

Incidence of Root Knot Nematodes of Cucumber in high plastic tunnels at Quetta and its Management in Greenhouse Conditions

¹Umair Khaliq, ¹Zobia Jabeen, ¹Muhammad Waris*, ²Qasid Hussain, ¹Abdul Bari, ³Hina Ali Ahmed, ⁴Aurang Zaib Jamali, ⁴Muhammad Sharif, ⁵Raees Ahmed*

¹Department of Plant Pathology, Balochistan Agriculture College Quetta, Pakistan.

²PARC- Agricultural Research Institute, Jaffarabad, Pakistan

³Zoology Department, Faculty of Life Sciences, Sardar Bahadur Khan Women's University Quetta, Pakistan

⁴Department of Soil Science, Balochistan Agriculture College Quetta, Pakistan.

⁵Department of Plant Pathology, University of Poonch Rawalakot, AJK, Pakistan.

Correspondence: raees@upr.edu.pk, waris.faqir@gmail.com

ABSTRACT

Cucumber (*Cucumis sativus* L.) is one of the most important vegetables worldwide and in Pakistan. Cucumber is being grown in high plastic tunnels but root knot nematode highly reducing its yield. The study was conducted to record the incidence of disease during survey of cucumber fields in high plastic tunnels at Quetta, Balochistan Pakistan moreover, diseased samples have been collected. The maximum disease incidence was recorded 30% at Baleli area and minimum 10% at Sariab and Nausar areas. Management experiment was conducted to evaluate the impact of various nematicides on the growth, and physiological traits of cucumber plants. Treatment includes chemicals viz., Carbofuran, Fostiazate, Fluopyrum, Oxamyl, and Cadusafos, compared against an untreated control group of cucumber plants. Findings revealed that Carbofuran consistently produced the highest values across all parameters, including number of fruits per plant (7.10), fruit weight (28.80 g), fruit length (13.2cm), seed number per fruit (40.0), number of leaves (19.2), plant height (47.8 cm), fresh shoot weight (78.8 g), fresh root weight (23.80 g), dry shoot weight (46.5 g), and dry root weight (14.0 g). Fostiazate and Fluopyrum followed in performance, showing significantly better results than Oxamyl, Cadusafos, and the control for most parameters. Oxamyl and Cadusafos displayed moderate improvements over the control on various parameters. The untreated control consistently recorded the lowest values in growth and yield characteristics. Notably, Carbofuran also induced the lowest number of root galls (6.0), however, Cudusaps showed the highest gall count (28.0). It was concluded from the current findings that Carbofuran followed by Fostiazate substantially enhance cucumber growth and are recommended for management of root knot nematode in green house condition

Keywords: Cucumber, Incidence, Quetta, Tunnels, Root Knot Nematode, Chemical control.

INTRODUCTION

Cucumber (*Cucumis sativus* L.) belongs to family Cucurbitaceae is an annual crop that has been grown both in field and green house (Naz et al., 2021). It is one of the most important vegetables in Pakistan,

which is grown in the home, gardens, fields and as well as in tunnel farming (Renner et al., 2019).

Cucumber is an important vine crop of Pakistan; its yield is low to a certain extent. In Pakistan, the production of cucumber is 112231 tonnes under 3573 hectares of land during the year 2022-2023. Production in Punjab, Sindh, Balochistan is 99272 tonnes, 1579 tons, and 11380 tonnes respectively (Statistics of Pakistan 2022-2023). The choice of the consumer is now determined by a number of individual preferences; Shape, size and quality. Cucumber's nutritional value stems from its composition of vitamins, minerals, and hydrating properties (Javid et al., 2024). Cucumbers are low in calories and contain a high percentage of water, making them a refreshing and healthy addition to the diet. cucumbers contain vitamins A, C, and K, which

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contribute to various health benefits. They provide essential minerals such as potassium, magnesium, and manganese (Chakraborty & Rayalu, 2021). It contains 118 genera and 825 species, it has enclosed dicotyledonous seeds and it develops from a flower, and therefore it is classified as a fruit (Mukherjee et al., 2013). Cucumbers require frequent and adequate watering; however, excessive water intake can adversely affect their growth and development. Insufficient moisture leads to increased water loss due to the crop's large leaf surface area. Additionally, high humidity levels may result in the formation of a fungal disease known as powdery mildew, which appears as bright pink spots on the leaf surface. The soil conditions ideal for cucumber cultivation include fertile, well-drained soil with a pH ranging from 6.0 to 7.0. When temperatures are favorable, cucumber seeds can germinate rapidly, often within three days (Grubben & Denton, 2004). Following planting, cucumber plants typically take 40 to 45 days to begin flowering. Male flowers usually appear first, followed shortly by the development of female flowers. Once flowering occurs, cucumber fruits can be harvested approximately one to two weeks later, depending on the variety and growing conditions (Wang et al., 2007). The yield losses caused by plant pathogens, pests and weeds are estimated between 20 to 40% of global agricultural productivity. Among these, plant parasitic nematodes caused losses of US\$ 100 billion per year to world agriculture (Parveen et al., 2020). Root-knot nematodes (*Meloidogyne* spp.) belong to the genus *Meloidogyne* within the family Heteroderidae (Dhaliwal & Koul, 2007). These nematodes have an extensive host range, attacking more than 300 plant species worldwide, and are predominantly found in subtropical and tropical climates (Mukhtar et al., 2017). They are known for inducing specialized and complex feeding structures called giant cells within the root tissues, which result in characteristic root knots or galls (Williamson and Hussey, 1996). So far over one hundred species of *Meloidogyne* have been described from different areas of the world (Kayani et al., 2016). Of all these root-knot nematode species only four (*M. incognita*, *M. javanica*, *M. arenaria* and *M. hapla*) have been found to be of economic significance and cause about 95% infestations in plantations. The worldwide distribution of these species is as follows: *M. incognita* 47%, *M. javanica* 40%, *M. arenaria* 7% and *M. hapla* 6%. In Pakistan the occurrence of these four major species is *M. incognita* 52%, *M. javanica* 31%, *M. arenaria* 8%, *M. hapla* 7% while the rest of the *Meloidogyne* species constitute about 2%. Root-knot nematodes have become a serious threat to the profitable cultivation of cucumber in the country. About 33% yield losses due to root-knot nematodes have been estimated in

