



RESEARCH ARTICLE

# Standardization of NPK with fertigation in parthenocarpic cucumber under protected structure

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Received: 10 May 2025; Accepted: 29 August 2025; Available online: Version 1.0: 04 February 2026

**Cite this article:** Abhilash S, Dhirendra S, Imamuiddin S, Narendra PV, Abhishek Y, Ankit S, Kartik T, Ajay S. Standardization of NPK with fertigation in parthenocarpic cucumber under protected structure. *Plant Science Today*. 2026; 13(sp1): 1-6. <https://doi.org/10.14719/pst.9399>

## Abstract

The present experiment was undertaken to standardize NPK fertigation in cucumber under polyhouse at Vegetable Research Centre of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand during two consecutive seasons, i.e. Summer 2020 and Winter 2020–21. The experiment was designed as a factorial randomized block design with an additional treatment that included four fertigation levels: F<sub>1</sub> (120 % of RDF), F<sub>2</sub> (100 % of RDF), F<sub>3</sub> (80 % of RDF) and F<sub>4</sub> (60 % of RDF). Two fertigation schedules were also included: S<sub>1</sub>, which applied 25 % of each N, P and K between days 6 and 35 Days After Sowing (DAS), 36 and 65 DAS, 66 and 95 DAS and 96 and 125 DAS, respectively and S<sub>2</sub>, which applied 25 %, 15 % and 20 % of N, P and K of fertigation levels between 6 and 35 DAS, respectively, 40 %, 15 % and 25 % of N, P and K of fertigation levels between 36 and 65 DAS, respectively, 20 %, 50 % and 40 % of N, P and K of fertigation levels between 66 and 95 DAS, respectively and 15 %, 20 % and 15 % of N, P and K of fertigation levels between 96 and 125 DAS, respectively. One control group (application of RDF to the soil with floods) was also included in the experiment and it was provided three times. The results of this study showed that timing and varying drip fertigation levels had a substantial impact on parthenocarpic cucumber performance. The parthenocarpic cucumber fertigation at 120 % RDF (F<sub>1</sub>) was the best among the various fertigation levels in terms of plant development characteristics, nutrient content and nutrient uptake. On the other hand, fertigation at 100 % RDF (F<sub>2</sub>) was the most effective in terms of the yield parameter. The best and most cost-effective method for growing cucumbers in a polyhouse is to fertigate parthenocarpic cucumbers at a ratio of 100:50:50 kg N, P and K per hectare by scheduling.

**Keywords:** cucumber; fertigation; nutrient; parthenocarpy; yield

## Introduction

An important and common vegetable crop, cucumber (*Cucumis sativus* L.) is a member of the Cucurbitaceae family. It has been cultivated for 3000–4000 years, making it one of the earliest cultivated vegetable crops (1). Cucumber is thought to have originated in India from *Cucumis sativus* var. *hardwickii*, a progenitor of the developed cucumber which is found within the Himalayan foothills of India. It appears to have spread eastwards to China and westwards to Asia Minor from India. It is one of the foremost imperative and consumed vegetable crops widely grown in all the seasons, i.e. spring, summer, rainy and early autumn in all parts of India. Cucumber is a monoecious annual, trailing or climbing vine which is primarily cultivated for its edible fruits. Even though fresh cucumbers are mostly composed of water, they still pack a lot of nutrition. In salads, the fruit is also consumed raw. It is well recognized to avoid indigestion, jaundice and constipation.

