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Growth and Yield of Bitter Gourd as Influenced by Inorganic Fertilizers in High Tunnel with Drip Irrigation System

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ABSTRACT

Purpose: *Bitter gourd (Momordica charantia L.) is one of the most important crops cultivated in the tunnel. However, its yield and quality are severely deteriorated by practicing non-judicious and untimed application of fertilizers. A study was envisaged to investigate the effect of fertilizer application at specific times on the production of off-season bitter gourd (PALEE F1 hybrid) in high tunnels.*

Research Method: *This study was conducted at the Nuclear Institute for Food and Agriculture (NIFA). The fertilizers (10-15 kg NPK ha^{-1}) were applied at 7, 14, and 21-day intervals starting from crop establishment till mid of July. The study was comprised of four treatments and three replicates and was carried out under a Randomized Complete Block Design (RCBD).*

Findings: *The results revealed that the maximum marketable bitter gourd yield (2047 kg/ 250 m^2 tunnel) was recorded in the treatment receiving NPK at 10-10-15 kg ha^{-1} as fertigation at 7-day intervals. Meanwhile, the minimum bitter gourd yield (392 kg/ 250 m^2) was recorded in control (no NPK fertilizer applied). Maximum straw yield (44 kg/ 250 m^2) and highest N, P & K uptake (7.05, 1.12 & 13.32) kg/ 250 m^2 tunnel were recorded in bitter gourd with the NPK application at 7 days intervals.*

Research Limitations: *The crop in tunnels needs optimum vigilance and laborious work. The optimum utilization of technical labor is considered to be a limitation.*

Originality/ Value: *The judicious and well-timed application of a balanced fertilizer regimen may serve as a more effective approach to achieve enhanced crop productivity and quality goals.*

Keywords: *Bitter Gourd, Crop Productivity, Fertigation, Inorganic Fertilizer, Mineral content, Tunnel Farming.*

INTRODUCTION

Bitter gourd (*Memordica charantia* L.) locally named Karela or bitter melon is a climber and belongs to the Cucurbitaceae family (Grover and Yadav, 2004). It is comprised of vitamins (B1, B2, B3 and C), minerals [Zinc (Zn), Iron (Fe), Phosphorus (P), Potassium (K), Manganese (Mn) and Calcium (Ca)], carbs and proteins, resultantly has several medicinal (blood detoxification, immunity boosting and weight control), nutritional and other excellent health benefits; therefore, it has a high market demand as being used for making juice and for culinary purpose (Akter*et al.*, 2009). In Pakistan, bitter gourd is cultivated on 6709 hectares of land with an approximate annual production of 120220 tonnes, while in Khyber Pakhtunkhwa (KP) the cultivated area is 1067 hectares yielding 12338 tonnes annual production (Statistics of Pakistan 2021-22). The cultivation of vegetables holds significant importance in ensuring the nutritional and economic stability of small-scale and marginalized farmers in countries like Pakistan and Sri Lanka. Enhanced productivity and profitability through vegetable cultivation are imperative to ensure the sustenance of farmers.

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Therefore, in current scenarios of water and fertilizer deprivation, judicious utilization is of main concern to enhance production and productivity. The utilization of suitable technology exerts a positive influence on the productivity of crops, the quality of agricultural produce, the economic aspects of production, and the overall environmental conditions. Tunnels are transparent coverings strategically placed over the beds of transplanted vegetables (Rajiv and Kumari, 2023). Their purpose is to optimize plant growth by creating a microclimate that effectively warms the surrounding air in the tunnel, particularly during the winter season (Sadek and Youssef, 2019).

In addition to their capacity to increase soil temperature, these protective coverings offer shielding effects against hails, cold winds, and potential harm to plants (Gude *et al.*, 2022). Furthermore, they have the potential to expedite crop development by approximately 30 to 40 days compared to the standard growing season. The utilization of this economically viable technology for cultivating cucurbits such as muskmelon, round melon, long melon, bitter gourd, bottle gourd, and summer squash during the off-season demonstrates its suitability and potential cost-effectiveness for growers in the northern regions of the country. This is particularly relevant in areas where the nocturnal temperatures during the winter season consistently fall below 8 °C for an extended duration of 30-40 days.