cucumber. In Pakistan *M. incognita* and *M. javanica* are major RKN species that cause greater damage to cucumber, tomato and other agricultural production in different areas. In the Khyber Pakhtunkhwa province *M. incognita* has been regarded as the most damaging RKN species while in Punjab province its incidence was reported as 58% that caused 25% annual yield losses in cucumbers plant on-open fields (Kayani et al., 2016). Different chemicals such as Fostiazate and Fluopyrum showed notable improvements in fruit yield parameters, significantly surpassing Oxamyl, Cudasaps, and the untreated control. Fostiazate has been reported as an effective nematicide that disrupts nematode nervous systems, thereby protecting root systems and enhancing nutrient acquisition (Netscher & Sikora, 2020). Several approaches have been followed to overcome the deleterious effects of nematodes in cucumber such as chemical control, organic amendments, resistant varieties, soil solarization and biological control (Sakhuja & Jain, 2001). There are many techniques to prevent RKNs, but the application of nematicides is still the frequently best technique. This compound along with chloropicrin was used against RKNs in pineapple. Chloropicrin considerably minimizes the RKNs because a harmful relationship was originated chloropicrin and RKNs (Taylor, 1943). Keeping in view the importance of cucumber being grown in high plastic tunnels and occurrence of root knot nematode The present study was conducted to record the disease incidence and its management at Balochistan

MATERIALS AND METHODS

Sample collection of cucumber from various tunnels at Quetta Balochistan

Severity of root-knot nematodes affecting cucumber crops in various regions at Quetta, Balochistan, Pakistan. The soil and root sampling was done randomly from different 10 cucumber plant in fields at different 5 tunnels for detailed examination. This sampling method was employed to evaluate the extent of nematode infestation and to gather reliable data on the spread and intensity of the root-knot nematode problem in the region. Soil samples were collected from a depth of 17 ± 2 cm while using a needle-nose shovel at that area nematode activity is most concentrated and was also ensured by accurate retrieval of the rhizosphere while the samples were taken from randomly selected cucumber plants were carefully uprooted to minimize damage to the root system and preserve the integrity of any nematode infestation. Approximately 100 grams of soil, along with the adhering roots, were collected from each plant. The infected roots and surrounding soil were placed in clean, labeled polythene bags to maintain proper identification and traceability of each sample. These samples were then transported to the Plant

Pathology Department at Balochistan Agriculture College, Quetta and stored at a temperature to maintain the viability of nematodes.

Incidence of Disease

The incidence of disease will be calculated as followed.

$$Incidence (\%) = \frac{Total\ number\ of\ infected\ cucumbers}{Total\ number\ of\ observed\ cucumbers} \times 100$$

Extraction of Nematodes from Soil

The soil will be thoroughly mixed and a 100 cm³ sub-sample will be used for nematode extraction, employing a modified sieving/Baermann funnel technique. The recovered nematodes will be enumerated using a stereo-binocular microscope (Olympus SZ 61) at 3.5× magnification and the density will be expressed as the number of nematodes in 100 cm³ of soil.

Extraction of Nematodes from Roots

Extraction of nematodes was done by root staining technique. Collected root samples with suspected nematodes were washed gently under tap water to remove soil and debris. Roots were soaked in 1% NaOCl (bleach) after washing for 3 minutes to remove pigments and make tissues more transparent. Wash the roots under tap water to stop beaching. Add roots

to acid fuchsin solution and heat for 3 minutes in hot plate for staining (Greco and Crozzoli, 2024). Transfer roots to acidified glycerol to clear excess dye from roots. Leave for 24 hours and then observe the roots under light microscope.

Identification of Species

Identification of root knot nematode was performed by morphometric analysis of different life forms i.e eggs, juveniles and females. The measurements were recorded using ocular micrometer at 40x. The following measurements were recorded in different stages of root knot nematode i.e total body length (µm), maximum body width (µm) and stylet length (µm) (Rusinque et al., 2023).

Evaluation of different Chemical against root knot nematode in green house condition

Sowing of Seedlings in Pots

Initially, the seeds were sown in growth Chamber under controlled conditions to ensure healthy germination and early growth at the plant breeding and genetics department. Once the seedlings reached 4-5 leaf, they were carefully transplanted into individual pots of suitable size to allow for proper root development and plant growth. Each pot was planted with a single seedling to avoid competition and to facilitate uniform growth and monitoring throughout the experiment.



Figure 1. Sowing of cucumber seeds in growth Chamber and transferring in pots

Soil Drench Method

Different chemicals were used to check the efficiency against *Meloidogyne* sp. shown in Table.1. Application of available chemicals was done in pots by using soil drench method. After two weeks of

transplanting, chemicals were applied having three replications for each treatment. Concentration of each chemical was prepared according to recommended doses.

Table 1. Description of various chemicals applied against root knot along with control

Sr. No	Products/treatment	Active Ingredients	Dosage
1	Rugby	Cadusafos	0.3g/liter
2	Velum	Fluopyrum	1ml/liter
3	Nemathorin 10% EC	Fosthiazate	0.5ml/liter
3	Feeldaan	Carbofuran	0.5g/liter
5	Vydate	Oxamyl	0.2ml/liter
6	Control	Untreated	

Nematode Inoculum preparation and Inoculation of Culture in the pots

Infected soil and root samples were utilized to isolate nematodes to serve as inoculum for the experiment.

