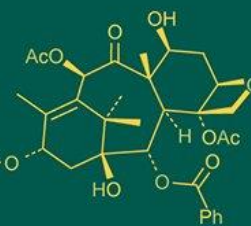
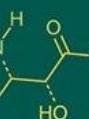
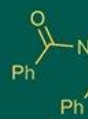


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Effect of NPK and foliar application of Humic acid on growth and yield of broccoli

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Abstract

A field experiment was conducted at the Instructional Farm, Department of Vegetable Science, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, during rabi 2024-25, to evaluate the effect of NPK and foliar application of humic acid on growth and yield of broccoli. The experiment was laid out in a Randomized Block Design with three replications and ten treatments, viz., T₁ (75% RDF + 0.5% humic acid), T₂ (100% RDF + 0.5% humic acid), T₃ (125% RDF + 0.5% humic acid), T₄ (75% RDF + 1.5% humic acid), T₅ (100% RDF + 1.5% humic acid), T₆ (125% RDF + 1.5% humic acid), T₇ (75% RDF + 2.5% humic acid), T₈ (100% RDF + 2.5% humic acid), T₉ (125% RDF + 2.5% humic acid) and T₁₀ (100% RDF; 125:60:60 NPK kg ha⁻¹). Among the growth parameters, plant height and number of leaves were significantly maximum with 125% RDF + 1.5% humic acid, and the maximum leaf area, stem diameter and chlorophyll index were observed with 125% RDF + 2.5% humic acid. Among all the treatments, 125% RDF + 1.5% humic acid took minimum days for curd initiation (40.33 days) and minimum days to 1st harvest (66.07 days). The treatment 125% RDF + 1.5% humic acid also gave the significantly maximum curd yield plant⁻¹ (653.40 g), curd yield ha⁻¹ (242.00 q ha⁻¹). Soil analysis revealed that 125% RDF + 2.5% humic acid recorded maximum available NPK in soil, whereas 125% RDF + 1.5% humic acid recorded maximum uptake of NPK (kg ha⁻¹) by plants. The study indicates that, T₆ (125% RDF + 1.5% humic acid) can be considered as the best treatment from growth, yield and plant uptake, whereas T₉ (125% RDF + 2.5% humic acid) was superior for leaf area, stem diameter and available NPK in soil in broccoli.

Keywords: Broccoli, NPK, humic acid, foliar application, growth, yield

Introduction

Broccoli (*Brassica oleracea* var. *italica*) is an important cool season vegetable of family Brassicaceae (2n=18) believed to have originated in Italy. The edible part is the compact curd formed by a mass of unopened florets along with a portion of fleshy stem. It thrives well at day temperature of 18-26 °C and night temperature of 15-16 °C and prefers well drained sandy loam soil with pH 5.5 to 6.8 (Kohil *et al.*, 2006) [10]. The world production of broccoli and cauliflower together was about 25 million tonnes from 1.4 million ha in 2022 (FAO, 2022) [7], with China, India and USA as major producers. The crop is gaining popularity due to its rich nutritional profile, as it is a good source of vitamin C, vitamin K, folate, fibre and bioactive compounds like glucosinolates, sulforaphane and indoles having anti-cancer and antioxidant properties.

The productivity and quality of broccoli largely depend on balanced nutrition. Nitrogen is required for vegetative growth and chlorophyll formation, phosphorus for root development and curd initiation, and potassium for maintaining water balance, enzyme activity and stress tolerance. Excess use of nitrogen alone may affect curd quality. Apart from major nutrients, humic acid as a bio stimulant and soil conditioner improves soil structure, water holding capacity, microbial activity and root growth, which helps in better nutrient availability and uptake by the plant.

Considering the role of NPK and humic acid in growth and curd development, the present investigation was undertaken to study the effect of NPK and foliar application of humic acid on growth, yield and quality of broccoli.

