STANDARDISATION OF FERTIGATION SCHEDULE FOR PARTHENOCARPIC CUCUMBER (*Cucumis sativus* L.) HYBRID KPCH 1 UNDER POLYHOUSE

By

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(2020-12-004)

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VELLANIKKARA, THRISSUR - 680 656
KERALA, INDIA

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THESIS

Submitted in partial fulfilment of the requirements for the degree of

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DECLARATION

I, hereby declare that this thesis entitled **"Standardisation of fertigation schedule for parthenocarpic cucumber (*Cucumis sativus* L.) hybrid KPCH 1 under polyhouse"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or Society.

Vellanikkara

Date: 08/03/23

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CERTIFICATE

Certified that this thesis entitled **"Standardisation of fertigation schedule for parthenocarpic cucumber (*Cucumis sativus* L.) hybrid KPCH 1 under polyhouse"** is a record of research work done independently by **Ms. Mintu Hanna Reji (2020-12-004)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associate ship to her.

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We, the undersigned members of the advisory committee of **Ms. Mintu Hanna Reji (2020-12-004)**, a candidate for the degree of **Master of Science in Horticulture**, with major field in **Vegetable Science**, agree that this thesis entitled **"Standardisation of fertigation schedule for parthenocarpic cucumber (*Cucumis sativus* L.) hybrid KPCH 1 under polyhouse"** may be submitted by **Ms. Mintu Hanna Reji**, in partial fulfilment of the requirement for the degree.

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Dedicated to my dearly loved Ammachi ...

Who still lives in my heart ...

And guides me ...

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Introduction

1. INTRODUCTION

Protected cultivation can be defined as the type of cropping system where the microenvironment around the plant is partially or completely regulated in accordance with the needs of the plant during its growth phase to increase production. Protected structures protect the crop from biotic and abiotic stresses (Maragal *et al*., 2018). Protected structures for vegetable cultivation comprise greenhouses, polyhouses, insect-proof net houses, plastic low tunnels polyhouses and zero-energy polyhouses (Sabir and Singh, 2013). Polyhouse is the most suitable and practical means for achieving the objectives of protected cultivation. In Kerala, fragmentation of land is the major limiting factor for commercial cultivation of vegetables. According to the data from Agriculture census (2019), the average size of operational land holding in Kerala is only 0.18 ha (45 cents), which is the lowest in India. Protected cultivation has a great capacity to achieve self-sufficiency in vegetable production even in limited land areas (Kumar and Singh, 2020). The most important advantages of polyhouse cultivation are maximum utilisation of vertical space and reduced occurrence of pests and diseases (Raghav *et al*., 2009). However, polyhouse restrict the entry of both beneficial and harmful insects. Therefore, natural pollination is difficult inside polyhouse. Hence, parthenocarpic or self-pollinated crops are generally preferred under polyhouse conditions. Moreover, protected cultivation is an intensive production method with high investment. So only high-value crops are economical under protected cultivation. Vegetables like capsicum, tomato, okra, cauliflower, cabbage, french beans and cucumber can be cultivated all-round the year. These vegetables can be cultivated inside the polyhouse with reduced incidence of pests and diseases, resulting in very low chemical residues in the produce (Kumar and Singh, 2002). Vegetables such as salad cucumber and cowpea are found feasible and more profitable to cultivate under polyhouse conditions in Kerala (Lakshmi *et al*., 2018).

Cucumber (*Cucumis sativus* L.) is one of the important vegetable crops belonging to the family Cucurbitaceae, which is grown mainly as a salad crop. Non-dessert types are typically used as vegetables (Chadha and Lal, 1993). Cucumber is well-liked all across the world for its crisp texture and flavour. It has multiple uses, which vary from salads to pickles and digestive aids to cosmetics. It is an excellent natural diuretic. Fruits are also beneficial for those with indigestion, constipation, and jaundice (Jilani *et al*., 2009). Even though, cucumber has extremely few calories and nutrients, it is a major provider of vitamins, minerals and fibre to the human body (Keopraparl, 1997). Nowadays, more farmers are choosing cucumbers to cultivate due to their higher productivity, demand and more stable price in the market. In India, cucumber covers an area of 82 thousand ha with a production of 1260 thousand MT during 2017-18. In Kerala, cucumber production is confined to an area of 3.39 thousand ha with a production of 36.28 thousand MT (NHB, 2018). Parthenocarpic cucumbers has more consumer acceptance as it produces seedless fruits with thin skin. It can be eaten as whole fruit along with its peel (Kumari *et al*., 2020). Parthenocarpic cucumber seeds are costly as their seed production is labour-intensive. 'KPCH 1 (KAU parthenocarpic cucumber hybrid 1)' is one of the few public sector parthenocarpic hybrid varieties available in the market at low cost (one rupee per seed). It has high demand all over India due to its high productivity of about 100 t/ha. Owing to its high production potential it requires better agro-techniques and manuring.

The application of soluble fertilizers to plant root zone through irrigation water is called fertigation. It is an advanced and efficient practice of fertilization (Singh *et al*., 2010). Fertigation saves about 25 to 30% of fertilizers in addition to ensure higher productivity and production of quality produce (Raman *et al*., 2000). Since soluble fertilizers are costly inputs, standardisation of fertigation schedule for different crops will helps to increase fertilizer use efficiency and profit to farmers. Hence, research works has to be conducted for scheduling fertilizer doses specific to individual crops. In this study, we are attempting to standardise the fertigation schedule specific for cucumber hybrid 'KPCH 1' under polyhouse. At present, Kerala Agricultural University (KAU) has only an *ad hoc* recommendation for precision farming for cucumber in Kerala. So, it is necessary to find an optimum fertilizer dosage for cucumber to make its cultivation remunerative to farmers. Hence this study is proposed with the following objectives:

- Standardisation of fertigation schedule for KPCH 1 under polyhouse
- Evaluation of different levels of fertigation on yield and quality of KPCH 1 grown under polyhouse.

Review of literature

2. REVIEW OF LITERATURE

Protected cultivation protects the crop from adverse outdoor climate conditions and facilitates the successful cultivation of crops. It also provides suitable microclimate for crop growth and offers protection from abiotic and biotic stresses. Self-pollinated and parthenocarpic vegetables are most widely cultivated under polyhouse conditions. Fertigation is the process in which water-soluble fertilizers are supplied through irrigation water. It helps to increase the efficiency of protected cultivation. The available pieces of literature regarding the research topic are presented under the following headings.

2.1 Status of protected cultivation

2.2 Protected cultivation of cucumber

2.3 Fertigation

2.4 Effect of fertigation on vegetative characters

2.5 Effect of fertigation on flowering

2.6 Effect of fertigation on yield and yield characters of cucumber

2.7 Effect of fertigation on yield and yield characters of other vegetables

2.8 Effect of fertigation on quality parameters

2.9 Economics

2.1 Status of protected cultivation

China is having the largest area under greenhouse cultivation (2,760,000 ha) in world. The world scenario of protected cultivation is given in Table 2.1 (Kumar and Singh, 2020).

Table 2.1. The area under greenhouse cultivation in major countries

Country	Greenhouse area (ha)
China	2,760,000
South Korea	57,444
Spain	52,170
Japan	49,049
Turkey	33,515
Italy	26,500
Israel	18,000
Mexico	11,759
Netherlands	10,370
France	9,620

In India, the area under protected cultivation was around 25,000 ha including 2,000 ha under greenhouse vegetable cultivation during 2004 - 2005 (Sabir and Singh, 2013). It further raised to 1,50,000 ha in the year 2014 - 15 (20% of which was under polyhouse) (Punera *et al*., 2017). The area under protected cultivation had tremendous growth in recent years and Karnataka is the leading state in adopting protected cultivation (Pradeepkumar *et al*., 2013).

2.2 Protected cultivation of cucumber

In Kerala, cucumber is one of the most popular vegetables grown under polyhouse conditions. High yielding parthenocarpic cucumbers are generally recommended under polyhouse.