To achieve this, nematodes were extracted from both the root and soil samples using established techniques. The Whitehead and Hemming tray method was employed to efficiently recover nematodes from the

soil by allowing them to migrate out of the soil into water over a period of time. Additionally, the Baermann funnel method was used to extract nematodes from root samples by suspending the roots in water, enabling the motile nematodes to move out of the root tissues and collect at the bottom of the funnel. These combined methods ensured effective isolation of viable nematodes for subsequent inoculation and study. Furthermore, the nematode culture, identified as *Meloidogyne* spp. (root-knot nematodes), was obtained from cucumber plants previously infected and exhibiting typical symptoms such as root galling (Greco and Troccoli, 2024). These infected plants served as a source for extracting viable nematodes, including eggs and second-stage juveniles (J2). The infected root systems were carefully processed using standard extraction techniques to isolate the nematodes, which were then used for experimental inoculation in order to study their impact and evaluate control measures under controlled conditions. After one week of application of chemicals, one thousand juveniles of *Meloidogyne* sp. were inoculated in treated seedlings. The inoculation was done by making holes around the roots of cucumber plants.

Data of different Plant-Pathogen Parameters

Number of Fruits

Number of fruits was counted from each infested cucumber plant before and after the application of different treatments.

Fruit Weight

After every week fruit weight noted through the weighing machine which was then be recorded in grams.

Fruit Length

After weighing of fruit, the length was measured. For this purpose, measuring scale was used and data was noted in centimeters.

Number of Seed per Fruit

After weighing of fruit, the number of seed per fruit was also be counted, similarly seed per fruit of each was also be counted.

Number of Leaves

Number of leaves was counted manually for each plant.

Plant Height

To measure the height of plant. From the base to the tip of the plant after every week. With statistical analysis, size of each replicate was measured.

Root Length

Cucumber root length was measured in centimeter with the measuring scale and was compared with the root length of plant in different treatments.

Fresh Shoot and Root Weight (g)

After recording all parameters, harvesting was done and roots was thoroughly be cleaned and then the weight of root and shoot was weight on weighing machine.

Dry Root and Shoot Weight (g)

Weight of dry root and shoot was weighed by wrapping the roots and shoots in wrapping paper and place overnight at 70°C. Next day weight of dry shoots and roots was weight on weighing machine and data was record.

No of Galls

Number of galls was counted from infested cucumber roots.

No of Juveniles

Number of juveniles was counted from infested cucumber soil.

Statistical Analysis

The experiment was conducted at the green house of Balochistan Agriculture College Quetta. The Completely Randomized Design (CRD) with three replications. The statistical analysis for analysis of variance and mean differences will be computed by LSD@ 0.05 Test.

RESULTS

Disease Incidence

Highest disease incidence was observed 30% at baleli location of Quetta district followed by 20 and 20% at Hana Urk and Sariab while minimum incidence of disease was observed at Lackpass and Nausar area tunnels as shown in Figure 2.

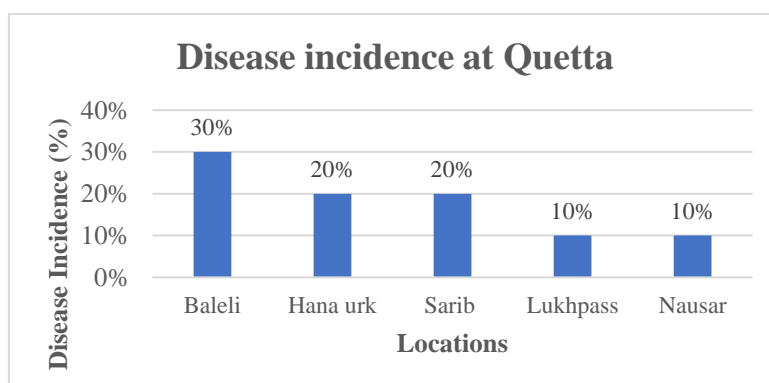


Figure 2. Incidence of root knot nematode in cucumber tunnels at different locations

Morphology and Morphometric description of the Root Knot Nematode

Morphology: -Mature Female

The body is globular to pear shaped and milky white, with a projecting neck and translucent cuticle. The neck has blurry annulations; the posterior part of the body is round and has no protuberance. The stylet is

slender and hard with round basal knobs. Excretory pore is located behind the level of stylet knobs.

J2 Stage

Body is slender, the labial disc and lips are joined to form smooth and continuous structure. The head region shows annulations. Stylet slender with small rounded basal knobs. Tail is simple and tapers steadily to the terminus.

Table 2. Morphometric characters of *Meloidogyne* sp. at all stages (egg to mature female)

<i>Meloidogyne</i> sp.	Length (µm)	Body width (µm)	Stylet length (µm)
Mature Female	619.30µm	368.35 µm	20.80µm
Juveniles (J2)	479.27µm	13.54 µm	16.65µm
Eggs	212.86 µm	88.78µm	



Figure 3. Measurement; Egg to Juvenile, female with stylet measurement, mature female and male Nematode

Management of Root Knot Nematode in Green House

Plant height (cm)

The tallest plants were observed in the Carbofuran treatment, which resulted in a mean plant height of 47.8 cm, indicating its strong influence on vegetative growth. Afterward, Fostiazate with an average height of 39.7 cm, and Fluopyryum at 34.4 cm. Oxamyl also contributed positively to plant height with a mean of 28.1 cm, while Cudusaps showed limited improvement, resulting in 25.3 cm. The shortest plants

(20.1 cm) were recorded in the control treatment, where no chemicals were applied as shown in (Figure 4). Carbofuran produced the tallest plants, significantly exceeding all other treatments. Overall, chemical treatments significantly enhanced plant height compared to untreated plants.