Fertigation is a highly efficient technique employed in agriculture, wherein the application of fertilizer is seamlessly integrated into the irrigation process through the utilization of a drip irrigation system. In this system, the fertilizer solution is uniformly distributed throughout the irrigation process. The nutrient availability exhibits a significant elevation, thereby resulting in enhanced efficiency (Wang *et al.*, 2023). Adaptation of micro irrigation systems like responsive drip irrigation systems saves 40 to 60% of water with almost a 15 to 30% increase in crop production (Sidhu*et al.*, 2021). Bitter gourd is one of the leading vegetable crops in Pakistan and farmers prefer this crop due to its higher yield and maximum return. The use of fertigation has demonstrated promising outcomes globally in terms of enhanced fertilizer utilization efficiencies, improved produce quality, and notable environmental benefits (Martínez-Dalmau *et al.*, 2021).

To optimize crop productivity, it is a common practice among farmers to frequently add nitrogenous fertilizers in conjunction with irrigation, often without adhering to research-derived guidelines. The excessive application of fertilizers leads to a decline in plant vitality and heightened vulnerability to plant pathogens and pests within a high tunnel environment. Excessive nitrogen fertilization has the potential to elicit the occurrence of blossom-end rot in various crops, i.e., tomatoes (Reitz *et al.*, 2021). Furthermore, it may promote vigorous vegetative development, thereby compromising overall productivity. The timing of fertilizer application has been demonstrated to be of utmost importance to attain optimal yield of bitter gourd (Ghimire *et al.*., 2023). The optimal utilization of the inherent capabilities of any given crop cultivated can only be achieved through implementing prudent water and fertilizer management techniques (Hari and Devi, 2016). The present study aimed to evaluate the fertigation requirement of bitter gourd under tunnel conditions at NIFA, Peshawar, and their impact on yield performance of bitter gourd cultivation under drip fertigation.

MATERIALS AND METHODS

The study comprising three treatments (NPK fertigation at 10-10-15 kg ha-1 at 7, 14, and 21days intervals) and a control (without application) was conducted in a high tunnel measuring 8.5 m × 37 m. with 3.5 m high fitted with polyethylene plastic and 1.8 m roll-up sides at Nuclear Institute for Food and Agriculture (NIFA), Peshawar. The experiment was laid out in a Randomized Complete Block (RCB) design having four treatments and three replicates. A nursery of the F1 hybrid of bitter gourd cultivar "PALEE" was raised in plastic tubes (6 cm x 4 cm) for 30 days and they were transplanted in the tunnel at 120 cm x 30 cm plant to plant and row to row distance. After plant establishment, fertigation was performed according to the treatment plan.

The weeds and insects were culturally managed in each treatment. Bitter gourd fruits were collected from each treatment plot on each harvest (Total of 14 pickings) and the total yield was calculated as the summation of each harvest. Plant samples (fruit and straw) were washed initially with tap water and then distilled water to remove the dust and other impurities, oven-dried at 70ºC until constant weight, and ground using a stainless steel grinder. Different soil samples collected from 0-30 cm depth from each treatment plot were air dried, ground, sieved through 2 mm mesh, and mixed to formulate a composite sample labeled and stored in plastic containers. Particle size analysis was done using the hydrometer method (Bouyoucos, 1962). Soil bulk density was measured using the core method and lime contents were measured using the method of Mclean (1982). The soil organic matter, total N, and Olsen's P were determined according to the method of Nelson and Sommers (1983), Bremner and Mulvaney (1982), and Okalebo *et al.* (2002), respectively.

Soil potassium and plant potassium were determined using a flame photometer (Watanabe and Olsen 1965). Organic carbon content in the soil was determined through a dichromate approach, using combustion at 160°C for 30 minutes (Allison, 1960). Nitrogen in plant samples was determined using the Kjeldahl apparatus, according to Gunning and Hibbard's method (Jackson, 1962). Total phosphorus in the plant was determined by analyzing the samples through a spectrophotometer at 400 nm (Watanabe and Olsen 1965). The data were analyzed statistically, and treatment means were compared by employing Duncan's multiple range test at a 5% probability level. The results obtained were subjected to statistical analysis using the computer software MSTATC (Freed and Scott, 1986). The differences among the treatment means were compared using the LSD test (Steel *et al.*, 1997).