2.2.1 Cucumber varieties

High yielding cucumber varieties or hybrids are used for commercial cultivation. PCUCH 1, PCUCH 3, Pusa Sanyog, AAUC 1 and AAUC 2 are some important cucumber hybrids (Kalloo *et al*., 2000). Swarna Ageti, Swarna Sheetal, PCUC 28, Japanese Long Green, Straight 8, Pusa Uday, Pusa Barkha, Himangi, Swarna Poorna, Sheetal, CO 1 are the important varieties of cucumber which are in cultivation (Kalloo *et al*., 2006). Pusa Sanyog, Phule Prachi and Phule Champa are some of the cucumber gynoecious lines commercially exploited in heterosis breeding (Megharaj *et al*., 2017). Snow white is a private sector gynoecious cucumber hybrid having high yield potential (Shinde *et al*., 2018). Parthenocarpic cucumbers are preferred over normal seeded varieties in polyhouse, since they can set fruits without pollination. DPaC 6, 4 DPaC 9 and 5 DPaC 10 from IARI, New Delhi and Pant Parthenocarpic Cucumber 2 and Pant Parthenocarpic Cucumber 3 from GBPUAT, Pantnagar are some of the major achievements of India in breeding parthenocarpic cucumber (Latha and Devaraju, 2022). 'KPCH 1' is a parthenocarpic gynoecious hybrid suitable for protected cultivation, with high yield capacity and quality, developed by the Department of Vegetable Science, College of Agriculture, Vellanikkara, Kerala Agricultural University. It is moderately resistant to downy mildew (Pradeepkumar *et al*., 2020). Kian, Hilton, Isatis, NS 492, NS 498 and Aviva are some of the private sector parthenocarpic cucumber hybrids (Singh *et al*., 2016; Latha and Devaraju, 2022). 'Punjab Kheera Hybrid 11' is a parthenocarpic gynoecious cucumber variety recently released from Punjab Agricultural University for polyhouse cultivation (Dhall, 2021). Details of major cucumber varieties commonly cultivated in India are summarised in Table 2.2.

Table 2.2. Cucumber varieties

Parthenocarpic varieties	Public sector	KPCH 1, PPC 2, PPC 3, Pusa Seedless Cucumber 6, 4 DPaC 9 and 5 DPaC 10, Punjab Kheera Hybrid 11
	Private sector	Kian, Hilton, Fadia, Isatis, King star, Multi star, Valley star, NS 492, NS 498, Aviva, Kafka
Non-parthenocarpic varieties	Gynoecious	Heera, Shubra, Pusa Sanyog, Phule Prachi, Phule Champa, Snow white
	Monoecious	Pusa Uday, Punjab Naveen

2.2.1.1 Parthenocarpy in cucumber

'Parthenocarpy' the term signifies the development of fruits without pollination and fertilization (Spena and Rotino, 2001). Therefore, parthenocarpy is a desirable trait for cultivating crops in the absence of pollinators. Parthenocarpic varieties or hybrids, especially in salad cucumber, opened the door for polyhouse cultivation (Pant *et al*., 2001). Environmental stresses like low and high temperatures have deleterious impacts on pollination and fertilization, whereas parthenocarpic plants produce fruits without pollination or fertilization, resulting in more stability in growth and yield (Fayaz *et al*., 2021). Parthenocarpic cucumber varieties produce fruits with a mild flavour, which are devoid of seeds and can be eaten without peeling since their peels are edible (Tiwari, 2015).

2.2.1.2 Effect of temperature on parthenocarpy and fruit set

Female sex expression is mostly favoured by factors like low temperature, low nitrogen supply, short day conditions and high moisture availability. These factors improve the carbohydrate build-up and alter the levels of endogenous hormones, especially ethylene, auxin and gibberellic acid, which, in turn influence sex expression (Agbaje *et al.,* 2012). Among these factors, temperature is the major element affecting the growth and development of parthenocarpic cucumber. Sun *et al*. (2006) opined that parthenocarpy in cucumber is promoted by low night temperatures (16 - 27℃). Nitsch *et al.* (1952) revealed that, high temperature prevents and postpones the initiation of female flowers. Whereas, low temperature and short photoperiod conditions favour parthenocarpy. Narayanankutty *et al*. (2013) stated that in parthenocarpic cucumbers low temperature had a direct correlation with earliness in flowering and fruit set.

2.2.1.3 Temperature management within polyhouse

Since the microclimate inside the polyhouse has a vital role in plant growth, temperature management within the polyhouse is important. It is regulated by the timely opening and closing of shade nets, side covers and fogging for better results (Kumar *et al*., 2014). The heating system, ventilation and fogging system, lighting and shading system, fertigation system, CO_2 injection system *etc.* are used to manage the greenhouse microclimate (Singh *et al*., 2017). Polyhouses that are having provision for natural ventilation are suitable for the humid tropics of Kerala.

2.2.2 Season

Cucumber is a popular warm season vegetable in Kerala. Temperature between 25 - 30℃ is ideal for its growth and development (Yu *et al.,* 2018). Frost and high temperatures are the major constraints for cucumber cultivation in open fields. Extreme climatic conditions from March to September in North India prevent cucumber cultivation in open fields (Singh *et al.,* 2016). Yadav *et al*. (2014) reported that 6 - 10℃ higher temperature is experienced inside polyhouse when compared to the outside temperature. Hence cucumber can be cultivated successfully inside polyhouse during winter (December - February) in North India. Whereas, in places like Kerala where winter is not severe cucumber can be cultivated in all three seasons under open fields as well as in protected structures. However, protected cultivation is preferred over open fields to reduce biotic and abiotic stresses and to achieve increase yield (Kumar and Arumugam, 2010). Even though, they can be cultivated year round they are not generally recommended during summer season due to heavy occurrence of pests. Moreover, high temperatures above 35℃ can cause damage to plants (Yu *et al.,* 2018). In Kerala, winter season (October - February) is found to be good for cucumber cultivation in terms of production and quality.

2.2.4 Spacing

Plant density contributes to marketable yield in several ways, like providing adequate sunlight for plant growth, reducing the competition for water and nutrients and reducing the risk of fungal diseases and insects (Sharma *et al*., 2018). In general, a plant requires about 0.5 m^2 of area with a good amount of sunlight, whereas in northern states of India, the plant demands more spacing because of low light intensity. A plant density of 2.2 – 2.5 /m^2 is found optimum for cucumbers grown under polyhouse (Pal *et al*., 2020).

Singh *et al*. (2016) reported that the cucumber variety ‘Isatis’ planted at a spacing of 50×50 cm under naturally ventilated polyhouse produced higher yield (15.5 kg/m^2), maximum number of fruits per plant (15 fruits per plant) and net returns of Rs.261/m^2.

Dhillon *et al*. (2017) conducted a study to evaluate the effect of plant density on the yield of cucumbers. Cucumber plants were planted at two spacing's *viz.,* 70×30 cm and 70×60 cm. Maximum yield per unit area was obtained at narrow spacing. This might be due to the higher number of plants per unit area at closer spacing.

2.2.5 Yield of cucumber

The productivity of cucumber plants grown under open fields is generally low. Protected cultivation can be used to increase the yield and quality of cucumber. Smitha and Sunil (2016) reported that higher vine length (2.78 m) and biomass yield were obtained for cucumber plants grown inside polyhouse compared to open fields and rain shelters. The average yield of a normal cucumber variety is 8 t/ha in the open field, whereas, it is 40 t/ha inside the polyhouse. However, the potential yield of parthenocarpic cucumber varieties inside a polyhouse is 180 t/ha (Singh and Padiyar, 2009).

2.2.6 Plant protection

Heavy incidences of pests and diseases are the major limitations of conventional farming. Indiscriminate use of pesticides leads to major environmental and health hazards. Polyhouse is a protected structure which offers protection from pests and diseases. Nevertheless, once these pests enter inside the polyhouse it gets flared up as the polyhouse provides congenial condition for pests and also protection from natural enemies. It is advantageous to grow fruits and vegetables that are particularly insect pest susceptible inside a polyhouse and it has been found that polyhouse cultivation is a better strategy for IPM. Singh *et al*. (2012) reported that the number of unmarketable fruits in tomato, capsicum and strawberry (pest attacked) were nearly zero under polyhouse compared to outdoor conditions.

2.2.6.1 Pests

Sucking pests act as a serious problem for polyhouse cultivation and their infestation is severe during summer. Whiteflies, leaf miners, red spider mites and thrips are the dominant sucking pests damaging cucumber (Banshiwal *et al*., 2018). Slugs and snails are important pests in polyhouse at high humidity. Their damage is mainly noticed during the night. Whereas, during the day time they hide inside cool moist places. Young seedlings are most susceptible to snail damage (Kaushik *et al*., 2021).

Vignesh and Patil (2020), screened eleven cucumber genotypes against two-spotted spider mites. When compared to all other evaluated genotypes, KPCH 1 variety was found to have a minor tolerance mechanism against the two spotted spider mites.

2.2.6.2 Diseases

Like all other vegetables cucumber is affected by numerous biotic agents like fungi, bacteria and viruses. Major fungal diseases causing severe yield reduction in cucumbers are powdery mildew, downy mildew, *Fusarium* wilt, scab and anthracnose. Bacterial diseases like bacterial wilt and bacterial leaf spot also cause severe yield reduction in cucumber throughout the world (Das *et al*., 2022). Additionally, other fungal diseases like damping off caused by *Pythium* and collar rot caused by *Rhizoctonia* affect cucumber plants in nurseries as well as in main fields. Viral pathogens like cucumber mosaic virus, cucumber green mottle mosaic virus, papaya ring spot virus, watermelon bud necrosis and zucchini yellow mosaic virus were reported to cause severe crop loss, especially in protected environments (Wang *et al*., 2020).