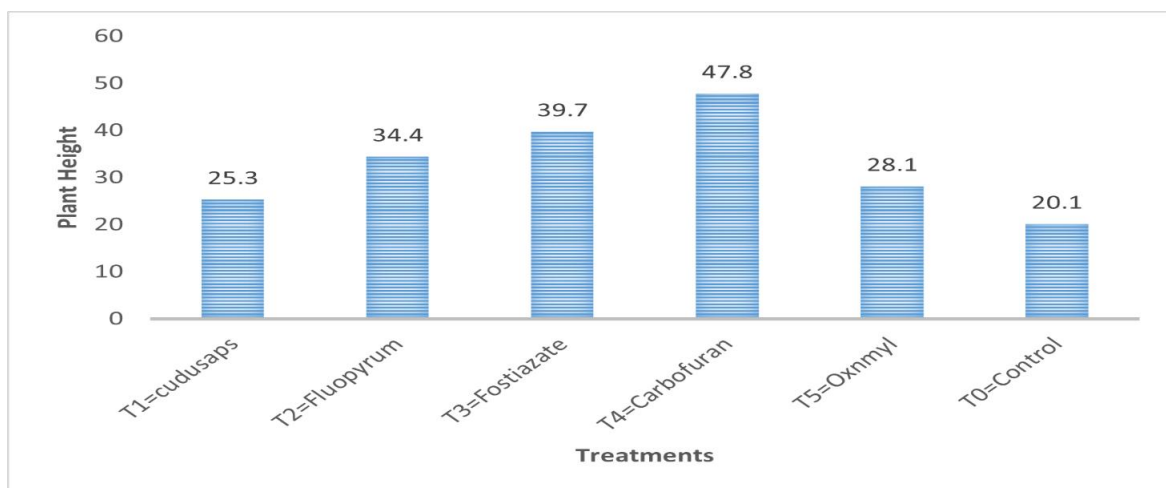


Figure 4. Effect of different chemicals on plant height (cm) of cucumber

Number of Fruits

The effect of different chemical treatments on the number of fruits in cucumber plants. Among all the

treatments, Carbofuran exhibited the highest number of fruits per plant, with a mean value of 7.1. This was followed by Fostiazate, which also performed well, yielding a mean of 6.1 fruits. The third highest fruit

count was recorded under Fluopyrum with 4.7 fruits. Oxamyl and Active ingredient Cudusafos resulted in lower fruit numbers, with mean values of 3.8 and 3.3

fruits respectively. The lowest number of fruits (1.50) was observed in the control treatment, where no chemical was applied as shown in (Figure 5).

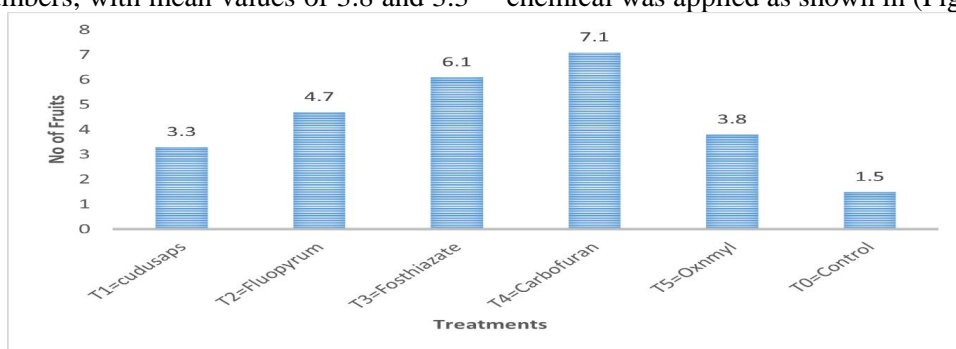


Figure 5. Effect of different chemicals on number of fruits of cucumber

Number of Leaves

The effect of different chemical treatments on the number of leaves per cucumber plant demonstrated a significant range in performance, from most to least effective. The highest number of leaves was observed in plants treated with Carbofuran, with a mean value of 19.2 leaves. This was followed by Fostiazate, which

produced 16.9 leaves, and Fluopyrum with 14.1 leaves. Oxamyl also contributed positively, resulting in an average of 12.9 leaves, while Cudusaps had a lesser effect, yielding 10.8 leaves. The lowest number of leaves (8.4) was recorded in the control treatment as shown in (Figure 6). These results indicate that all chemical treatments significantly enhanced leaf production compared to the untreated plants.

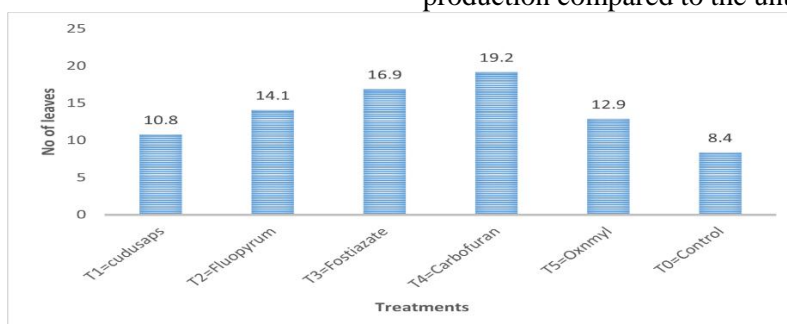


Figure 6. Effect of different chemicals on number of leaves of cucumber

Fruit Weight (g)

The application of different chemical treatments had a significant impact on the fruit weight of cucumber. The maximum fruit weight was observed in plants treated with Carbofuran, recording a mean weight of 59.2 g. This was closely followed by Fostiazate, which produced fruits with an average weight of 42.5 g.

Fluopyrum also showed promising results, with an average fruit weight of 36.6 g. Meanwhile, Oxamyl and Cudusaps resulted in lower fruit weights, with mean values of 26.9 g and 21.7 g, respectively. The lowest fruit weight (14.9 g) was recorded in the control group (T0), where no chemical treatment was applied as shown in (Figure 7).