RESULTS AND DISCUSSION

The soil of the experimental tunnel was loam to clay loam (Inceptisol, Typic Calciustepts) and found deficient in organic matter, nitrogen, and phosphorus. Before the establishment of the experiment, the composite soil samples were collected from various depths viz. 0-15 and 15-30 and analyzed for various physico-chemical properties (Table 1). The analysis of the soil particle size indicated that the proportion of sand, silt, and clay in the soil profile ranged between 21% and 42%, 32 and 42%, and 26 and 37% respectively. The amount of organic C in the surface 0-15 cm was 0.54%, which gradually decreased to 0.28%. The amount of total N was 0.05% in the 0-15 cm to 0.032% in 15-30 cm. The available phosphorus was 7.5 µg P g^{-1} in the 0-15 cm and decreased to 5.9 µg P g^{-1} in 15-30 cm depth. The soil was alkaline in reaction (pH 7.9-8.0), non-saline (EC 0.24-0.25 dSm^{-1}), moderately calcareous in nature (14.5 to 15.0% lime), having bulk density 1.43 to 1.45 Mg/m^3. The site is 525 m above mean sea level and has a cool climate in winter and warm to hot in the summer and comes under a semi-arid climatic zone.

Plant Height, Fruit Length, Size, and Single Fruit Weight

The results of agronomic parameters of bitter gourd as influenced by varying NPK intervals are presented in Table 2. The analysis of variance illustrated that different intervals of NPK fertilizer had a significant ($P<0.05$) effect on the plant height, fruit length, fruit size, and single fruit weight of bitter gourd. The highest length of 328 cm was found at 7 days of fertigation interval treatment and it was statistically different from all other treatments while the minimum (160 cm) was recorded in control.

The longer fruit length 24.5 cm was found in fertigation treatment at 7 days interval followed by 22.0 cm in fertigation treatment at 14 days interval. The least length (20.3 cm) and lower number of fruits per row were obtained in fertigation treatment at 21-day intervals compared to other treatments. Sanap *et al.* (2010) reported that the application of 250 kg N, 50 kg P2O5 and 100 kg K ha^{-1} significantly increased the yield of bitter gourd. Islam and Irabangon (1994) also observed that the application of 240 kg N, 120 kg P2O5, and 60 kg K2O ha^{-1} markedly improved the number of fruit and yield of bitter gourd. Fruit size varied substantially among the treatments as the longest fruit size was recorded in treatment at 7 days interval and the shortest fruit size was observed in control. The highest single fruit weight 135.5 g was recorded in 7-day interval treated plants that were eloquently higher than all other treatments while the minimum (60 g) was recorded in control where no fertilizer was applied. Rajan and Markose (2005) reported that the maximum fruit set and yield were obtained with 90:25:50 kg NPK/ha. The maximum yield/ha produced where NPK & S were received at the rate of 120:40:80:30 treatments was mainly due to cumulative effects of the number of fruits/plants, fruit size, and fruit weight.

Yield of Bitter Gourd

The effect of NPK on the fresh yield of bitter gourd applied at different day intervals is presented in Table 3. The fruit yield/tunnel of bitter gourd was significantly influenced by different treatment intervals (Table 3). Fertilizer application in general increased fruit yield from 661.7 to 2047.7 kg per tunnel. These results are in conjunction with the results presented by Du *et al.* (2021). The application of NPK at 7-day intervals produced maximum yield (2047.7 kg/ 250 m^2) followed by 14-day intervals (952 kg/ 250 m^2) and 21-day intervals (661.7 kg/ 250 m^2). It was also observed that NPK applied at 7, 14, and 21-day intervals enhanced the yield significantly ($P<0.05$) as compared with no fertilizer application. Sanap *et al.* (2010) reported that applying 250 kg N, 50 kg P2O5, and 100 kg K2O/ha significantly increased the yield of bitter gourd in India. Islam and Irabangon (1994) also observed that the application of 240-120-60-kg NPK/ha markedly improved the number of fruits and yield of bitter gourd. Rajan and Markose (2005) reported that the maximum fruit set and yield were obtained with an application of 90:25:50 kg NPK/ha.

Table 1: Physico-chemical properties of soil before transplant.

Physico-chemical properties	Soil depth	
	0-15 cm	15-30 cm
pH	7.9	8.0
Electrical conductivity (dS/m)	0.24	0.25
Organic carbon (%)	0.52	0.24
Organic matter (%)	0.88	0.41
Nitrogen (%)	0.05	0.03
Phosphorus (μg/g)	7.5	5.9
Potassium (μg/g)	80	60
Lime content (%)	15.0	14.5
Bulk density Mg/m^3	1.43	1.45
Soil texture	Silt loam	

Table 2: Effect of time interval of NPK application on growth and yield parameters of bitter gourd.