2.2.7 Physiological disorders

Boron, calcium and magnesium are the vital nutrients affecting the quality of cucumber fruits. Boron becomes less available to plants with increasing soil pH. Whereas, the availability of calcium and magnesium increases with pH.

High relative humidity and calcium deficiency in developing cucumber fruits resulted in a white porous mesocarp known as pillowy fruit disorder (PFD) (Staub *et al*., 1988).

Boron deficiency symptoms were first noticed on the younger leaves, which alter the leaf colour and the leaf becomes hardened, malformed, and necrotic (Dursun *et al*., 2010). Tiwari *et al*. (2015) reported that deficiency of boron, in general, can cause terminal die back, rosette of thick, curled, brittle and discoloured leaves and cracked fruits. In cucumber, boron deficiency results in aborted fruits and show symptoms of twisting and scarring (Vitosh *et al*., 1994).

The first evident symptom of magnesium deficiency in cucumber is inter-veinal chlorosis (Carmona *et al*., 2015).

2.3 Fertigation

Fertigation is the technology which involves the injection of soluble fertilizers into irrigation systems. Fertigation offers a great chance to increase crop production with minimum environmental pollution by enhancing fertilizer use efficiency and reducing fertilizer application rate (Hagin *et al*., 2002). Nutrient use efficiency in traditional methods of fertilizer application is as low as 40 - 60% compared to 90% in fertigation (Sivanappan, 1985). Due to improved fertilizer use efficiency and reduced leaching loss, fertigation guarantees better fertilizer savings (Kumar and Singh, 2002). In comparison with traditional fertilizer application methods, fertigation saves about 40% of fertilizers and increase crop yield (Sathya *et al*., 2008).

2.3.1 Fertigation dosage for salad cucumber

Fertigation dosage is the optimum amount of nutrients required for the balanced growth and development of plants. Fertigation dosage for salad cucumber based on the research findings of PFDCs (Precision Farming and Development Centres) trials conducted all over India are furnished in Table 2.3.

Table 2.3. Fertilizer recommendations for cucumber

Sl. No.	Institute	Fertilizer recommendation (kg/ha)	Reference
1.	GBPUAT, Pantnagar, Uttarakhand	50:25:25 NPK	NCPAH, 2017
2.	UAS, Bangalore, Karnataka	60:50:80 NPK	
3.	IGKV, Raipur, Chhattisgarh	100:50:50 NPK	
4.	SKRAU, Bikaner, Rajasthan	120:80:100 NPK	
5.	KCAET, Tavanur, Kerala	175:125:300 NPK	

2.3.2 Fertigation stage

In a study conducted by Kumar *et al*. (2014) fertigation (N:P:K) for cucumber started 10 days after sowing (DAS) at the ratio 2:3:1, 1:2:3 and 1:2:3 in the first, second and third month of crop growing period, respectively was found successful.

According to Feleafel (2014), for cucumber, the entire dose of fertilizers needs to be given in 24 splits within a crop duration of 13 weeks (two splits in a week). Eight splits during the vegetative stage (two to five weeks after sowing) and 16 splits during the flowering and fruiting stage (six to thirteen weeks after sowing). Thirty per cent of the fertilizer recommendation was given in the vegetative stage and the remaining 70% in the flowering and fruiting stage.

To monitor the performance of cucumber in response to fertigation, an experiment was carried out at G.B. Pant University of Agriculture and Technology, Pantnagar. From the study, it was finalised that fertigation with 120 kg N, 60 kg P_2O_5, and 60 kg K_2O /ha and scheduling 25% N, 15% P and 20% K between six to 35 DAS, 40% N, 15% P and 25% K between 36 to 65 DAS, 20% N, 50% P and 40% K between 66 to 95 DAS and 15% N, 20% P and 15% K between 96 to 125 DAS gave best results under polyhouse (Singh *et al*., 2022).

2.3.3 Frequency of fertigation

Gluer *et al.* (2006) investigated the effect of nitrogen and its frequency of application on the yield and leaf nutrient content of cucumber. The highest yield and number of fruits were obtained by the application of nitrogen twice a week.

The fertigation frequency in which the fertilizers are applied once in a week from one to 30 DAS and 60 to 90 DAS and once in three days during the peak growth stage *i.e.* from 30 to 60 DAS was found optimum for cucumber (Janapriya *et al.*, 2010).

Badr and El-Yazied (2007) studied the effect of various fertigation frequencies on tomatoes. The fertigation interval varied from one to 14. The treatment with more frequent fertilizer application resulted in increased nitrogen uptake and higher yield (67.75 t/ha).

Shedeed *et al*. (2009) reported that a daily supply of N, P, and K along with irrigation water boosted the availability of these nutrients in the root zone. It also enhanced fruit yield and quality of tomatoes and decreased N and K losses in sandy soils.

2.3.4 Fertilizers used in fertigation

Fertilizers used for fertigation should possess some essential criteria like full solubility, rapid dissolution in water, increased crop production, safety for field use, compatibility with other fertilizers, minimal content of conditioning agents, and lack of chemical interaction with irrigation water (Bucks and Nakayama, 1980, Solaimalai *et al.,* 2005).

Nitrogenous fertilizers such as urea, ammonium nitrate, calcium nitrate and ammonium phosphate are water soluble and are extensively used in fertigation. Phosphatic fertilizers like mono ammonium phosphate, phosphoric acid and urea phosphate easily precipitate when they were injected into hard water. Even though all potassium fertilizers are water soluble, their rate of solubility varies. KCl (potassium chloride) is the most extensively used potassium fertilizer but its continuous use will lead to chloride accumulation and can cause chloride toxicity in plants (Kafkafi, 2005).

All water-soluble fertilizers can be supplied through fertigation, but this method of supplying phosphorus and other microelements was discouraged in actual practice since their precipitation can easily trigger the blockage of the irrigation system when pH is higher than 7.0 (Bar-Yosef, 1999).

2.3.5 Fertigation equipment

Venturi pumps, fertilizer tanks and fertilizer injection pumps are the commonly used types of fertigation equipment for injecting fertilizers into drip irrigation systems (Biswas, 2010).

2.3.6 Application of micronutrients

Fertigation helps plant roots to receive all necessary mineral nutrients in the correct quantity and near vicinity. However, in most cases, only three major nutrients such as nitrogen (N), phosphorus (P), and potassium (K) are delivered in this manner. Calcium (Ca), magnesium (Mg), and sulphur (S) are also supplied occasionally. Other necessary micronutrients such as boron (B), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), and molybdenum (Mo), are required only in modest amounts, these nutrients are typically provided as foliar sprays (Thamara *et al*., 2010).

Sampoorna KAU multimix for vegetables is a micronutrient mixture specific for vegetables developed by Kerala Agricultural University to supplement plant growth. Studies have shown that foliar application of Sampoorna KAU multimix in direct sown vegetables at the rate of 5 g/L at 30, 45 and 60 DAS and in transplanted vegetables at 15, 30 and 45 DAP can result in enhanced yield (Thulasi *et al*., 2022).

2.4 Effect of fertigation on vegetative characters

Jilani *et al*. (2009) found that the application of NPK fertilizers at the rate of 120:60:60 kg/ha had a significant influence on vine length (3.85 m).

According to Pushpendra and Hardaha (2016), maximum vine length (4.31 m) was achieved by the use of 125% recommended dose of fertilizers (RDF) in cucumber (180:84:192 kg NPK/ha).

Iwalewa and Amujoyegbe (2019) reported that the longest vine length (1.66 m) in the cucumber variety 'Poinsette' was observed by the application of 120 kg N/ha.

Mohammed *et al*. (2021) assessed that maximum plant height is directly related to higher nitrogen application since nitrogen enhances the vigour of the plant.

2.5 Effect of fertigation on flowering

Research was carried out under plastic tunnels to understand the effect of different levels of N:P:K fertilizers on the growth and yield of cucumber plants. The results showed that application of 100:50:50 kg NPK/ha took minimum days (39.33 days) to flower emergence in cucumber (Jilani *et al*., 2009).

Arshad *et al*. (2014) reported that plants supplied with a higher dose of fertilizers resulted in early flowering.

Maragal *et al*. (2018) reported that higher doses of fertilizer (30:22:31 kg NPK/ ha) application in cucumber took minimum number of days to first flower opening (22 DAS).

In an experiment conducted by Kumar *et al*. (2020), minimum number of days to first flower opening (30.2 days) was recorded with the application of 100% RDF (100: 50: 50 kg NPK/ ha).

2.6 Effect of fertigation on yield and yield characters of cucumber

According to the studies conducted by Choudhari and More (2002) on tropical gynoecious cucumber hybrid, Phule Prachi, 150:90:90 kg NPK/ha was found effective for obtaining maximum number of fruits per vine, fruit weight, yield per plant (2.538 kg) and yield per hectare (49.039 t). In a second experiment, the combined effect of spacing and fertigation was evaluated in two varieties; Phule Prachi and Phule Champa. Based on the results it was concluded that these varieties need to be sown at a spacing of 1.8 x 0.45 m with fertigation at the rate of 200:125:125 kg NPK /ha for good yield (38.02 t/ha).