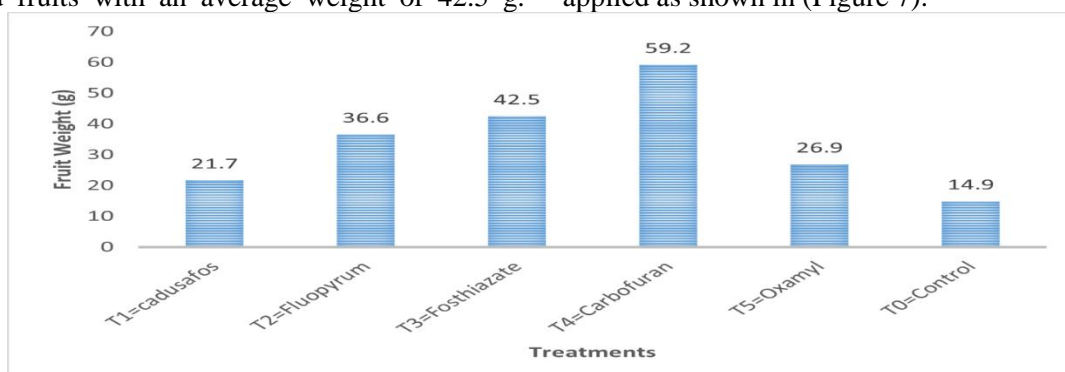


Figure 7. Effect of different chemicals on fruit weight (g) of cucumber

Fruit Length (cm)

The longest fruits were observed in plants treated with Carbofuran, achieving a mean fruit length of 13.2 cm. This was followed by Fostiazate, which also promoted considerable fruit growth, resulting in an average length of 11.5 cm. Fluopyrum ranked third with a

mean fruit length of 10.1 cm. Oxamyl and Cudusaps led to shorter fruits, measuring 9.8 cm and 7.8 cm, respectively. The shortest fruits (5.8 cm) were recorded in the control treatment, where no chemicals were applied as shown in (Figure 8).

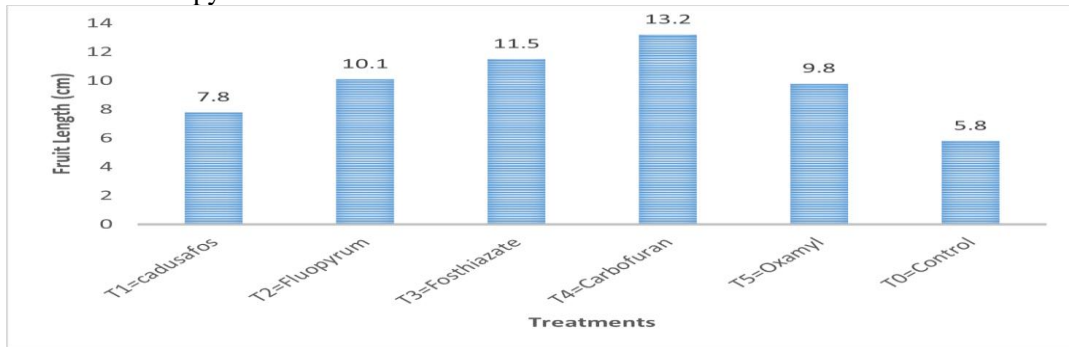


Figure 8. Effect of different chemicals on fruit length (cm) of cucumber

Number of Seed per Fruit

The number of seeds per cucumber fruit, with a clear trend from maximum to minimum. The highest number of seeds was recorded in fruits from plants treated with Carbofuran, averaging 40.0 seeds per fruit. This was followed closely by Fostiazate with 31.8 seeds, and Fluopyrum with 26.9 seeds. Oxamyl

and Cudusaps resulted in moderate seed counts, averaging 23.4 and 20.3 seeds, respectively. The lowest number of seeds (7.9) was observed in the control treatment, where no chemical intervention was applied as shown in (Figure 9). The number of seeds per cucumber fruit was significantly influenced by the chemical treatments.

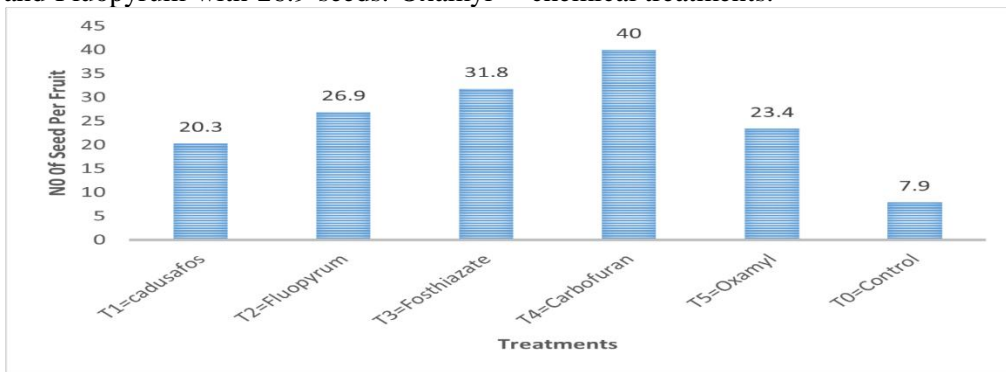


Figure 9. Effect of different chemicals on number of seed per fruit of cucumber

Root Length (cm)

The longest roots were recorded in plants treated with Carbofuran, which produced an average root length of 14.0 cm, demonstrating its strong positive impact on root development. This was followed by Fostiazate with a mean root length of 13.3 cm, and Fluopyrum at 12.1 cm, both indicating significant enhancement of

root growth. Oxamyl and Cudusaps resulted in moderate root lengths of 11.9 cm and 10.4 cm, respectively. The shortest roots (8.5 cm) were found in the control group (T6), where no chemical treatment was applied as shown in (Figure. 10). Overall, chemical treatments enhanced root length compared to untreated plants.