Material and Methods

This study was conducted at the Instructional Farm, Department of Vegetable Science, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (Maharashtra), during rabi 2024-25. Ten

treatments were tested in a Randomised Block Design with three replications: T₁ (75% RDF + 0.5% humic acid), T₂ (100% RDF + 0.5% humic acid), T₃ (125% RDF + 0.5% humic acid), T₄ (75% RDF + 1.5% humic acid), T₅ (100% RDF + 1.5% humic acid), T₆ (125% RDF + 1.5% humic acid), T₇ (75% RDF + 2.5% humic acid), T₈ (100% RDF + 2.5% humic acid), T₉ (125% RDF + 2.5% humic acid) and T₁₀ (100% RDF; 125:60:60 NPK kg ha⁻¹). Seedlings of broccoli were transplanted into the field on 5th December 2024, spaced at 60 × 45 cm. Before transplanting, FYM was incorporated in the field @ 25 t ha⁻¹. Other than these treatments, the crop was managed as per the standard package of practices followed in the region. Growth was tracked through plant height and number of leaves plant⁻¹ recorded at 30, 45 and 60 days after transplanting (DAT) and leaf area. For yield, the parameters recorded included days required to curd initiation, days required to 1st harvest and curd yield ha⁻¹. Data were analysed statistically following Panse and Sukhatme (1989) [13]; standard error of mean (S.E m±) and critical difference (CD) at the 5% level

were computed for every character studied.

Results and Discussion

A. Growth parameters

Plant height (cm): The application of RDF with humic acid significantly affected plant height at 30, 45 and 60 DAT. Among the treatments, 125% RDF + 1.5% humic acid (T₆) produced the tallest plants, recording 22.27, 53.33 and 71.47 cm, respectively, while the shortest plants were observed in 75% RDF + 0.5% humic acid (T₁) with 13.07, 32.13 and 43.67 cm. The greater plant height in T₆ could be attributed to the improved availability and uptake of nutrients under higher RDF, particularly nitrogen, which supports chlorophyll formation, protein synthesis and cell growth. The addition of humic acid may have further promoted root development and improved nutrient-use efficiency, thereby encouraging better vegetative growth. Comparable responses have been reported by Al-Jaf *et al.* (2018) [2], who reported improved plant height in broccoli with humic acid application.

Table 1: Effect of NPK and foliar application of humic acid on growth parameters of broccoli

Treatments	Growth parameters				
	Plant height (cm) 60 DAT	Number of leaves 60 DAT	Stem diameter (cm) 60 DAT	Leaf area (cm ²) 60 DAT	Chlorophyll index 60 DAT
T ₁ (75% RDF + 0.5% humic acid)	43.67	20.00	4.49	481.27	53.40
T ₂ (100% RDF + 0.5% humic acid)	59.93	21.73	4.83	493.70	57.57
T ₃ (125% RDF + 0.5% humic acid)	69.03	22.00	5.24	504.07	63.86
T ₄ (75% RDF + 1.5% humic acid)	49.73	21.20	4.71	486.43	54.92
T ₅ (100% RDF + 1.5% humic acid)	62.20	22.33	5.06	499.43	61.32
T ₆ (125% RDF + 1.5% humic acid)	71.47	23.27	5.54	511.20	66.55
T ₇ (75% RDF + 2.5% humic acid)	46.60	20.40	4.93	490.63	57.53
T ₈ (100% RDF + 2.5% humic acid)	56.07	22.13	5.37	502.87	62.87
T ₉ (125% RDF + 2.5% humic acid)	65.07	22.47	5.63	515.90	70.59
T ₁₀ (100% RDF; 125:60:60 NPK kg ha ⁻¹)	52.60	21.40	4.74	476.23	52.88
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.
S.E (m) ±	2.58	0.91	0.04	1.66	2.59
CD (5%)	7.67	2.71	0.13	4.88	7.70