A fertigation experiment was carried out at Mahatma Phule Krishi Vidyapeeth, Rahuri to understand the efficacy of liquid fertilizers using the cucumber variety 'Himangi'. From the results, it was concluded that the application of 100% RDF (150:50:50 kg NPK /ha), out of which 50% through inorganic fertilizers and 50% through FYM was superior over 100% through inorganic fertilizers in terms of yield (26.4 t/ha) and quality (Surve *et al*., 2002).

Al-Jaloud *et al.* (2006) assessed the effect of N:P:K on the growth and yield of cucumber plants. Three experiments were done separately, keeping two nutrient levels at the highest concentration and the third one at four different levels. From this study 150 ppm nitrogen, 60 ppm P_2O_5, and 200 ppm K_2O were found best for the successful cultivation of cucumber.

Al-Wabel *et al.* (2006) evaluated the response of nitrogen use efficiency under conventional fertilizer application methods and fertigation in cucumbers. The results showed that the highest yield (33.74 t/ha) was obtained with the application of nitrogen at the rate of 180 mg/L through the drip irrigation system.

To determine the effect of different levels of NPK fertilizer on the growth and yield of cucumber (*Cucumis sativus*) research was carried out under a plastic tunnel polyhouse. Application of 100:50:50 kg NPK/ha was adequate in terms of least days to fruit set, maturity, maximum number of fruits per plant, maximum fruit length, maximum fruit weight and yield per hectare (60.02 t) (Jilani *et al*., 2009).

Sharma *et al.* (2009) investigated the effect of different growing media and fertigation levels on cucumbers. The study proved that growing media containing soil, vermicompost and sand in the ratio 2:1:1 combined with fertigation at the rate of 300 kg NPK/ha was highly beneficial for growing cucumber under naturally ventilated polyhouse for producing an average yield of 104.12 t/ha.

Janapriya *et al*. (2010) evaluated the effect of soilless media in combination with drip fertigation at Tamil Nadu Agricultural University. The results of the study confirmed that peat, vermicompost and sand in the ratio 2.5:2.5:1 combined with 100% drip fertigation (150:75:100 kg NPK/ha) had a positive influence on the growth and yield (113.89 t/ha) of cucumber.

Eifediyi *et al.* (2011) proved that by increasing the farmyard manure and fertilizer levels there was an increase in dry matter production and the yield of cucumber. Application of 10 t of farmyard manure combined with 80:40:40 kg NPK/ha produced maximum dry matter.

Zhang *et al*. (2011) evaluated the effect of different drip irrigation and nitrogen fertilization level on the yield and quality of cucumber. Moderate irrigation and nitrogen application level (450 kg N/ha) under subsurface drip irrigation was found to be effective.

Arshad *et al*. (2014) reported that 200 g NPK per fertigation was found suitable for cucumber in terms of fruit set, maturity, maximum fruit per plant, maximum fruit length, maximum fruit weight, and yield per hectare (58.82 t/ha).

Research was undertaken to evaluate the response of cucumbers to different levels of fertigation. Based on this study it was revealed that 100 per cent recommended dose of NPK (175:125:300 kg NPK/ha) was the best fertigation dose with highest nutrient use efficiency for nitrogen, phosphorous and potassium, highest water use efficiency and yield (89.06 t/ ha) (Chand, 2014).

Feleafel *et al*. (2014) examined the effect of NPK fertigation rate and starter fertilizers on the growth and yield of cucumbers in a greenhouse. It was found that application of starter fertilizers SF1: 7-14-7 or SF2: 7-28-7 in soil along with 125% RDF (220:150:50 kg NPK/ha) through fertigation gave the highest significant mean values for the percentage of fruit set (65.4%), number of fruits per plant (20.35), fruit yield (3.88 kg/plant), and highest phosphorus and potassium content in leaves.

Gupta *et al*. (2014) attempted to standardise the drip irrigation and fertigation practices for the commercial cultivation of cucumber hybrid ‘SH-CH-1’ under Kashmir conditions. The study proved that the combined effect of drip irrigation and fertigation had a more positive response towards growth and yield characteristics than the individual effects. Among 16 treatment combinations, the combined effect of irrigation at 80% evapotranspiration (ET) and fertigation with 80% RDF (70:30:30 kg NPK/ha) gave maximum yield of 144.41 t/ha.

An experiment was carried out at Navsari Agricultural University to evaluate the effect of fertigation and training systems on cucumbers. From the study, it was concluded that the combined effect of 150% RDF *i.e.* 90 kg N, 75 kg P_2O_5 and 75 kg K_2O per hectare and plants trained in the 'V' system produced higher fruit yield of 107.6 t/ha (Kumar *et al*., 2014).

Patil and Gadge (2016) conducted a research at Mahatma Phule Krishi Vidyapeeth, Rahuri, to find out the yield response of the cucumber variety 'Gypsy' at different fertigation levels. The study showed that fertigation had significant effect on yield attributes like average fruit girth, average fruit length, and average fruit weight. Fertigation with 125% RDF (125:62.5:62.50 kg NPK/ha) recorded maximum yield of 21.87 t/ha.

Pushpendra and Hardaha (2016) conducted a study at Jawaharlal Nehru Agricultural University, Jabalpur to determine the suitable fertigation level for cucumber using gynoecious F_1 hybrid 'Sandhya'. Observations of the study indicated that 100% RDF (150:70:160 kg of NPK/ha) was optimum for maximum number of fruits per plant and highest fruit yield (54.43t/ha).

Balwinder and Ramesh (2018) proved that the parthenocarpic cucumber variety 'Multistar' grown during autumn, planted at a spacing of 40×50 cm and supplied with 250:125:312.5kg NPK/ha gave the highest yield (4.86 kg/vine) under naturally ventilated polyhouse in Punjab.

Pawar *et al*. (2018) undertook a study to assess the interactive impact of irrigation and fertigation levels on the yield and growth of cucumbers. Maximum yield (132.62 t/ha), number of fruits per plant, average fruit weight, average fruit length, average fruit diameter and least days to first harvest were observed in drip irrigation at 80% ET and fertigation at 100% RDF.

Dawer *et al*., 2019 examined the effect of different levels of nitrogen on the growth and yield of parthenocarpic cucumber. Maximum fruit diameter, fruit length (21.54 cm) and fruit weight (221.02 g) was recorded at 140:125:125 kg NPK/ha. Whereas, the average yield per plot and average yield per hectare (54.04 t/ha) were maximum at 220:125:125 kg NPK/ha.

Iwalewa and Amujoyegbe (2019) reported that the application of 120 kg N/ha boosted the yield and growth of cucumber plants.

Lawal *et al.* (2019) reported that the combined application of 45:45:45 kg NPK/ha and tithonia compost at the rate of 2.5 t/ha was sufficient for the production of cucumber.

According to Wang *et al*. (2019), different irrigation and fertigation levels had significant effects on the growth, yield and quality of cucumber. Drip irrigation at 80% ET combined with nitrogen at the rate of 360 kg/ha was found optimum for cucumber cultivation.

The research was carried out for two consecutive years from 2019 to 2020 inside a polyhouse to study the effect of fertigation on the growth and fruit yield of cucumbers. The research findings showed that yield attributes like average fruit weight, number of fruits per plant, average fruit diameter, average fruit length, yield per plant (4.8 kg/plant) and fruit yield per hectare (72 t/ha) were highest at 100% RDF (100:50:50 kg NPK/ha) (Kumar *et al*., 2020).

An investigation entitled "Effect of fertigation levels and spacing on growth and yield of cucumber (*Cucumis sativus* L.) cv. KPCH-1 grown under polyhouse" was carried out at Bihar Agricultural University, Sabour. The results of the experiment revealed that, treatment combination with 100% RDF (100:50:75 kg NPK/ha) and spacing at 60×55 cm showed the best interaction effect for yield (4.2 kg/vine) and yield characters (Kumari *et al*., 2020).

Mohammed *et al*. (2021) studied the response of cucumber plants to water-soluble fertilizers. From the results, it can be concluded that maximum yield (56.76 t/ha), fruit weight, and number of fruits were obtained at higher doses of fertilizers (150:120:120 kg NPK/ha) among different treatments tested.