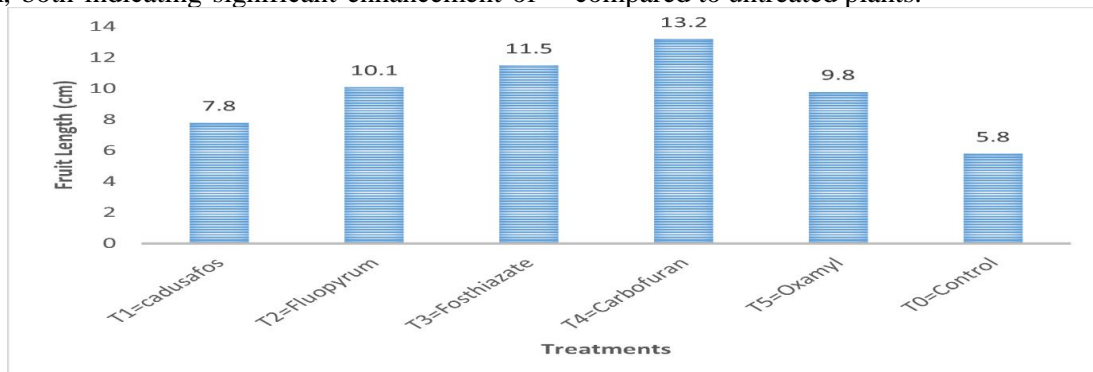


Figure 10. Effect of different chemicals on root length (cm) of cucumber

Fresh shoot weight (g)

The impact of different chemical treatments on the fresh shoot weight of cucumber plants showed significant variation. The greatest fresh shoot weight was recorded in plants treated with Carbofuran, yielding a mean weight of 78.5 g. This was followed by Fostiazate, which produced an average fresh shoot weight of 59.5 g, and Fluopyryum with 51.5 g. Oxamyl and Cudusaps contributed moderately, with fresh shoot weights of 42.3 g and 38.6 g, respectively. The lowest fresh shoot weight (30.8 g) was observed in the control treatment, where no chemical treatment was applied as shown in (Figure 11). These findings indicate that chemical treatments effectively enhanced shoot biomass production.

and Cudusaps contributed moderately, with fresh shoot weights of 42.3 g and 38.6 g, respectively. The lowest fresh shoot weight (30.8 g) was observed in the control treatment, where no chemical treatment was applied as shown in (Figure 11). These findings indicate that chemical treatments effectively enhanced shoot biomass production.

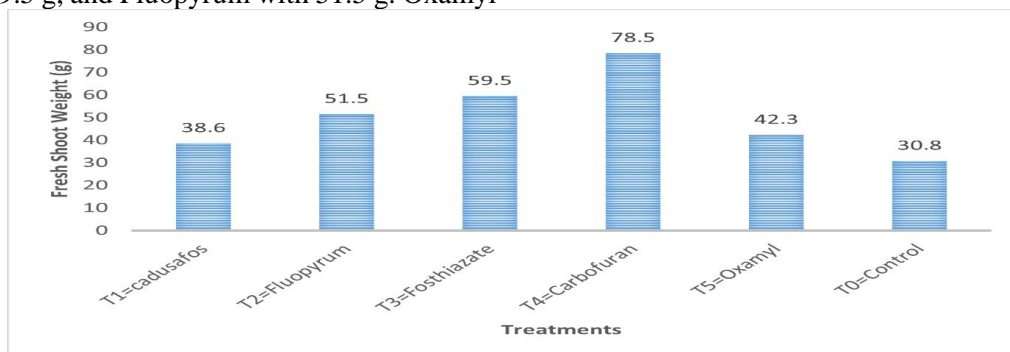


Figure 11. Effect of different chemicals on fresh shoot weight (g) of cucumber

Fresh Root Weight (g)

The maximum fresh root weight was observed in plants treated with Carbofuran, recording a mean weight of 23.8 g. Following this, Fostiazate resulted in a substantial fresh root weight of 21.6 g, while Fluopyryum also showed considerable improvement with 18.7 g. Oxamyl and Cudusaps produced moderate fresh root weights of 16.9 g and 15.6 g, respectively. The lowest fresh root weight (12.5 g) was recorded in the control treatment where no chemicals were applied as shown in (Figure. 12). Overall, chemical applications effectively enhanced root biomass in cucumber plants.

moderate fresh root weights of 16.9 g and 15.6 g, respectively. The lowest fresh root weight (12.5 g) was recorded in the control treatment where no chemicals were applied as shown in (Figure. 12). Overall, chemical applications effectively enhanced root biomass in cucumber plants.

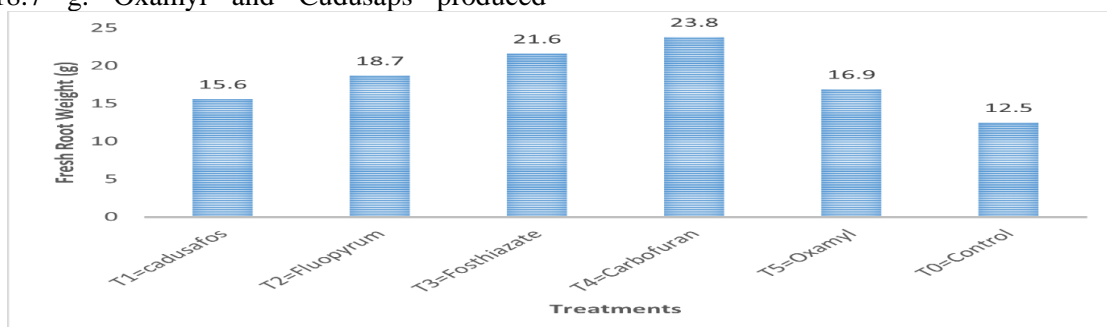


Figure 12. Effect of different chemicals on Fresh root weight (g) of cucumber.

Dry Root Weight (g)

The influence of different chemical treatments on the dry root weight of cucumber plants showed. The maximum dry root weight was recorded in plants treated with Carbofuran, with a mean value of 14.0 g. This was followed by Fostiazate, which produced a dry root weight of 11.4 g, and Fluopyryum with 10.7 g. Oxamyl and Cudusaps resulted in moderate dry root weights of 7.7 g and 7.2 g, respectively. The lowest dry root weight (5.6 g) was found in the control treatment, where no chemical treatment was applied as shown in (Figure 13). These results indicate that chemical treatments effectively enhanced root dry matter accumulation.