Cucumber fruit contains 96.30 g of moisture, 0.49 g of protein, 0.10 g of calcium, 25 mg of phosphorous, 1.5 mg of iron, 0.20 mg of niacin, 0.03 mg of thiamine and 7 mg of vitamin C per 100 g edible portion of cucumber (2). It also contains caffeic acid and ascorbic acid, which makes a difference in diminishing skin irritation (3). Since cucumber is cultivated all over the world, the global area under its cultivation is 2.26 million hectares with a production of 91.26 million tonnes and a productivity of 40.37 t ha<sup>-1</sup> (4). China holds the rank 1<sup>st</sup> in both area and production of cucumber with an area of 1.28 million hectares and production of 72.83 million tonnes (4). In India, the harvested area and production of cucumber is 0.11 million hectares and 1.59 million tonnes, respectively with average productivity of 14.45 t ha<sup>-1</sup> (5). Since cucumber is relatively less popular in hilly region of Uttarakhand, researchers/farmers have revealed that it can be popular very fast in this region due to its year-round cultivation in protected structures. It also possesses high

cultivation potential in hills as well as plains of Uttarakhand because it can give high benefits per unit area.

In India, polyhouse agriculture is still a relatively young and developing method of raising vegetables, but the primary method of producing cucumbers is open-field farming. Parthenocarpic and gynoecious cucumber cultivars have high yield potential in controlled environments, resulting in a high harvest index. For off-season farming, plastic tunnels and protected culture have been the most common methods. However, insufficient fertilization in greenhouses has resulted in significant soil salinization and low crop yields in recent years (6). Generally, a protected structure provides controlled environmental conditions and protection from heavy rain, pests and harmful radiation. The various protected structures i.e., green shed net, insect-proof net, polyhouses, etc., are used to protect high-value crops from insect-pest, diseases, extreme winds and very high and low temperatures (7). Moreover, these structures facilitate longer utilization of nutrients from the soil (8).

As the irrigation water is limited, its efficiency may depend upon the adoption of improved irrigation methods, such as pressurized irrigation systems. These methods minimize loss through runoff, evaporation and conveyance. As a result of the trickle irrigation method's adaptation with only partial soil wetting, crop root system distribution became mostly restricted to the wetted zone. These restricted root systems significantly alter traditional fertilization techniques. To meet the nutrient requirements of the trickle-irrigated crop, the practice of broadcast fertilizer application was replaced by banded fertilization or fertilizer applied through the irrigation water. Drip irrigation is one of the efficient and effective methods of irrigation, having about 90 % water application efficiency. It is a type of micro-irrigation that has the potential to save nutrients as well as water by allowing water to drip slowly to near root zones of plants and minimize evaporation and leaching and other losses. Water is distributed using drip irrigation systems using a series of emitters, valves, pipes and tubing. Effective use of water and fertilizer is essential to maintaining agricultural output, especially considering pollution, rising fertilizer costs and dwindling per capita land and water availability. Fertigation may contribute significantly to crop productivity in this scenario. Fertigation is an effective technique for applying fertilizer via irrigation systems, which distribute and transport crop nutrients (9).

Nitrogen, phosphorus and potassium are the three main plant nutrients that are essential to the process of growth and development. Enhancing plants' nitrogen use also depends on the fertilizer's quantity and application technique. A significant amount of fertilizer may not be available to the crop with the traditional fertilizer application method since most nutrients are fixed or lost in the soil when they contact with a huge quantity of soil, which lowers the crop's nutrient availability. Improved efficiency of nutrients in crops may be possible if the fertilizers are applied at the right time of their requirement in the right amount at the right place and in the right manner. Fertigation, providing fertilizers together with a water system, is one of the foremost, viable and helpful methods for providing supplements with water according to the necessities of the crop to preserve ideal soil fertility and to extend the quality of the delivery. Fertigation is the foremost effective strategy of fertilizer application, because it guarantees application of the fertilizers specifically to the plant roots (10).

In cucumber, giving the indicated climate for crop is not adequate since other variables like planting time and supplement

composition, particularly nitrogen is too known to have a definitive part in effective generation with upgraded efficiency by means of influencing sex expression. Exceptionally few reports are accessible on cucumber production under secure conditions in India. Subsequently, a performance trial was carried out to find the right fertilizer doses for cucumber variety Infinity under polyhouse conditions. Despite the levels of fertilizers (F) and schedules of fertilizer applications employed in this research, which are conveniently accessible and potentially cost-effective for agricultural production, the primary objective of this study is to standardize NPK with fertigation in parthenocarpic cucumber under protected conditions. The main aim of this experiment is to increase the farmers' profit for providing quality fruit yield with suitable fertilizer timings and a good amount of fertilizer dose.

