0$)	466.90		396.92	144.53		115.58
5.	T_5 (N_0P$_0$K)	271.56		242.33	94.98		65.12
6.	T_6 (N_0PK$_0$)	349.06		258.75	108.41		75.21
7.	T_7 (NP$_0$K$_0$)	375.34		268.45	116.36		78.18
8.	T_8 (control)	250.75		162.55	77.74		48.39
		I	T	I x T	I	T	I x T
S.Em. ±		1.03	2.92	4.13	1.05	2.97	4.20
CD at 5 %		2.93	8.27	11.7	2.97	8.41	N/S

I-irrigation, T-treatment

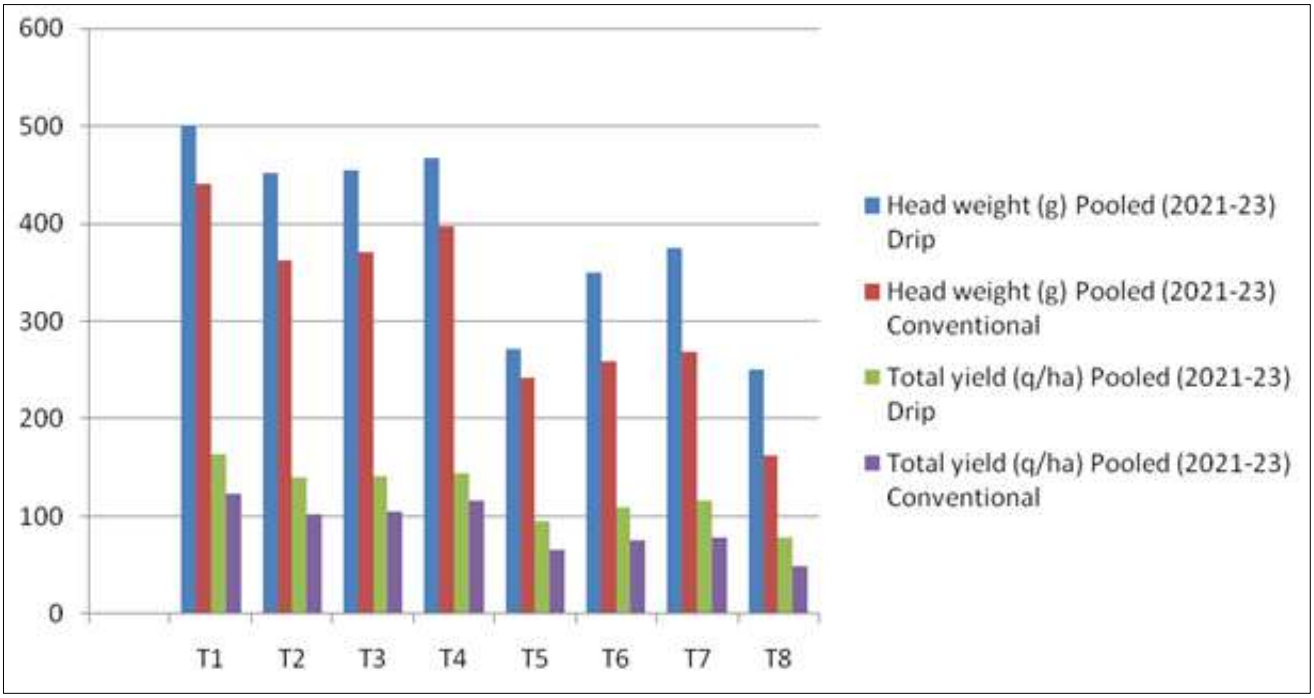

Fig 1: Influence of NPK on head weight (g) and total head yield (qha^{-1}) under drip and conventional irrigation system

3. Nitrogen, Phosphorus and Potassium content in broccoli head

NPK content of head was significantly enhanced by irrigation methods and fertilizers application level during both the year while interaction of irrigation methods and fertilizer application was not found significant for both the years of experiment. Pooled data revealed that fertilizers application through drip increased the nitrogen, phosphorus and potassium amount in head of broccoli. Under drip fertigation nitrogen, phosphorus and potassium amount in broccoli head was found maximum in T_1 (fertigation with 100 % of NPK) i.e. 3.15, 0.68 and 2.26 percent respectively and under conventional method highest NPK content in head was observed under T_1 3.08, 0.52 and 2.17 percent respectively. The improved nutrient status of broccoli heads, specifically attributing it to factors like timely availability of water and nutrients, and their favorable interaction in the root zone. This interaction likely led to increased nutrient use efficiency, ultimately benefiting the nutrient content and overall health of the broccoli heads. Proper irrigation and nutrient management are indeed crucial for optimizing plant growth and yield. These results are in correlated with the result of Vazquez *et al*. (2010) [24], Bhatt *et al*. (2006) [4] and Selim *et al.* (2010) [15]. Higher NPK of curd in cauliflower fertigated with NPK fertilizer was also reported by Singh *et al.* (2016) [20].

Table 4: Influence of NPK on nitrogen, phosphorus and potassium content in broccoli head under drip and conventional irrigation system (Pooled data)

S.N.	Treatment	Nitrogen content (%)		Phosphorus content (%)			Potassium content (%)		
		Pooled (2021-23)		Pooled (2021-23)			Pooled (2021-23)		
		Drip	Conventional	Drip		Conventional	Drip		Conventional
1.	T_1 (NPK)	3.15	3.08	0.68		0.52	2.26		2.17
2.	T_2 (N_0PK)	2.42	2.33	0.55		0.45	2.16		2.10
3.	T_3 (NP$_0$K)	3.10	2.94	0.44		0.42	2.17		2.12
4.	T_4 (NPK$_0$)	2.88	2.77	0.57		0.49	2.11		2.07
5.	T_5 (N_0P_0K)	2.18	2.13	0.42		0.37	2.14		2.10
6.	T_6 (N_0PK$_0$)	2.21	2.10	0.54		0.48	2.11		2.06
7.	T_7 (NP$_0$K$_0$)	2.59	2.53	0.44		0.40	2.10		2.05
8.	T_8 (control)	2.12	2.06	0.39		0.30	2.04		1.98
	I	T	I x T	I	T	I x T	I	T	I x T
S.Em. ±	0.02	0.05	0.07	0.001	0.004	0.005	0.40	1.13	1.56
CD at 5 %	0.05	0.15	N/S	0.004	0.011	N/S	0.60	1.20	N/S

I-irrigation, T-treatment

Conclusion

As per the results of the present study suggest that fertigation of NPK (Nitrogen, Phosphorus, and Potassium) has yielded significantly better outcomes compared to the conventional method of irrigation. Fertigation showed significant impact on growth, yield and nutrient content in broccoli head. Based on the overall performance it suggests that the treatment with a fertilizer ratio of 120:60:60 kg N: P_2O_5: K2O per hectare is considered the best and most economical for growing broccoli. This specific nutrient ratio provided optimal growth and yield results for the broccoli plants.

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