Oxamyl and Cudusaps resulted in moderate dry root weights of 7.7 g and 7.2 g, respectively. The lowest dry root weight (5.6 g) was found in the control treatment, where no chemical treatment was applied as shown in (Figure 13). These results indicate that chemical treatments effectively enhanced root dry matter accumulation.

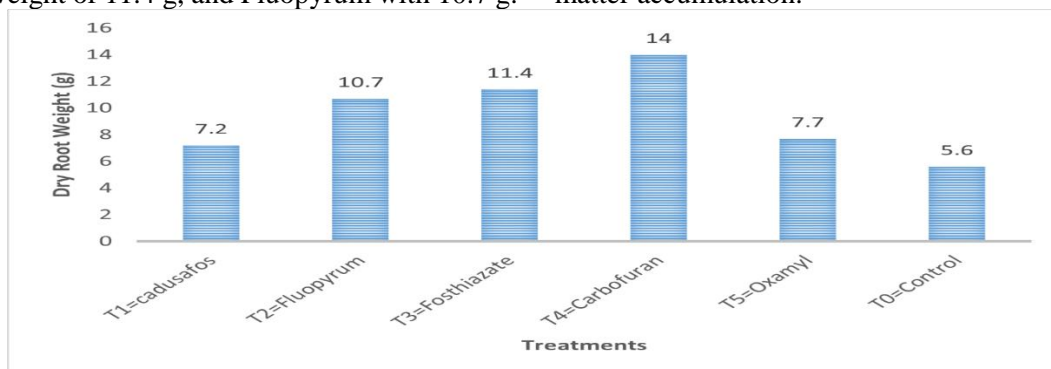


Figure 13. Effect of different chemicals on dry root weight (g) of cucumber

Dry Shoot Weight (g)

The highest dry shoot weight was observed in plants treated with Carbofuran, averaging 46.5 g, which indicates its strong ability to enhance the accumulation of dry biomass in shoots. This was closely followed by Fostiazate with 30.7 g, and Fluopyrum at 24.8 g. Oxamyl and Cudasaps yielded

moderate dry shoot weights of 21.9 g and 19.6 g, respectively. The lowest dry shoot weight (14.7 g) was recorded in the control treatment, where no chemicals were applied as shown in (Figure 14). Overall, chemical treatments substantially enhanced dry shoot biomass accumulation in cucumber plants.

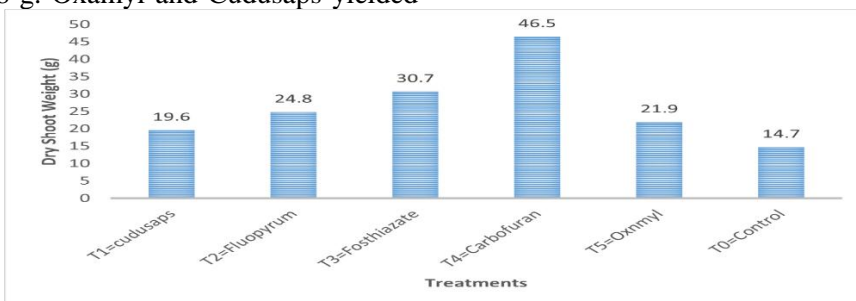


Figure 14. Effect of different chemicals on dry shoot weight (g) of cucumber

Number of Galls

The evaluation of different chemical treatments on the number of galls in cucumber revealed a clear variation in effectiveness. Among all treatments, Cntrol (T0) resulted in the highest mean number of galls, recorded at 57.0. Following cadusafos, oxamyl showed a moderately high mean gall count of 28.0 and 26.0. The treatment with Active ingredient Fluopyrum and

Fostiazate produced an intermediate gall number, with a mean value of 15.0 and 11.0. Better results were observed with Carbofuran, which recorded a lower mean gall number of 6.0. The most effective chemical treatment in reducing gall numbers was Carbofuran as shown in (Figure 15). The treatments showed significant differences in the number of galls on cucumber plants

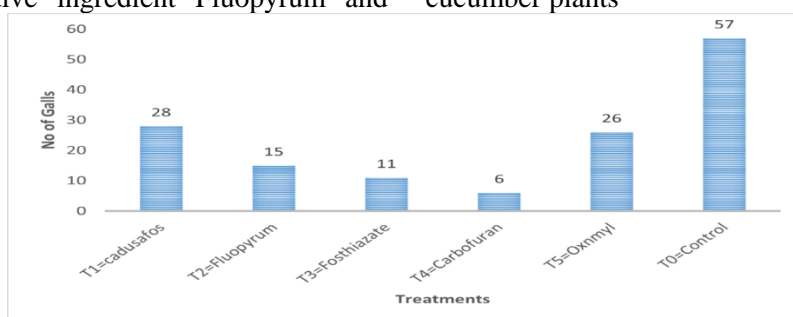


Figure 15. Effect of different chemicals on number of galls of cucumber

Number of Juveniles

The control treatment (T0), which received no chemical application, recorded the highest number of juveniles at 1223.0. Among the chemical treatments, Carbofuran (T4) emerged as the most effective nematicide, with the lowest juvenile count of just 8.0. Fostiazate (T3) also demonstrated excellent efficacy, reducing the juvenile population to 25.0. Fluopyrum (T2) exhibited moderate control, reducing the juvenile

count to 42.0. Oxamyl (T5) resulted in a mean juvenile count of 59.0. On the other hand, Active ingredient cudasaps (T1) showed limited efficacy, with a juvenile count of 74.0 as shown in (Figure 16). The results reveal significant differences among treatments in reducing the number of cucumber juveniles, In contrast, the control group had a dramatically higher juvenile count, highlighting the effectiveness of chemical treatments overall.