## Materials and Methods

### Experimental site and weather conditions

The experiment was carried out at Vegetable Research Centre, G B Pant University of Agriculture and Technology, during two cropping seasons of 2020 (summer season and winter season) under Natural Ventilated Polyhouse (NVPH) conditions. The Vegetable Research Centre is situated in the geographical regions of 29°00' N latitude and 79°18' E longitude, where it is 243.84 m above mean sea level. Pantnagar lies in the humid sub-tropical zone and is situated in the Tarai region at the foothills of the Shivalik range of the Himalayas. Pantnagar has a humid sub-tropical climate, with summer temperatures reaching 33–44 °C and winter temperatures falling between 0 °C and 10 °C. The summers are hot and humid, winter is too cold and frost can be expected from the last week of December to the last week of January. The occurrence of monsoon is mostly noticed from the last week of June and continues up to the mid of September and the maximum rainfall was received during this period. The average annual rainfall was approximately 1300 mm. The soil was clay, loam having pH 7.0–7.5.

### Experimental materials and technical details of the experiment

The Infinity variety of cucumber was used as experimental material in this research. The experiment was laid out in a Factorial Randomized Block Design (FRBD) with 2 factors, viz., fertigation levels (F) and scheduling of fertigation levels (S). The first factor of fertigation levels were 120 % RDF (F<sub>1</sub>), 100 % RDF (F<sub>2</sub>), 80 % RDF (F<sub>3</sub>) and 60 % RDF (F<sub>4</sub>) whereas, the second factor of scheduling levels of fertigation were divided into two part and these parts of scheduling (S<sub>1</sub> and S<sub>2</sub>) have four crop growth stage (06–35 DAS, 36–65 DAS, 66–95 DAS and 96–125 DAS) with eight split doses of NPK. In the first level of scheduling (S<sub>1</sub>) at all growth stages, the same amount of NPK (25 %) was applied. While, in second level of scheduling (S<sub>2</sub>) different doses were applied in different stages i.e., at first growth stage, 25 % N, 15 % P and 20 % K, at second growth stage, 40 % N, 15 % P and 25 % K, at third growth stage, 20 % N, 50 % P and 40 % K and at fourth growth stage, 15 % N, 20 % P and 15 % K were applied through fertigation. Apart from these, a control (soil application of RDF with surface irrigation) was also used to compare all eight treatments in this experiment. The seeds of cucumber were sown on 16 March 2020 and 3 October 2020. The seeds were sown in lines at a spacing of 60 × 50 cm within the lines with a depth of 2.0–2.5 cm.

### Agronomic and cultural operations

The soil of the experimental field was prepared by the preparatory

tillage operations viz., ploughing, harrowing and levelling. The field was levelled and then split into 12 m<sup>2</sup> (20 m × 0.60 m) size. At the time of field preparation, 10 % of the recommended dose of NPK was applied as a starter dose in the form of urea, DAP and MOP. Manure in the form of FYM @ 20 t ha<sup>-1</sup> was also applied at the time of field preparation. The whole amount of P and K as well as half of the N dose were applied as a basal method in the case of the traditional fertilization approach. Two splits of the remaining nitrogen dosage were provided at 30 and 70 DAS. Cucumber vines were trained with plastic strings fixed on hanging wire installed horizontally at 10 ft above the ground along with length of planting bed. Plants of cucumber started tying after three weeks, tying started at 10 cm above ground level. Two healthy branches were retained and other overcrowded branches were pruned after 30 days of sowing. The quantity of water applied through drip once in a day during summer and thrice in a week during winter. The cultural operations like weeding, spraying of chemicals against diseases and insect pests etc. were applied whenever needed. Drenching with Fungicides Carbendazim 70 % WP @ 2.5 g L<sup>-1</sup> of water was used to prevent the incidence of damping off. To control downy mildew disease in cucumber Mancozeb 64 % WP @ 2 g in 1 L of water was sprayed, to avoid the incidence of pest like jassid and aphids one spray of Thiomethoxam 25 WG @ 4 g/10 L of water was used and Imidachloprid was also used to counter the attack of aphids.