Number of leaves plant⁻¹: The treatments significantly affected number of leaves at 30, 45 and 60 DAT. Among the treatments, 125% RDF + 1.5% humic acid (T₆) recorded the highest number of leaves, with 16.47, 21.60 and 23.27 leaves plant⁻¹, respectively. In comparison, 75% RDF + 0.5% humic acid (T₁) recorded the lowest values of 8.67, 13.93 and 20.00 leaves plant⁻¹ at the corresponding stages. The higher leaf number observed in 125% RDF + 1.5% humic acid may be associated with improved nutrient availability, particularly nitrogen, which is important for leaf initiation and development. Humic acid application may have promoted root growth and nutrient absorption, thereby supporting better vegetative growth and leaf formation. Similar findings in broccoli were reported by Al-Taey *et al.* (2019) [3].

Stem diameter (cm): Among the treatments, stem diameter showed marked differences. T₉ consisting of 125% RDF (156.25:75:75 NPK kg ha⁻¹) with 2.5% humic acid produced the boldest stems measuring 2.27 cm at 30 DAT, 3.17 cm at 45 DAT and 5.63 cm at 60 DAT, which remained statistically at par with T₆ and T₈ at 45 DAT (3.06 cm and 2.96 cm) and with T₆ at 60 DAT (5.54 cm). The poorest stem growth of 1.26 cm, 2.54 cm and 4.49 cm at respective stages was recorded in T₁ receiving 75% RDF with 0.5% humic acid. The better stem thickness in T₉ could be

attributed by sufficient nutrient availability from higher RDF level and the stimulatory effect of humic acid on root development, nutrient absorption and photosynthate accumulation. The results are in line with those reported by Selim and Mosa (2012) [15].

Leaf area (cm²): The treatments significantly influenced leaf area in broccoli. Among all the treatments, 125% RDF + 2.5% humic acid (T₉) recorded significantly maximum leaf area (515.90 cm²) which was statistically at par with 125% RDF + 1.5% humic acid (T₆) with leaf area of 511.20 cm². The minimum leaf area (481.27 cm²) was recorded in 75% RDF + 0.5% humic acid (T₁). The increase in leaf area under higher RDF and humic acid might be attributed to enhanced availability of nitrogen which is essential for cell division, cell expansion and overall vegetative growth, coupled with the beneficial effect of humic acid in improving nutrient uptake, photosynthetic efficiency and production of growth promoting substances. The present findings are in conformity with the results reported by Al-Jaf *et al.* (2018) [2] and Abdulrahman *et al.* (2025) [1] who reported enhanced leaf growth and leaf area in broccoli with humic acid and nutrient application.

Chlorophyll index: The chlorophyll index of leaves varied significantly among treatments. The highest chlorophyll

index of 70.59 was recorded in T₉; 125% RDF with 2.5% humic acid, which was comparable to T₆ (66.55) and T₃ (63.86), while the lowest reading of 52.88 was found in T₁₀ with only 100% RDF. This maximum chlorophyll index in T₉ might be because of more nitrogen available from the higher fertilizer dose, which is essential for chlorophyll synthesis, and humic acid further helped in better nutrient uptake and utilization. The low value in T₁₀ could be due to absence of humic acid. Similar results were reported by Vidigal *et al.* (2021) ^[16] and Ibrahim *et al.* (2024) ^[8] in broccoli.

B. Yield and yield attributing parameters

Days to curd initiation: The treatment T₆;125% RDF (156.25:75:75 NPK kg ha⁻¹) + 1.5% humic acid induced curd initiation earliest in 40.33 days, whereas 75% RDF + 0.5% humic acid (T₁) took the longest time of 60.00 days for curd initiation. The early attainment of curd stage under T₆ (125% RDF + 1.5% humic acid) might be due to sufficient NPK supply that supported better vegetative growth and higher photosynthetic efficiency, along with humic acid which enhanced root development and nutrient absorption, leading to early accumulation of assimilates required for curd formation. On the other hand, lower nutrient level in T₁ (75% RDF + 0.5% humic acid) restricted plant vigour and delayed curd initiation. These results are in line with the findings of Selim and Mosa (2012), Kumar and Kandpal (2017) and Al-Jaf *et al.* (2018) ^[2, 11, 15] in broccoli.