Based on the studies conducted in different parts of India it is confirmed that there is a huge variation in the fertilizer dosage of cucumber. Fertigation dosage varies from 70:30:30 kg NPK/ha to 300:300:300 kg NPK/ha. The yield of cucumber also varies from 21.87 t/ha to 243 t/ha. Different fertigation doses reported based on various studies conducted all over India are given in Table 2.4

Table 2.4. Fertigation dosage for cucumber based on the reports of different studies

Sl. No.	Variety	Spacing (m)	Fertigation (kg NPK/ha)	Yield (t/ha)	References
1.	Phule Prachi	1.8 x 0.45	200:125:125	38.02	Choudhari and More, 2002
2.	Himangi	0.6 x 0.3	150:50:50	26.40	Surve *et al.,* 2002
3.	KH 401	1 x 0.8	300:300:300	104.12	Sharma *et al*., 2009
4.	Green long	0.6 x 0.3	150:75:100	113.89	Janapriya *et al.,* 2010
5.	Hilton	0.9 x 0.9	175:125:300	89.06	Chand, 2014
6.	SH CH 1	1.2 x 0.4	70:30:30	144.41	Gupta *et al*., 2014
7.	Dinamik		90:75:75	107.60	Kumar *et al*., 2014
8.	Gypsy		125:62.5:62.5	21.87	Patil and Gadge, 2016
9.	Sandhya	1.1 x 0.45	150:70:160	54.43	Pushpendra and Hardaha, 2016
10.	Multistar	0.4 x 0.5	250:125:312.5	243.00	Balwinder and Ramesh, 2018
11.	Parthenocarpic cucumber	1.5 x 1	140:125:125	54.04	Dawer *et al*., 2019
12.	Fadia	1.2 x 0.5	100:50:50	72.00	Kumar *et al*., 2020
13.	KPCH 1	0.6 x 0.55	100:50:75	127.27	Kumari *et al*., 2020

2.7 Effect of fertigation on yield and yield characters of other vegetables

In spine gourd, addition of 80 kg nitrogen and 60 kg phosphorus per hectare took minimum number of days for germination, first female flower opening and first harvest, and the highest mean values for the number of nodes to first female flower emergence, number of fruits per plant, fruit length, fruit diameter, average fresh weight, yield per plant, vine length, chlorophyll and total soluble solids (Vishwakarma *et al*., 2007).

Kadam *et al*. (2009) undertook a study to determine the water and fertilizer requirement of watermelon. The results showed that irrigation at 0.3 PE and fertigation with 80% RDF (80:40:40 kg NPK/ha) gave maximum output.

Brahma *et al*. (2010) investigated the effect of N and K fertigation on growth and yield of tomato variety 'Arka Abha'. The observations indicate that highest yield was achieved from cent per cent fertigation (75:60 kg/ha N and K).

Gupta *et al.* (2010) conducted a study using four levels of fertigation and irrigation in capsicum. From the study, it can be concluded that the combined effect of irrigation and fertigation had upper hand over individual effects. The treatment combination with 80% irrigation and 80% RDF resulted in maximum yield.

According to Shafeek *et al*. (2015), in muskmelon highest fruit yield, plant growth, and improved physical and chemical characteristics of fruits were achieved by the application of the highest level of NPK fertilizers (140:64:60 kg NPK/ha).

The studies on fertigation in bitter gourd (*Momordica charantia* L.) variety 'Preethi' conducted at the College of Agriculture, Vellayani revealed that fruit yield in bitter gourd was influenced by fertigation. Fertigation with 100% RDF (70:25:25 kg NPK/ha) recorded the highest fruit yield (Hari and Devi, 2016).

Nayak *et al*. (2018) reported that the pointed gourd variety 'Swarna Alaukik' performed well when it was supplied with fertilizers at the rate of 150:60:80 kg NPK/ha (100% RDF) along with mulching and it remained on par with the treatment 80% RDF combined with mulching.

Ananda Murthy *et al*. (2020) conducted a study at the Indian Institute of Horticultural Research, Bangalore to estimate the effect of water-soluble fertilizers on the growth and yield of ridge gourd hybrid, Arka Vikram. This investigation revealed that fertigation with 150:90:150 kg NPK/ha was found optimum for better growth and yield of ridge gourd.

2.8 Effect of fertigation on quality parameters

Fertigation had no significant effect on total soluble solids and fruit firmness. Whereas, fertigation had positive response on titratable acidity and ascorbic acid content in field-grown tomatoes under NPK drip fertigation (Hebbar *et al*., 2004).

Hartz *et al.* (2005) stated that potassium fertigation was ineffective in increasing soluble solids in tomato fruits.

Brahma *et al.* (2010) showed that percentage of fruit juice, total soluble solids and ascorbic acid content were maximum at cent percentage fertigation (75 kg N/ha and 60 kg K/ha), whereas, the highest titratable acidity was obtained at fifty per cent fertigation.

Petre *et al*. (2016) proved that the highest dry matter and reducing sugar content were observed for crops fertigated with chemical fertilizers.

2.9 Economics

Protected structures are long-term investments even though their cost of construction is too high. Horticulture crops like tomato, salad cucumber, bell pepper, gerbera, rose and carnation can be successfully cultivated under protected structures (Chandra *et al*., 2000). Lakshmi *et al*. (2018) examined the economic feasibility of polyhouse cultivation in central and high ranges of Kerala. A report of the study claimed that more farmers are adopting saw tooth type polyhouse having an area of 400 m^2 for raising major crops like salad cucumber and cowpea. Murthy *et al.* (2009) studied the economic feasibility of capsicum and tomato cultivation under polyhouse. The results of the study indicated that capsicum is economical under polyhouse, as the break-even price of capsicum under polyhouse cultivation was less than the actual wholesale price. Whereas, that of tomato was higher making it unfit for polyhouse cultivation.

Research was carried out at Precision Farming Development Centre, KCAET, Tavanur, Kerala with four levels of fertigation in cucumber. The study showed highest benefit-cost ratio (3.40) was observed for treatment supplied with 100% RDF (175:125:300 kg NPK/ha) (Chand, 2014).

Gupta *et al*. (2014) reported that the highest benefit-cost ratio (5.99) in cucumber was recorded for plants supplied with fertigation at 80% RDF (70:30:30 kg NPK/ha) and irrigation at 80% ET.

According to Kumar *et al*. (2014), cucumber plants trained in a single stem system and fertigated through 150% RDF (90:75:75 kg NPK/ha) earned the highest benefit-cost ratio (1.30).

Kumari *et al*. (2020) stated that cucumber plants fertigated through 100% RDF (100:50:75 kg NPK/ha) and planted at a spacing of 60×55 cm gave maximum benefit-cost ratio (2.90).

According to research conducted by Murthy *et al*. (2020), the highest net income and B:C ratio of 2.22 was observed in ridge gourd fertigated with 100% RDF (150:90:150 kg NPK/ha).

Materials and Methods

3. MATERIALS AND METHODS

An experiment entitled 'Standardisation of fertigation schedule for parthenocarpic cucumber (*Cucumis sativus* L.) hybrid KPCH 1 under polyhouse' was conducted at the Department of Vegetable Science, College of Agriculture (COA), Vellanikkara, Thrissur. The details of the materials used and methods employed in the experiment are given in this chapter.

3.1 Experimental site

The present study was carried out in a naturally ventilated polyhouse having 384 m^2 area (24×16 m) at the Department of Vegetable Science, COA, Vellanikkara from January to March, 2022. The polyhouse is located at 10.551544° N latitude and 76.284652° E longitude. The area belongs to the agro-ecological unit ten and agro-ecological zone 'midland laterites'.

3.1.2 Soil

The soil type of the site is laterite. Soil inside the polyhouse was tested before the experiment. Soil was almost neutral in reaction with macronutrients like available organic carbon, available calcium, available magnesium, available sulphur and micronutrients like zinc and copper in the medium range. The level of available phosphorus and potassium was high and that of boron was low. The data on chemical properties of the soil inside the polyhouse is given in Table 3.1.

3.1.3 Cropping history

The crop raised inside the polyhouse during the previous season was cowpea.

3.1.4 Season and weather condition

The area experiences a warm humid tropical climate. The crop was raised from January to March, 2022. The data on weather parameters like daily maximum and minimum temperature, average relative humidity, rainfall, and evaporation rate during the cropping period are represented in Figure 3.1. Data regarding weather parameters were obtained from the Department of Agricultural Meteorology, COA, Vellanikkara.