### Growth and yield parameters

The observations on growth and yield parameters in cucumber measured in 5 randomly selected tagged plants includes vine length (cm), germination percentage, days to 50 % of flowering, number of nodes per vine, stem diameter (mm), internodal length (cm), days to fruit setting, number of fruits per vine, fruit length (cm), fruit diameter (cm), fruit yield per vine (kg) and fruit yield (t ha<sup>-1</sup>). The vine length of five randomly selected plants was measured in centimetres through centimetre scale at final DAS. Days to 50 % of flowering measured by number of days taken after sowing of plants to the flowering of 50 % of the plants was counted and recorded for each treatment. Total number of nodes for each observational vine was counted at 90 DAS and at the time of final harvesting and their mean was computed. The stem and fruit diameter of each tagged plant was recorded with the help of vernier calliper and takes the mean of diameter and expressed in mm). The internodal and fruit length were recorded for each treatment with the help of measurement scale at the time of final harvesting and expressed in centimetres. The minimum days of fruit setting taken by 50 % of plants in a plot to fruit was observed. At each time of fruit picking, the quantity of fruits in each vine from each observation plot was noted. Weighing the total number of fruits from each observed vine and adding the weights of all the plucked fruits helped us find the fruit weight in each vine according to treatment. The germination percentage and fruit yield tonnes per hectare was calculated by using following formula:

Germination percentage =

$$\frac{\text{Seeds germinated}}{\text{Number of seed sown}} \times 100 \quad (\text{Eqn. 1})$$

$$\frac{\text{Fruit yield} = \text{Fruit weight (kg per plant)}}{1000} \times \text{No. of plants} \quad (\text{Eqn. 2})$$

### Statistical analysis

The collected data underwent statistical analysis and were subjected to variance analysis using the appropriate methodology as outlined by previous researchers (11). The significant difference among the treatments were tested as per ANOVA table suggested for factorial design for two factors by MS Excel and AGRISTAT software.

## Results

### Effect of fertilizer levels on growth and yield parameters

Data on growth and yield parameters included vine length (cm), days to 50 % flowering, number of nodes per vine, stem diameter (mm), internode length (cm), days to fruit setting, number of fruits per vine, fruit length (cm), fruit diameter (cm), fruit yield per vine (kg) and fruit yield (t ha<sup>-1</sup>) at different stages of growth after sowing, which were significantly affected by varying levels of NPK fertigation during both seasons of the study except germination percentage (Table 1a, b).

During both seasons (summer and winter), at the time of final harvesting, fertigation with 120 % RDF resulted in maximum vine lengths of 296.37 cm and 299.19 cm, followed by 100 % RDF with vine lengths of 279.15 cm and 281.33 cm, respectively. In the summer season (first season), the fewest days taken for 50 % flowering were noted in F<sub>4</sub> (39 DAS). Similarly, in the winter season, the minimum number of days for 50 % flowering was recorded in F<sub>4</sub>, followed by F<sub>3</sub> (39 DAS). Data from both summer and winter harvests revealed that F<sub>1</sub> (28.57 and 29.53) had the highest number of nodes per vine, with values of 28.57 and 29.53 for the respective seasons. Among the different fertigation levels tested, maximum stem diameter (12.12 mm) and internodal length (12.21 mm) were measured in F<sub>1</sub> during both seasons. Among the fertigation levels examined, the fewest days required for fruit to set were noted in F<sub>4</sub> (37 DAS and 36 DAS), followed by F<sub>3</sub> (39 DAS and 37 DAS) for both seasons. The highest values for the number of fruits per vine (22.48 and 23.35), fruit length (16.68 cm and 17.33 cm), fruit diameter (4.23 cm and 4.27 cm), fruit yield per vine (3.12 kg and 3.27 kg) and total fruit yield (103.92 t and 109.14 t) were observed in F<sub>2</sub> among the various drip fertigation levels examined in both seasons, namely summer and winter. Among the treatments, all parameters were found to be superior in comparison to the control during both seasons.