Days to 1st harvest: The crop reached first harvest earliest under 125% RDF + 1.5% humic acid (T₆) in 66.07 days after transplanting, whereas 75% RDF + 0.5% humic acid (T₁) took the maximum of 75.23 days. It seems that with higher NPK, plants grew more vigorously and accumulated photosynthates faster, and the addition of humic acid at 1.5% helped in better root growth and nutrient uptake, so curds matured early. Interestingly, increasing humic acid to 2.5% did not give any further earliness, showing a concentration dependent response. Delayed harvest in low nutrient treatment was due to poor growth. These results are in conformity with Katiyar *et al.* (2012) ^[9] in broccoli.

Curd yield plant⁻¹ (g): With respect to curd yield per plant, significant variation was observed due to different levels of NPK and humic acid. Treatment 125% RDF (156.25:75:75 NPK kg ha⁻¹) + 1.5% humic acid (T₆) produced the highest curd weight of 653.40 g plant⁻¹ and remained at par with 100% RDF + 1.5% humic acid (T₅) which gave 616.00 g. The lowest value of 457.08 g was obtained under 75% RDF + 0.5% humic acid (T₁). The increase in yield under 125% RDF + 1.5% humic acid might be because of higher nutrient supply coupled with humic acid on nutrient use efficiency, root development and photosynthesis which helped in better assimilate accumulation in the curd. At par yield of T₅ and T₆ indicates that beyond 100% RDF, yield did not improve markedly when 1.5% humic acid was applied. The poor performance under 75% RDF + 0.5% humic acid could be due to insufficient nutrition and restricted growth. These findings are in agreement with those of Selim and Mosa (2012) ^[15], Al-Jaf *et al.* (2018) and Al-Taey *et al.* (2019) ^[2, 3] in broccoli.

Curd yield ha⁻¹ (q): Among all treatments, 125% RDF + 1.5% humic acid recorded significantly maximum (242.00 q ha⁻¹) curd yield, which was found to be statistically at par with 100% RDF + 1.5% humic acid (228.14 q ha⁻¹), whereas minimum (169.28 q ha⁻¹) curd yield recorded in 75% RDF + 0.5% humic acid (T₁). The significantly higher yield under 125% RDF + 1.5% humic acid (T₆) may be attributed to adequate nutrient availability, enhanced vegetative growth, photosynthetic activity and better assimilate translocation towards curd development, while humic acid further promoted root growth and nutrient uptake improving nutrient utilization, whereas the lower yield under 75% RDF + 0.5% humic acid (T₁) indicates limited nutrient availability and restricted growth under reduced RDF; these findings are in close agreement with Selim and Mosa (2012) ^[15] who reported increased total marketable yield of broccoli with humic substances along with NPK, Al-Jaf *et al.* (2018) ^[2] who observed improved total yield with humic acid.

Table 2: Effect of NPK and foliar application of humic acid on yield and yield attributing parameters of broccoli.

Treatments	Days to curd initiation	Days to 1 st harvest	Curd yield plant ⁻¹	Curd yield ha ⁻¹
T ₁ (75% RDF + 0.5% humic acid)	60.00	75.23	457.08	169.28
T ₂ (100% RDF + 0.5% humic acid)	54.20	71.07	544.70	201.74
T ₃ (125% RDF + 0.5% humic acid)	50.60	67.60	577.89	214.03
T ₄ (75% RDF + 1.5% humic acid)	57.80	73.00	517.88	191.80
T ₅ (100% RDF + 1.5% humic acid)	44.40	68.93	616.00	228.14
T ₆ (125% RDF + 1.5% humic acid)	40.33	66.07	653.40	242.00
T ₇ (75% RDF + 2.5% humic acid)	59.97	73.87	492.00	182.22
T ₈ (100% RDF + 2.5% humic acid)	48.73	69.60	562.20	208.22
T ₉ (125% RDF + 2.5% humic acid)	45.73	66.73	596.00	220.73
T ₁₀ (100% RDF; 125:60:60 NPK kg ha ⁻¹)	52.80	71.47	526.33	194.93
'F' test	Sig.	Sig.	Sig.	Sig.
S.E (m) ±	1.82	1.72	18.36	6.80
CD (5%)	5.41	5.11	54.56	20.21