Table 3.1. Chemical characters of the soil before crop raising

Particulars	Value	Rating	Method used	Reference
Soil reaction (pH)	6.51	Neutral	pH meter with a glass electrode	Jackson, 1973
Electrical conductivity (dS/m)	0.05	Normal	Digital conductivity meter	
Organic carbon (%)	1.11	Sufficient	Walkley and Black rapid titration method	
Available phosphorus (kg/ha)	383.49	High	Brays colourimetric method	
Available potassium (kg/ha)	835.50	High	Ammonium acetate method	
Available calcium (mg/kg)	2002.00	Sufficient	EDTA method	
Available magnesium (mg/kg)	218.44	Sufficient		
Available sulphur (mg/kg)	113.91	Sufficient	$CaCl_2$ extraction method	Tabatabai, 1982
Micronutrients				
Iron (mg/kg)	68.31	High	DTPA extraction method	Lindsay and Norwell, 1978
Manganese (mg/kg)	48.70	High		
Zinc (mg/kg)	15.98	Sufficient		
Copper (mg/kg)	14.76	Sufficient		
Boron (mg/kg)	0.02	Deficient	Hot water extraction method	Gupta, 1967

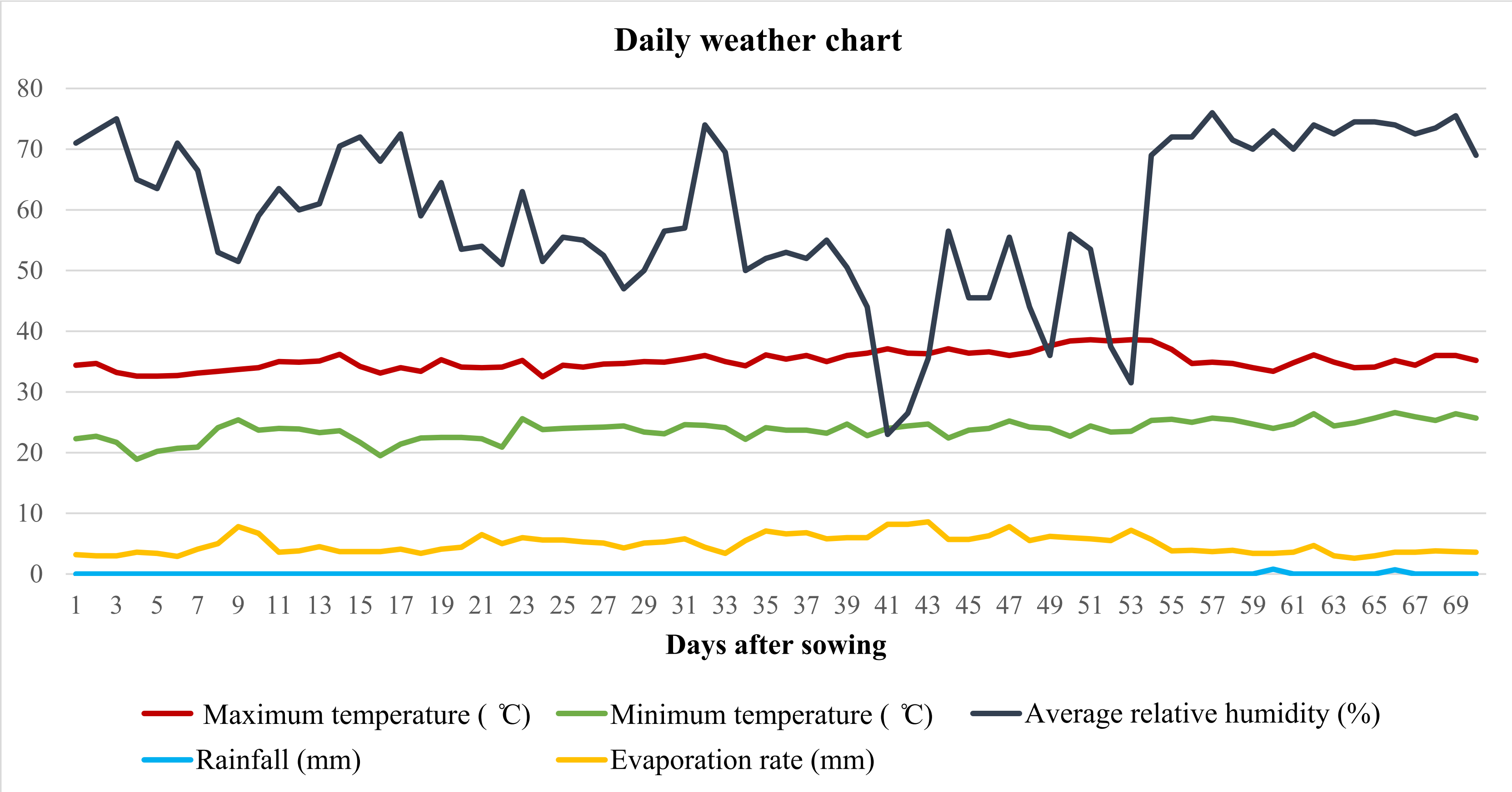


Figure 3.1. Data on daily maximum temperature, minimum temperature, average relative humidity, rain fall and evaporation rate

3.2 Materials

3.2.1 Polyhouse

A naturally ventilated polyhouse of 384 m^2 area constructed in the North - South direction having 24 m length and 16 m width was used for the study. An ultraviolet (UV) stabilised polythene sheet of 200 micron thickness was used as cladding material. Shade nets were used inside the polyhouse. The beds were mulched with silver-coloured mulching sheets of 25 micron thickness.

3.2.2 Fertilizer injector

A battery-operated mobile fertilizer injector designed for fertigation in different treatments within a polyhouse was used for the study. The drip system was controlled using valves.

3.2.3 Variety

Salad cucumber hybrid variety ‘KPCH 1’ released from the Department of Vegetable Science, COA, Vellanikkara was used in the study. ‘KPCH 1’ is a parthenocarpic F_1 hybrid generated from a cross between parthenocarpic and gynoecious lines. This variety bears long dark green fruits. It is an early maturing variety suitable for polyhouse cultivation and is moderately resistant to downy mildew. It is suitable for the humid tropics of Kerala and its average yield is about 1 t/100m^2. Detailed information about ‘KPCH 1’ is given in appendix II.

3.2.4 Source of seed material

The seeds of KPCH 1 were obtained from the Department of Vegetable Science, COA, Vellanikkara.

3.2.5 Manures and Fertilizers

Trichoderma-enriched farmyard manure was added at the rate of 1.5 kg/m^2 (15 t/ha). Urea (46 per cent N), rajphos (18 per cent P_2O_5) and sulphate of potash (SOP - 50 per cent K_2O) were used for basal application in T7. Water soluble fertilizers *viz.,* urea, NPK mixture (19:19:19) and potassium nitrate (KNO_3 - 13:0:45) were used for fertigation.

3.3 Methods

3.3.1 Design and layout

Research was conducted inside polyhouse using the hybrid 'KPCH 1' from January to March, 2022. Treatments contain seven levels of fertigation, including a control.

Location: Department of Vegetable Science
Experimental design: Randomised Block Design
Number of treatments: 7
Number of replications: 3
Total number of experimental plots: 21
Number of plants per plot: 8
Spacing: 1×0.5 m
Season: January to March, 2022

3.3.2 Treatments

T1: Control - 100% RDF - KAU *ad hoc* recommendation for precision farming in Kerala (175:125:300 kg NPK/ha)
T2: 50% dose of KAU *ad hoc* recommendation
T3: 60% dose of KAU *ad hoc* recommendation
T4: 70% dose of KAU *ad hoc* recommendation
T5: 80% dose of KAU *ad hoc* recommendation
T6: 90% dose of KAU *ad hoc* recommendation

In treatments one to six, 50% dose of phosphorus was added to the soil as basal in the form of rock phosphate.

T7: 70% dose of KAU *ad hoc* recommendation (100% P, 25% N and 25% K were applied as basal dose)

3.4 Cultural operations

3.4.1 Field preparation and planting

The field was ploughed and harrowed to a fine tilth and liming (2 kg/cent) was done (Plate 3.1). Ten soil samples were collected from different spots of the polyhouse and a representative sample of 500 g was given for soil analysis. Soil analysis was done at Radio Tracer Laboratory (RTL), COA, Vellanikkara. Seven beds were prepared, each 20 m in length, 60 cm in width and around 20 cm height. The distance between two adjacent beds was 40 cm. Fumigation was done to control soil-borne pathogens. Formalin (40%) at the rate of 100 mL/m^2 was drenched and covered with a thick polythene sheet. Two weeks after the application of formaldehyde, *Trichoderma*-enriched cow dung was applied. Three days after the application of *Trichoderma*-enriched cow dung, *Paecilomyces lilacinus* was applied at the rate of 10 g/L. Basal application of phosphorus was done in all the treatments and in T7 basal application of N, P and K was applied in the form of urea, rock phosphate and SOP two days before planting. Drip lines of 16 mm diameter and made of High-Density Polyethylene (HDPE) with non-pressure compensating in-line emitters spaced at 40 cm and having a flow rate of 2 LPH were laid at the center of each bed. Mulching sheets were spread over the beds and sides were fixed by laying soil. Holes were punched over the mulching sheet at 50 cm spacing using PVC pipes of three inch diameter. Seeds of 'KPCH 1' were soaked in a solution containing 1% *Pseudomonas fluorescens* and 0.5% KNO_3 for four hours. Two seeds were sown in each pit and few seeds were sown in portrays to facilitate gap filling at later stage (Plate 3.3).