### Effect of scheduling levels of fertilizers on growth and yield parameters

Among the scheduling levels, significant effect on all growth and yield parameters except for germination percentage, stem diameter (mm), internodal length (cm), days to fruit setting, fruit length (cm) and fruit diameter (cm), were recorded at various stages of growth after sowing, which were significantly affected by varying levels of scheduling during both seasons of the study (Table 1a, b).

During both season (summer and winter), maximum vine length (272.27 cm and 275.17 cm), germination percentage (97.76 % and 98.31 %) number of nodes per vine (28.20 and 28.81), stem diameter (11.16 mm and 11.42 mm), internode length (10.00 cm and 10.20 cm), number of fruits per vine (20.47 and 21.37), fruit length (15.95 cm and 16.34 cm), fruit diameter (4.19 cm and 4.19 cm), fruit yield per vine (2.71 kg and 2.85 kg) and fruit yield (90.40 t and 95.04 t) were recorded under S<sub>2</sub> were superior over S<sub>1</sub>. While days to 50 % flowering (42 DAS and 41 DAS) and days to fruit setting (40 and 38 days) showed minimum value during both seasons.

**Table 1a.** Effect of fertigation levels (NPK) and its scheduling on vine length, germination percentage, days to 50 % of flowering, number of nodes per vine, stem diameter and Internodal length in plant