C. Available NPK in soil (kg ha⁻¹)

Available nitrogen (kg ha⁻¹): Available nitrogen varied significantly across treatments. The maximum available nitrogen of 135.2 kg ha⁻¹ was recorded in T₉ (125% RDF + 2.5% humic acid), while the lowest of 131.7 kg ha⁻¹ was in T₁ (75% RDF + 0.5% humic acid). In general, 125% RDF treatments retained more nitrogen than 75% and 100% RDF. This might be because T₉ supplied more nitrogen and humic

acid helped to hold nutrients and boost microbial activity, keeping nitrogen available. Lower nitrogen in T₁ was likely due to low fertilizer and humic acid dose. Similar trends were reported by Ibrahim *et al.* (2024) ^[8] and Ampong *et al.* (2022) ^[4] in broccoli.

Available phosphorus (kg ha⁻¹): The available phosphorus content in soil changed significantly with treatments.

Maximum available phosphorus of 17.86 kg ha⁻¹ was recorded in T₉; 125% RDF with 2.5% humic acid, which was at par with T₆ and T₃, while lowest of 14.86 kg ha⁻¹ was in T₁; 75% RDF with 0.5% humic acid. In general, treatments receiving higher RDF showed more phosphorus in soil. This may be because more phosphorus was added through 125% RDF and humic acid helped to reduce its fixation in soil and keep it in available form. Low available phosphorus in T₁ could be simply due to less fertilizer and low humic acid. Similar results were also reported by Wang *et al.* (1995) and Du *et al.* (2013) [6, 17].

Available Potassium (kg ha⁻¹): Available potassium differed significantly among treatments, with the maximum available potassium in soil, 360.0 kg ha⁻¹ recorded in T₉ (125% RDF + 2.5% humic acid) and the lowest of 353.0 kg ha⁻¹ in T₁ (75% RDF + 0.5% humic acid), and overall 125% RDF maintained more potassium than 75% and 100% RDF, possibly due to higher potassium input and humic acid improving retention and availability, while low values in T₁ were due to lower fertilizer and humic acid; similar results were reported by Selim and Mosa (2012) [15] and Ayyar (2018) [5].

Table 3: Effect of NPK and foliar application of humic acid on available NPK (kg ha⁻¹) in soil

Treatments	Available NPK (kg ha ⁻¹)		
	N	P	K
T ₁ (75% RDF + 0.5% humic acid)	131.7	14.86	353.0
T ₂ (100% RDF + 0.5% humic acid)	133.0	16.16	356.0
T ₃ (125% RDF + 0.5% humic acid)	134.0	16.86	358.0
T ₄ (75% RDF + 1.5% humic acid)	134.2	15.16	353.6
T ₅ (100% RDF + 1.5% humic acid)	132.0	16.36	356.5
T ₆ (125% RDF + 1.5% humic acid)	134.7	17.26	359.0
T ₇ (75% RDF + 2.5% humic acid)	132.2	15.36	354.0
T ₈ (100% RDF + 2.5% humic acid)	133.7	16.66	357.0
T ₉ (125% RDF + 2.5% humic acid)	135.2	17.86	360.0
T ₁₀ (100% RDF; 125:60:60 NPK kg ha ⁻¹)	132.7	15.86	356.3
'F' test	Sig.	Sig.	Sig.
S.E (m) ±	0.10	0.38	0.29
CD (5%)	0.31	1.15	0.87

D. Plant uptake

Nitrogen uptake: Nitrogen uptake varied significantly among the treatments, with maximum uptake of 129.09 kg ha⁻¹ in T₆ (125% RDF + 1.5% humic acid) which was at par with T₉ (125.81 kg ha⁻¹) and minimum uptake of 81.17 kg ha⁻¹ in T₁₀ (100% RDF alone); better uptake with 125% RDF + humic acid could be due to higher nitrogen availability and improved root growth and absorption by humic acid, while low uptake in T₁₀ was due to absence of humic acid, similar to Selim and Mosa (2012) and Selladurai and Purakayastha (2016) [14, 15].