3.4.2 Aftercare

Gap filling was done using five to seven days old seedlings (Plate 3.4). Thinning was performed two weeks after planting, by retaining one healthy plant per pit. Nets for trailing plants were laid vertically before the germination of seeds and seedlings were trailed when plants reached the vining stage (Plate 3.2). Hand weeding was carried out at fortnightly intervals. Sampoorna KAU multimix for vegetables, which is a water-soluble micronutrient mixture produced by KAU was sprayed at the rate of 5 g/L at 15 days interval on 15, 30 and 45 DAS. Foliar spray of Pseudomonas at the rate of 20 g/L was done at weekly intervals.

3.4.3 Irrigation

Water supplied through the irrigation network of KAU stored in a tank at the Department of Vegetable Science was used for irrigation. The pumped water was provided through drip irrigation daily at 60% Cumulative Pan Evapotranspiration (CPE). The water used for irrigation through drip lines was filtered using a sand filter as the primary filter and screen filter as the secondary filter.

3.4.4 Fertigation

Fertigation was done at three days interval using water soluble fertilizers like urea, KNO_3 and NPK mixture (19:19:19). KAU *ad hoc* recommendation (175:125:300 kg NPK/ha) is for a crop duration of 90 days (30 splits), and a plant population of 20,000 plants/ha following a spacing of 1×0.5 m. The entire crop duration is divided into three stages *viz.,* establishment, vegetative and fruiting stage, each stage spanning 18 days (6 splits), 36 days (12 splits) 36 days (12 splits) respectively. Recommended fertilizer dosage for salad cucumber has an equal ratio of nitrogen, phosphorus and potassium throughout the crop span. Hence, 30 equal splits for a total crop duration of 90 days was the recommendation (Table 3.2). However, in the present study, due to high temperatures towards the fag end of the cropping season, the crop ended by 70 DAS. Hence only 20 splits of the fertilizers could be applied for the experiment (116.67:104.2:200 kg NPK/ha) (Table 3.3). Fertigation started three days after transplanting and it was done towards the end of irrigation. Fertigation was done with the help of a battery-operated mobile fertilizer injector (Plate 3.5 and 3.6). The measured quantity of fertilizers was dissolved in one litre of water. Suction tube of the injector was immersed in the nutrient solution and its delivery was connected to the laterals for injecting soluble fertilizers. Fertigation was done slowly through each lateral over a period of five minutes. Irrigation water was passed through the drip lines after the end of the fertigation for few minutes, to flush out whole nutrients. Flushing of drip lines and cleaning of filters were done at regular intervals before the start of fertigation.

Table 3.2: KAU *ad hoc* recommendation for salad cucumber per hectare

Nutrients	Basal	Establishment (6 splits)	Vegetative (12 splits)	Fruiting (12 splits)
Nitrogen (kg/ha)		35.0	70.0	70.0
Phosphorus (kg/ha)	62.5	12.5	25.0	25.0
Potassium (kg/ha)		60.0	120.0	120.0

3.4.5 Plant protection

Plant protection measures were taken wherever necessary.

3.4.6 Harvesting

Fruits were plucked seven days after flowering when they were tender and crisp. Harvesting was done at three days interval.

Table 3.3. Recommended and supplied quantity of nutrients for a single plant

<table>
<tr><th rowspan="3">Treat ments</th><th colspan="2">Nitrogen (g)</th><th colspan="5">Phosphorus (g)</th><th colspan="2">Potassium (g)</th></tr>
<tr><th rowspan="2">Full dose (30 splits)</th><th rowspan="2">Actual dose given (20 splits)</th><th rowspan="2">Full dose (30 splits)</th><th colspan="3">Actual dose given (20 splits)</th><th rowspan="2">Full dose (30 splits)</th><th rowspan="2">Actual dose given (20 splits)</th></tr>
<tr><th>Basal (B)</th><th>Fertigation (F)</th><th>Total</th></tr>
<tr><td>100% RDF</td><td>8.75</td><td>5.83</td><td>6.25</td><td>3.13</td><td>2.80</td><td>5.21</td><td>15.00</td><td>10.00</td></tr>
<tr><td>90% RDF</td><td>7.88</td><td>5.25</td><td>5.63</td><td>2.81</td><td>1.88</td><td>4.69</td><td>13.50</td><td>9.00</td></tr>
<tr><td>80% RDF</td><td>7.00</td><td>4.67</td><td>5.00</td><td>2.50</td><td>1.67</td><td>4.17</td><td>12.00</td><td>8.00</td></tr>
<tr><td>70% RDF</td><td>6.13</td><td>4.08</td><td>4.38</td><td>2.19</td><td>1.46</td><td>3.65</td><td>10.50</td><td>7.00</td></tr>
<tr><td>60% RDF</td><td>5.25</td><td>3.50</td><td>3.75</td><td>1.88</td><td>1.25</td><td>3.13</td><td>9.00</td><td>6.00</td></tr>
<tr><td>50% RDF</td><td>4.38</td><td>2.92</td><td>3.13</td><td>1.56</td><td>1.04</td><td>2.60</td><td>7.50</td><td>5.00</td></tr>
<tr><td>T7</td><td>6.13</td><td>1.53 (B) + 3.06 (F) = 4.59</td><td>4.38</td><td>4.38</td><td>0</td><td>4.38</td><td>10.50</td><td>2.63 (B) + 5.25 (F) = 7.88</td></tr>
</table>

3.5 Observations recorded

3.5.1 Biometric observations

3.5.1.1 Vine length (m)

Vine length of the plants in each replication was recorded after uprooting at the final harvest using a measuring tape and the average was calculated.

3.5.1.2 Days to first flower opening

Number of days from sowing to first flower opening was counted and the average was worked out.

3.5.1.3 Number of flowers per node

Number of flowers per node was recorded by taking five nodes uniformly in all the treatments at peak flowering time and the average was estimated.

3.5.1.4 Parthenocarpic expression (%)

Ten flowers from each replication were tagged randomly and the percentage of flowers that developed into full-fledged fruits was calculated.

3.5.1.5 Number of fruits per plant

Number of fruits from each plant was counted in each harvest separately and the sum of fruits was calculated after the last harvest.

3.5.1.6 Average fruit length (cm)

Ten fruits were taken randomly in each harvest from a replication and fruit length was measured by considering the length from base to tip of each fruit using a scale and the average was worked out.

3.5.1.7 Average fruit weight (kg)

Ten fruits were taken randomly in each harvest and the weight of the individual fruits was documented and the average was figured out.

Plate 3.1. Land preparation and liming

Plate 3.2. Laying of trailing nets

Plate 3.3. Sowing of cucumber seeds

Plate 3.4. Gap filling using one week old seedlings

Plate 3.5. Ferigation using battery-operated mobile fertilizer injector

Plate 3.6. Fertilizer injector

Fifteen days after sowing

Thirty days after sowing

Forty five days after sowing

Plate 3.7. General view of the experimental plot

3.5.1.8 Average fruit girth (cm)

Ten fruits were taken randomly in each harvest and girth was measured from the middle of the fruit using a thread and scale and the average was determined.

3.5.1.9 Days to first harvest

Number of days from sowing to first harvest was recorded for each plant and the average was taken.

3.5.1.10 Number of harvests

Total number of harvests obtained for each plant was recorded and the average was computed.

3.5.1.11 Yield per plant (kg)

Individual plant yield was recorded during each harvest and the total yield per plant was calculated.

3.5.2 Qualitative characters

3.5.2.1 TSS (°B)

Ten fruits were taken randomly from each replication and the fruits were cut open and made into small pieces after peeling and ground using a mortar and pestle. Total soluble solids of fruit juice were measured using a hand refractometer having 0 - 30 °B range.

3.5.3 Incidence of pests and diseases

Incidence of pests and diseases were recorded and controlled using proper management measures.

3.5.4 Physiological disorders

Physiological disorders due to high temperature and nutritional deficiencies were recorded.

3.5.5 B:C ratio

B: C ratio for each treatment was calculated by taking into consideration the total returns and variable costs involved.

3.5.6 Soil analysis

Soil analysis was done before and after the cropping period. Only one representative sample was tested before the crop. After the crop, composite samples weighing 500 g were taken separately from each treatment and were used for soil analysis. pH, EC, organic carbon, available P, K, Ca, Mg, S, and micronutrients *viz.,* Fe, Mn, Zn, Cu and B content of each treatment were analysed after the crop. For analysing soil samples, facilities at RTL, COA, Vellanikkara were utilised.

3.5.7 Agro-meteorological observation

Weather parameters like daily maximum and minimum temperature, average relative humidity, rainfall and evaporation rate were recorded from the Agro-meteorological observatory maintained at COA, Vellanikkara. The temperature inside the polyhouse was also documented using a digital temperature and relative humidity sensor (Data logger).