Treatments	Vine length (cm)		Germination percentage		Days to 50 per cent of flowering		Number of nodes per vine		Stem diameter (mm)		Internodal length (cm)	
	Summer season	Winter season	Summer season	Winter season	Summer season	Winter season	Summer season	Winter season	Summer season	Winter season	Summer season	Winter season
<b>Fertigation levels</b>												
F <sub>1</sub>	296.37 <sup>a</sup>	299.19 <sup>a</sup>	98.04 <sup>a</sup>	99.02 <sup>a</sup>	46 <sup>a</sup>	44 <sup>a</sup>	28.57 <sup>a</sup>	29.53 <sup>a</sup>	12.12 <sup>a</sup>	12.21 <sup>a</sup>	10.93 <sup>a</sup>	11.24 <sup>a</sup>
F <sub>2</sub>	279.15 <sup>b</sup>	281.33 <sup>b</sup>	97.89 <sup>a</sup>	98.44 <sup>ab</sup>	44 <sup>b</sup>	42 <sup>b</sup>	27.99 <sup>ab</sup>	28.37 <sup>ab</sup>	11.07 <sup>ab</sup>	11.48 <sup>ab</sup>	10.19 <sup>ab</sup>	10.49 <sup>ab</sup>
F <sub>3</sub>	260.29 <sup>c</sup>	263.10 <sup>c</sup>	97.69 <sup>a</sup>	98.03 <sup>ab</sup>	41 <sup>c</sup>	39 <sup>c</sup>	25.92 <sup>bc</sup>	26.41 <sup>ab</sup>	10.21 <sup>b</sup>	10.61 <sup>b</sup>	9.44 <sup>bc</sup>	9.70 <sup>bc</sup>
F <sub>4</sub>	241.44 <sup>d</sup>	244.31 <sup>d</sup>	97.30 <sup>a</sup>	97.64 <sup>b</sup>	39 <sup>d</sup>	38 <sup>d</sup>	24.56 <sup>c</sup>	25.04 <sup>b</sup>	9.93 <sup>b</sup>	10.25 <sup>b</sup>	8.73 <sup>c</sup>	9.02 <sup>c</sup>
SE(m) ±	0.72	0.58	0.49	0.36	0.24	0.21	0.71	1.09	0.42	0.43	0.38	0.43
CD (5 %)	2.14	1.74	NS	NS	0.71	0.63	2.14	3.28	1.27	1.29	1.13	1.27
<b>Scheduling</b>												
S <sub>1</sub>	266.36 <sup>b</sup>	268.80 <sup>b</sup>	97.70 <sup>a</sup>	98.25 <sup>a</sup>	43 <sup>a</sup>	41 <sup>a</sup>	25.31 <sup>b</sup>	25.87 <sup>b</sup>	10.51 <sup>a</sup>	10.86 <sup>a</sup>	9.65 <sup>a</sup>	10.03 <sup>a</sup>
S <sub>2</sub>	272.27 <sup>a</sup>	275.17 <sup>a</sup>	97.76 <sup>a</sup>	98.31 <sup>a</sup>	42 <sup>b</sup>	41 <sup>a</sup>	28.20 <sup>a</sup>	28.81 <sup>a</sup>	11.16 <sup>a</sup>	11.42 <sup>a</sup>	10.00 <sup>a</sup>	10.20 <sup>a</sup>
SE(m) ±	0.51	0.41	0.34	0.25	0.17	0.15	0.51	0.77	0.30	0.30	0.27	0.30
CD (5 %)	1.52	1.23	NS	NS	0.49	0.44	1.52	2.32	NS	NS	NS	NS
<b>Control vs Rest</b>												
Control	220.09 <sup>b</sup>	221.81 <sup>b</sup>	97.21 <sup>a</sup>	97.55 <sup>a</sup>	46 <sup>a</sup>	45 <sup>a</sup>	22.35 <sup>b</sup>	23.54 <sup>b</sup>	9.41 <sup>b</sup>	9.73 <sup>b</sup>	8.15 <sup>b</sup>	8.37 <sup>b</sup>
Rest	269.31 <sup>a</sup>	271.98 <sup>a</sup>	97.73 <sup>a</sup>	98.28 <sup>a</sup>	42 <sup>b</sup>	41 <sup>b</sup>	26.76 <sup>a</sup>	27.34 <sup>a</sup>	10.83 <sup>a</sup>	11.14 <sup>a</sup>	9.82 <sup>a</sup>	10.11 <sup>a</sup>
SE(m) ±	0.76	0.62	0.52	0.38	0.25	0.22	0.76	1.16	0.45	0.46	0.40	0.45
CD (5 %)	2.27	1.85	NS	NS	0.76	0.66	2.27	3.48	1.34	1.37	1.20	1.35
<b>Interaction (F × S)</b>												
SE(m) ±	1.01	0.82	0.69	0.50	0.34	0.30	1.01	1.55	0.60	0.61	0.53	0.60
CD (5 %)	3.03	2.47	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

**Table 1b.** Effect of fertigation levels (NPK) and its scheduling on days to fruit setting, number of fruits per vine, fruit length, fruit diameter, fruit yield per vine and fruit yield in plant