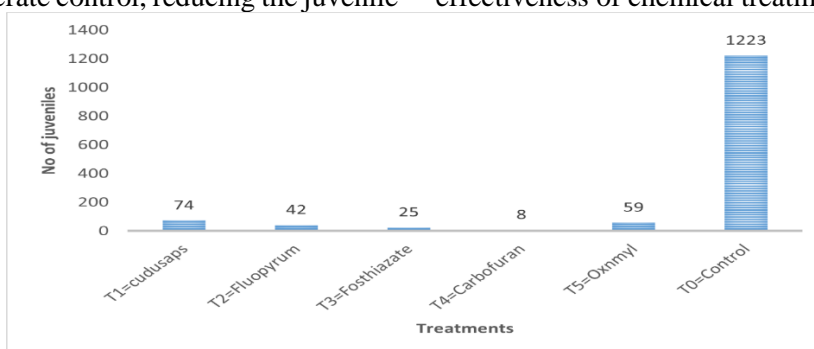


Figure 16. Effect of different chemicals on number of juveniles of cucumber

DISCUSSION

Root knot nematodes are major threat for vegetable crop production in Pakistan (Fiaz et al., 2018). The increased fruit number and weight under Carbofuran may be attributed to reduced nematode infestation, which otherwise impairs nutrient and water uptake, ultimately restricting fruit development (Sikora & Fernández, 2005). Similarly, Fluopyrum, known for its systemic action, has demonstrated efficacy against root-knot nematodes, translating to improved fruit set and size in cucurbits (Khan et al., 2019). In another study Abd-Elgawad (2021) revealed that Among all applied treatments, Carbofuran consistently outperformed others, resulting in the highest number of fruits per plant (7.1), fruit weight (59.2 g), and fruit length (13.2 cm). These findings align well with earlier studies that demonstrated Carbofuran's role in improving yield attributes by effectively controlling nematode populations and soil-borne pests (Sharma et al., 2016) these findings having similarity with the findings of current study as Carbofuran showed the effective findings by increasing the number of fruits per plant moreover similar study was conducted by Talwana et al. (2021) was showed that performance of Oxamyl and Cudusaps furthermore Carbofuran and Fostiazate were evaluated with similar less to moderate findings. In an-other findings it was observed that the untreated control recorded the lowest fruit number and weight, reinforcing the detrimental impact of nematode infestation and pest pressure on cucumber yield. This is consistent with the literature, where nematode-infested cucumber plants show reduced fruiting due to impaired root function (McSorley et al., 2023). Moreover Jones et al. (2021) evaluated vegetative parameters such as number of leaves (19.2), plant height (47.8cm), fresh shoot weight (78.5 g), and fresh root weight (23.80 g) were highest under Carbofuran treatment. Enhanced vegetative growth likely results from improved root health and nutrient uptake, as nematode damage is mitigated. In another study Fostiazate and Fluopyrum again followed closely, providing significant vegetative growth benefits over Oxamyl, Cudusaps, and control. These results corroborate previous findings where nematicide application promoted better root growth and shoot development in cucurbits by alleviating root-knot nematode infestation (Ali et al., 2020). Oxamyl and Cudusaps treatments, while improving growth parameters relative to the untreated plants, were less effective than Carbofuran and Fostiazate. This could be due to differences in chemical composition, soil persistence, or target specificity (Minton & Riggs, 2020). The untreated control plants showed stunted growth, likely resulting from compromised root systems and insufficient nutrient uptake caused by nematode infection (Moens

et al., 2023) Findings of these studies for varous parameters showing the similarity with the finding of current work. Furthermore, in another work dry shoot weight (78.5 g) and dry root weight (23.8 g) were also highest in Carbofuran treatments, suggesting that effective nematode control contributes not only to immediate growth but also to biomass accumulation. Enhanced biomass is critical for sustaining fruit production and improving overall plant resilience (Husna et al., 2019). The increased root biomass under Carbofuran likely reflects reduced gall formation or nematode penetration, promoting better root function and storage of assimilates (Atkinson et al., 2022). A noteworthy finding was the highest number of root galls (58.0) recorded under Control, significantly exceeding other treatments. In contrast, Carbofuran showed the lowest gall count (6.0), suggesting its possible nematicidal activity or suppression of gall induction mechanisms, although this did not translate into superior growth or yield. This discrepancy emphasizes the complexity of nematode-plant-chemical interactions and suggests that gall number alone may not directly correlate with yield performance (Jones et al., 2021). The present results are consistent with extensive literature documenting the positive effects of nematicides on cucurbit crops. For instance, Sikora & Fernández (2005) emphasized the critical role of nematicides in reducing root-knot nematode damage and enhancing yield. Abd-Elgawad (2021) also reported Carbofuran as an effective nematicide that increases cucumber fruit yield by improving root health. Similar yield improvements with Fostiazate and Fluopyrum have been documented by Khan et al. (2019) and Ali et al. (2020), who noted enhanced growth and reduced nematode populations in treated plants. Conversely, studies by Minton & Riggs (2020) and Chitwood (2023) observed moderate efficacy of Oxamyl, similar to the current findings, and highlighted the variability in nematicidal performance depending on application rates and soil conditions. The control group's poor performance aligns with findings by McSorley et al. (2023) and Moens et al. (2023), who demonstrated that nematode infestation severely limits cucumber growth and yield.

CONCLUSION

From the findings of current study, it was concluded that application of different chemical treatments significantly influenced the growth, yield, and physiological parameters of cucumber plants in greenhouse condition. Carbofuran consistently showed high performance in growth, yield, and physiological parameters followed by Fostiazate and Fluopyrum also enhanced cucumber growth and yield. Moreover, carbofuran is recommended for maximizing cucumber fruit yield and growth performance due to its effectiveness against root knot

nematode followed by Fostiazate and Fluopyrum for cucumber growers. Further studies are suggested to be done in high plastic tunnels on large scale and at different localities.

Competing of Interest

The authors declare no competing interests.

Author Contributions

The authors declare that there is no conflict of interests regarding this publication

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