Treatments		Plant height (cm)	Fruit length	Fruit size	Fruit weight (g)
T1	Control	160d	14.7c	4.1c	60.0d
T2	07 days	328a	24.5a	6.0a	135.5a
T3	14 days	278b	22.0b	5.5ab	123.5b
T4	21 days	233c	20.3b	4.8b	103.5c
LSD		15.73	2.01	0.37	3.65

Values in each column indicated by similar letters are not significantly different at P<0.05

Table 3: Effect of time interval of NPK application on yield of bitter gourd

Treatments		Bitter gourd	
		Fruit Yield	Straw Yield
		kg/ 250 m2	kg/ 250 m2
T1	Control	392.1d	20.22c
T2	07 days	2047.7a	44.13a
T3	14 days	952.0b	36.21b
T4	21 days	661.7c	33.01b
LSD		39.72	3.19

Values in each column indicated by similar letters are not significantly different at P<0.05

The experimental soil was highly deficient in different nutrients. Therefore, the application of different nutrients to the soil resulted in the highest uptake by plants which ultimately increased the production of assimilates that caused higher fruit size and yield. Plants grown without fertilizer application (native nutrient) produced the lowest yield (6.47 t/ha in 2010 and 8.50 t/ha in 2011). The highest dry straw yield (44.13 kg/ 250 m^2) was recorded in the treatment with 7 days intervals followed by (36.21 kg/ 250 m^2), (33.01 kg/ 250 m^2) 14 and 21 days of application, respectively, The results further indicated that there was a significant ($P<0.05$) difference among the treatments due to NPK application at different intervals.

NPK Uptake of Bitter Gourd Fruit

Plant nutrition is one of the vital factors affecting the proper growth and development of the plants. Methods and time of fertilizer application are critical components for adequately supplying the nutrients to the plants as the soil-applied fertilizers may be lost or fixed, resulting in lower efficacy. Table 4 shows the effect of NPK applied after 7, 14, and 21-day intervals on total NPK uptake of bitter gourd. The maximum total nitrogen uptake (7.05 kg/ 250 m^2 tunnel) was recorded in NPK applied at 7-day intervals followed by 14 days interval application (4.06 kg/ 250 m^2 tunnel) whereas, the minimum was recorded in control (0.79 kg/ 250 m^2 tunnel). Likewise, the highest total phosphorus uptake (1.12 kg/ 250 m^2 tunnel) in 7 days interval application, followed by 14 days interval application (0.59 kg/ 250 m^2 tunnel), 21 days interval

Table 4: Effect of time interval of NPK application on mineral contents & Physiological loss in weight (PLW) of bitter gourd fruits.

Treatments		Uptake (bitter gourd fruit)			PLW
		N	P	K	
		Kg/ 250 ² tunnel			%
T1	Control	0.79^{d}	0.11^{d}	1.09^{c}	17.80^{c}
T2	07 days	7.05^{a}	1.12^{a}	13.32^{a}	23.60^{a}
T3	14 days	4.06^{b}	0.59^{b}	7.31^{b}	20.63^{b}
T4	21 days	2.27^{a}c	0.33^{c}	3.64^{bc}	18.88^{c}
LSD		0.96	0.14	2.04	0.67

Values in each column indicated by similar letters are not significantly different at P<0.05

application (0.33 kg/ 250 m^2 tunnel) and control (0.11 kg/ 250 m2 tunnel). In the case of K, the highest K uptake (13.32 kg/ 250 m^2 tunnel) was recorded in the treatment of NPK after 7 days of application as compared to 14 (24.87.31 kg/ 250 m^2 tunnel), 21 (3.64 kg/ 250 m^2 tunnel) days interval and control (1.09 kg/ 250 m^2 tunnel). It was investigated that NPK nutrients are required for better plant growth and fruit development, so their lower concentrations decreased NPK uptake and ultimately the plant yield (Singh *et al*., 2010).

CONCLUSION

Based on this study, it is recommended that a balanced application of NPK nutrition is essential for attaining the desired yield outcomes in bitter gourd cultivation. However, the application of nitrogen, phosphorus, and potassium (NPK) in divided increments also plays a crucial role in fulfilling the nutrient requirements of bitter gourd. The application of 10-10-15 kg ha^{-1} at 7-day intervals is deemed to be the optimal level for attaining the highest fruit yield. It is imperative to conduct additional research in various geographical areas and diverse climatic conditions to optimize the nitrogen, phosphorus, and potassium (NPK) requirements specific to bitter gourd cultivation.

Socio-Economic benefits:

Vegetables cultivated during non-traditional growing seasons within the confines of low or high tunnels have the potential to command a significantly elevated value within the agricultural marketplace. The utilization of this technology exhibits notable cost-effectiveness in facilitating the cultivation of off-season vegetables within the water-limited conditions prevalent in the region of Khyber Pakhtunkhwa.

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