Treatments	Days to fruit setting		Number of fruits per vine		Fruit length (cm)		Fruit diameter (cm)		Fruit yield per vine (kg)		Fruit yield (t ha <sup>-1</sup> )	
	Summer season	Winter season	Summer season	Winter season	Summer season	Winter season	Summer season	Winter season	Summer season	Winter season	Summer season	Winter season
<b>Fertigation levels</b>												
F <sub>1</sub>	44 <sup>a</sup>	42 <sup>a</sup>	21.43 <sup>a</sup>	22.04 <sup>a</sup>	16.02 <sup>ab</sup>	16.29 <sup>b</sup>	4.19 <sup>a</sup>	4.22 <sup>a</sup>	2.84 <sup>b</sup>	2.95 <sup>b</sup>	94.62 <sup>b</sup>	98.21 <sup>b</sup>
F <sub>2</sub>	41 <sup>b</sup>	39 <sup>b</sup>	22.48 <sup>b</sup>	23.35 <sup>b</sup>	16.68 <sup>a</sup>	17.33 <sup>a</sup>	4.23 <sup>a</sup>	4.27 <sup>a</sup>	3.12 <sup>a</sup>	3.27 <sup>a</sup>	103.92 <sup>a</sup>	109.14 <sup>a</sup>
F <sub>3</sub>	39 <sup>c</sup>	37 <sup>bc</sup>	19.04 <sup>c</sup>	20.18 <sup>c</sup>	15.43 <sup>bc</sup>	15.64 <sup>bc</sup>	4.14 <sup>ab</sup>	4.17 <sup>ab</sup>	2.47 <sup>c</sup>	2.63 <sup>c</sup>	82.18 <sup>c</sup>	87.75 <sup>c</sup>
F <sub>4</sub>	37 <sup>d</sup>	36 <sup>c</sup>	17.91 <sup>d</sup>	18.85 <sup>d</sup>	14.92 <sup>c</sup>	15.08 <sup>c</sup>	4.07 <sup>b</sup>	4.08 <sup>b</sup>	2.27 <sup>d</sup>	2.40 <sup>d</sup>	75.75 <sup>d</sup>	79.90 <sup>d</sup>
SE(m) ±	0.30	0.94	0.21	0.20	0.24	0.31	0.03	0.04	0.03	0.03	0.92	1.08
CD (5 %)	0.89	2.82	0.63	0.60	0.72	0.94	0.10	0.13	0.08	0.10	2.75	3.25
<b>Scheduling</b>												
S <sub>1</sub>	41 <sup>a</sup>	38 <sup>a</sup>	19.96 <sup>b</sup>	20.84 <sup>b</sup>	15.57 <sup>a</sup>	15.82 <sup>a</sup>	4.12 <sup>a</sup>	4.18 <sup>a</sup>	2.63 <sup>b</sup>	2.77 <sup>b</sup>	87.83 <sup>b</sup>	92.46 <sup>b</sup>
S <sub>2</sub>	40 <sup>a</sup>	38 <sup>a</sup>	20.47 <sup>a</sup>	21.37 <sup>a</sup>	15.95 <sup>a</sup>	16.34 <sup>a</sup>	4.19 <sup>a</sup>	4.19 <sup>a</sup>	2.71 <sup>a</sup>	2.85 <sup>a</sup>	90.40 <sup>a</sup>	95.04 <sup>a</sup>
SE(m) ±	0.21	0.67	0.15	0.14	0.17	0.22	0.02	0.03	0.019	0.02	0.65	0.77
CD (5 %)	NS	NS	0.45	0.43	NS	NS	NS	NS	0.058	0.07	1.94	2.30
<b>Control vs Rest</b>												
Control	44 <sup>a</sup>	42 <sup>a</sup>	16.73 <sup>b</sup>	17.89 <sup>b</sup>	14.67 <sup>b</sup>	14.89 <sup>b</sup>	4.00 <sup>b</sup>	4.00 <sup>b</sup>	2.09 <sup>b</sup>	2.24 <sup>b</sup>	69.55 <sup>b</sup>	74.59 <sup>b</sup>
Rest	40 <sup>b</sup>	38 <sup>b</sup>	20.21 <sup>a</sup>	21.11 <sup>a</sup>	15.76 <sup>a</sup>	16.08 <sup>a</sup>	4.16 <sup>a</sup>	4.18 <sup>a</sup>	2.67 <sup>a</sup>	2.81 <sup>a</sup>	89.12 <sup>a</sup>	93.75 <sup>a</sup>
SE(m) ±	0.32	1.00	0.22	0.21	0.26	0.33	0.04	0.04	0.03	0.03	0.97	1.15
CD (5 %)	0.95	2.99	0.67	0.64	0.77	1.00	0.11	0.13	0.09	0.10	2.91	3.45
<b>Interaction (F × S)</b>												
SE(m) ±	0.42	1.33	0.30	0.57	0.34	0.44	0.05	0.06	0.04	0.05	1.30	1.53
CD (5 %)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

**Interaction effect**

Among the parameters, all at different stages of growth after sowing were found to have a non-significant effect by using different levels of NPK fertigation and its scheduling during both seasons of the study, except vine length (Supplementary Table 1, 2).