Phosphorus uptake: Phosphorus uptake differed significantly, with maximum of 38.57 kg ha⁻¹ in T₆ (125% RDF + 1.5% humic acid) at par with T₉ (36.30 kg ha⁻¹) and minimum of 21.13 kg ha⁻¹ in T₁ (75% RDF + 0.5% humic

acid); higher uptake in T₆ may be due to more phosphorus supply and humic acid improving root growth and availability, while 1.5% to 2.5% humic acid did not give extra benefit, in line with Mohapatra *et al.* (2014) and Ibrahim *et al.* (2024) [8, 12].

Potassium uptake: Potassium uptake varied significantly among the treatments, with maximum uptake of 117.6 kg ha⁻¹ in T₆ (125% RDF + 1.5% humic acid) which was at par with T₉ (108.6 kg ha⁻¹) and minimum of 95.58 kg ha⁻¹ in T₁₀ (100% RDF alone); better uptake in T₆ could be due to higher potassium availability and humic acid improving root growth and nutrient retention, while 1.5% to 2.5% humic acid did not give extra benefit, in line with Selim and Mosa (2012), Mohapatra *et al.* (2014) [12, 15].

Table 4: Effect of NPK and foliar application of humic acid on plant uptake (kg ha⁻¹)

Treatments	Plant uptake (kg ha ⁻¹)		
	N	P	K
T ₁ (75% RDF + 0.5% humic acid)	84.66	21.13	95.66
T ₂ (100% RDF + 0.5% humic acid)	89.13	28.82	101.74
T ₃ (125% RDF + 0.5% humic acid)	109.82	32.96	105.70
T ₄ (75% RDF + 1.5% humic acid)	86.26	26.71	96.77
T ₅ (100% RDF + 1.5% humic acid)	91.04	34.30	103.79
T ₆ (125% RDF + 1.5% humic acid)	129.09	38.57	117.60
T ₇ (75% RDF + 2.5% humic acid)	78.07	26.05	99.13
T ₈ (100% RDF + 2.5% humic acid)	93.94	30.98	104.20
T ₉ (125% RDF + 2.5% humic acid)	125.81	36.30	108.60
T ₁₀ (100% RDF; 125:60:60 NPK kg ha ⁻¹)	81.17	28.94	95.58
'F' test	Sig.	Sig.	Sig.
S.E (m) ±	2.42	1.30	3.12
CD (5%)	7.18	3.86	9.28

Future Scope

The optimum dose, concentration, time of application and number of foliar sprays of humic acid along with varying levels of NPK in broccoli still needs to be standardized, and their effect should be studied in detail. There is also scope to test these combinations on different cultivars, in different seasons and under varied agro-climatic conditions to confirm the results on a broader scale. Future studies should also focus on the impact on soil properties, nutrient uptake, shelf life and post-harvest quality of broccoli as well as its economic viability under actual field conditions, which would require multi-season and multi-location trials beyond the present single-season investigation.

Conclusion

On the whole, among all the treatments, 125% RDF + 1.5% humic acid (T₆) was found to be the most effective. It recorded higher plant height, more leaves per plant, earlier curd initiation and earliest harvesting along with maximum curd yield per plant, yield per hectare and uptake of NPK by plant. For parameters like leaf area, stem diameter and available NPK in soil, 125% RDF + 2.5% humic acid (T₉) showed better results and gave maximum values.

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