**Discussion**

The data on growth and yield parameters at different stages, which were significantly affected by various levels of NPK with fertigation during both seasons of the study. It was found that as the level of fertigation increased, vine length, internodal length and stem diameter also increased. This may be because higher fertigation levels are applied as they are believed to improve the nutritional

environment in the root zone and the entire plant system. Additionally, it may be due to the complete mobility, solubility and availability of nutrients at regular intervals in required quantities because of nutrient partitioning (12), which enhances the absorption of nutrients by plants and promotes better growth and development. An increased vine length due to the application of 150 kg N per hectare in cucumber cv. Himangi was reported earlier (13). Significantly lower number of days required for 50 % of flowering, maximum internodal distance was noticed with higher fertigation level (120 % RDF through fertigation) because of prolonged vegetative growth. Low fertility with drip irrigation may be the reason. Under naturally ventilated polyhouses, it delayed the maturity of cucumbers and increased their vegetative growth (14,15).

When compared to 100-50-50 kg ha<sup>-1</sup>, the fruit length initially increased and then diminished, indicating that excessive fertilizer application ultimately reduced fruit length (16–18). The different levels of fertigation show a significant effect on the diameter of fruit. This may be due to nutrients supplied in fertigation in the required form have helped in efficient uptake, resulting in increased diameter of the fruits. Previous studies recorded increases in diameter of fruit with increasing dose of fertilizer up to a certain extent in cucumber (15,17,18). Due to balanced NPK application in all the crop period, which improves the availability and uptake of nutrients by plants and fruit. The highest yield under S<sub>2</sub> may be ascribed to an improvement in all yield-related traits. Furthermore, it is clear from the data that the scheduling S<sub>2</sub> had a larger maximal NPK uptake of plants and fruit (19). The different levels of NPK with fertigation significantly influenced the growth and yield of cucumber. The maximum levels of fertigation enhanced the vine length, internodal length and fruit diameter due to improved nutrient availability. However, an excessive fertilization level reduced the fruit length. Optimal fertigation scheduling with S<sub>2</sub> ensured the balanced uptake of nutrients, which maximize the growth and yield of the plant.

## Conclusion

The level of fertigation schedule S<sub>2</sub> was found the most economical method for growing cucumber in polyhouse structure based on overall performance. 25 %, 15 % and 20 % of recommended doses of nitrogen, phosphorus and potassium were applied from 6 to 35 DAS, 40 %, 15 % and 25 % from 36 to 65 DAS, 20 %, 50 % and 40 % from 66 to 95 DAS and 15 %, 20 % and 15 % from 96 to 125 DAS. It is recommended that commercial cucumbers be grown in polyhouse using this fertigation technique. Secondly, it was also observed that cultivation of cucumber is more profitable during winter season under polyhouse because it is off season for cucumber, so the rate of cucumber was almost double in comparison to summer season. So, it could be more beneficial for farmers to grow cucumber under polyhouse especially in winter season.

## Acknowledgements

Authors are thankful to all the teaching and non-teaching staff of the Department of Vegetable Science, G B Pant University of Agriculture and Technology for providing necessary technical guidance and financial support for the successful research work.

## Authors' contributions

AS<sup>1</sup> conducted the field trial, performed data analysis and drafted the manuscript. DS advised and critically supervised the entire research work. IS assisted with the field trial, manuscript drafting and data analysis. NPV contributed to manuscript drafting and editing. AY assisted in manuscript editing and data analysis. AS<sup>2</sup> contributed to manuscript drafting, editing and final revision. KT assisted in manuscript editing and AS<sup>3</sup> contributed to manuscript editing. All authors read and approved the final manuscript. [AS<sup>1</sup>- Abhilash Singh; AS<sup>2</sup>- Ankit Singh; AS<sup>3</sup>- Ajay Singh].

## Compliance with ethical standards

**Conflict of interest:** Authors do not have any conflict of interests to declare.

**Ethical issues:** None

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