3.5.8 Statistical analysis

The observed values pertaining to various treatments were subjected to statistical analysis (two-way ANOVA) using the online KAU GRAPES software version 1.0.0. (Gopinath *et al*., 2020) (https://www.kaugrapes.com/home).

Results

4. RESULTS

An experiment was conducted at the Department of Vegetable Science, COA, Vellanikkara to standardise the fertigation schedule and to evaluate different levels of fertigation on yield and quality of salad cucumber parthenocarpic hybrid 'KPCH 1' grown under polyhouse. The results of the experiment are presented below.

4.1 Biometric observations

4.1.1 Vine length (m)

The vine length recorded for various treatments is presented in Table 4.1. The data revealed that different levels of fertigation had significant effect on vine length. The vine length was highest (2.88 m) for 100% RDF and it was statistically on par with 90% RDF, 80% RDF and T7.

4.1.2 Days to first flower opening

Data pertaining to the effect of different fertigation levels on days to first flower opening is furnished in Table 4.1. Different levels of fertigation had significant effects on days to first flower opening. Treatment seven took lower days (33 DAS) to first flower opening when compared to other treatments and it was on par with 100% RDF.

Table 4.1. Effect of different levels of fertigation on vine length and days to first flower opening

Sl. No.	Treatments	Vine length (m)	Days to first flower opening
1.	T1 - 100% RDF	2.88^{a}	33.33^{bc}
2.	T6 - 90% RDF	2.72^{ab}	34.27^{a}
3.	T5 - 80% RDF	2.63^{abc}	33.93^{ab}
4.	T4 - 70% RDF	2.51^{bc}	34.33^{a}
5.	T3 - 60% RDF	2.37^{c}	33.93^{ab}
6.	T2 - 50% RDF	2.40^{c}	34.60^{a}
7.	T7 -70% RDF (100% P and 25% N and K were applied as basal)	2.62^{abc}	33.00^{c}
	CV (%)	**6.809**	**1.26**
	CD (0.05)	**0.314**	**0.76**
	SE(m)	**0.102**	**0.247**

4.1.3 Number of flowers per node

Observation on number of flowers per node is given in Table 4.2. The data indicate that fertigation levels did not have any significant effect on the number of flowers per node. An average number of flowers per node ranged between 2.53 to 2.87.

Table 4.2. Effect of different levels of fertigation on number of flowers per node

Sl. No.	Treatments	Number of flowers per node
1.	T1 - 100% RDF	2.67
2.	T6 - 90% RDF	2.67
3.	T5 - 80% RDF	2.73
4.	T4 - 70% RDF	2.87
5.	T3 - 60% RDF	2.60
6.	T2 - 50% RDF	2.53
7.	T7 -70% RDF (100% P and 25% N and K were applied as basal)	2.53
	CV (%)	**7.437**
	CD (0.05)	**NS**
	SE(m)	**0.114**

4.1.4 Parthenocarpic expression (%)

Parthenocarpic expression was influenced by different levels of fertigation and it varied significantly between treatments. The observation regarding parthenocarpic expression for different treatments is presented in Table 4.3.

Application of 100% RDF resulted in the highest percentage of fruit set (66.67 %) and it was significantly superior over other treatments.

4.1.5 Number of fruits per plant

The number of fruits per plant from initial harvest to 70 DAS was recorded and the results are tabulated in Table 4.3. Critical analysis of data indicates that the number of fruits per plant varied significantly due to different levels of fertigation. Among the different levels of fertigation studied 100% RDF registered the highest number of fruits per plant (12.67 fruits) and it was closely followed by 90% RDF (12.53 fruits) which was statistically on par.

Table 4.3. Effect of different levels of fertigation on parthenocarpic expression and number of fruits per plant

Sl. No.	Treatments	Parthenocarpic expression (%)	Number of fruits per plant
1.	T1 - 100% RDF	66.67^{a}	12.67^{a}
2.	T6 - 90% RDF	53.33^{b}	12.53^{a}
3.	T5 - 80% RDF	43.33^{bc}	10.13^{bc}
4.	T4 - 70% RDF	40.00^{c}	9.20^{cd}
5.	T3 - 60% RDF	36.67^{c}	9.07^{cd}
6.	T2 - 50% RDF	36.67^{c}	8.60^{d}
7.	T7 -70% RDF (100% P and 25% N and K were applied as basal)	43.33^{bc}	11.07^{b}
	CV (%)	**15.095**	**6.948**
	CD (0.05)	**12.276**	**1.294**
	SE (m)	**3.984**	**0.42**

4.1.6 Average fruit length (cm)

The fruit length did not show significant variation due to fertigation levels (Table 4.4, Plate 4.1). Average fruit length was highest in 100% RDF (17.67 cm) and it was lowest in 50% RDF (16.25 cm).

4.1.7 Average fruit weight (kg)

Observations recorded for fruit weight are provided in Table 4.4. Perusal of the data indicates that different levels of nutrients had no significant effect on average fruit weight. However, the maximum fruit weight was recorded in 100% RDF (0.215 kg) and the minimum in 50% RDF (0.200 kg).

4.1.8 Average fruit girth (cm)

Results obtained for fruit girth are depicted in Table 4.4. The data show that fertigation levels did not significantly influence fruit girth. Maximum average fruit girth was observed for 100% RDF and minimum for 50% RDF.

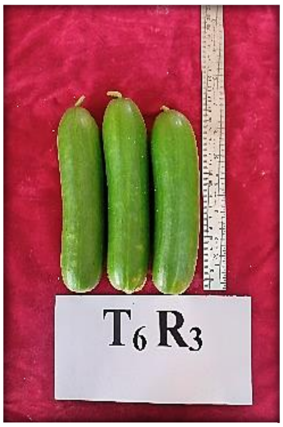
Table 4.4. Effect of different levels of fertigation on average fruit length, average fruit weight and average fruit girth

Sl. No.	Treatments	Average fruit length (cm)	Average fruit weight (kg)	Average fruit girth (cm)
1.	T1 - 100% RDF	17.67	0.215	14.48
2.	T6 - 90% RDF	17.50	0.210	14.23
3.	T5 - 80% RDF	17.50	0.209	14.05
4.	T4 - 70% RDF	17.07	0.206	13.97
5.	T3 - 60% RDF	16.70	0.206	13.49
6.	T2 - 50% RDF	16.25	0.200	13.73
7.	T7 -70% RDF (100% P and 25% N and K were applied as basal)	16.80	0.205	13.75
	CV (%)	**3.301**	**8.037**	**4.465**
	CD (0.05)	**NS**	**NS**	**NS**
	SE (m)	**0.326**	**0.010**	**0.360**

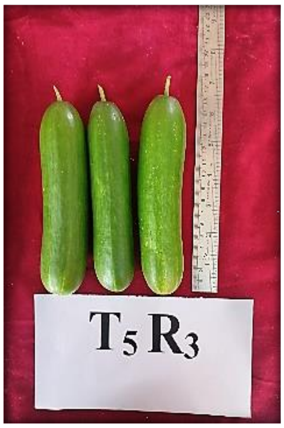
4.1.9 Days to first harvest

No significant difference was observed in the data recorded for days to first harvest at different levels of fertigation (Table 4.5). On average, days to first harvest varied from 40.47 to 42.80 DAS.

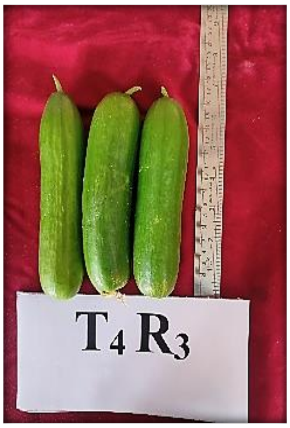
100% RDF



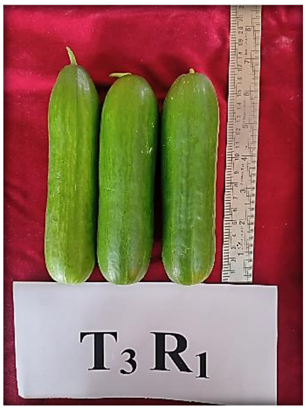
90% RDF



80% RDF



70% RDF



60% RDF

50% RDF

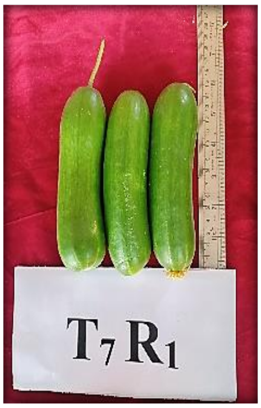


Plate 4.1. Variation in fruit size at different fertigation levels

4.1.10 Number of harvests

The number of harvests recorded for each treatment is presented in Table 4.5. The data revealed that number of harvests remained unchanged with different levels of fertigation. On average, seven to eight harvests were obtained from a crop of 70 days duration.

Table 4.5. Effect of different levels of fertigation on days to first harvest and number of harvests

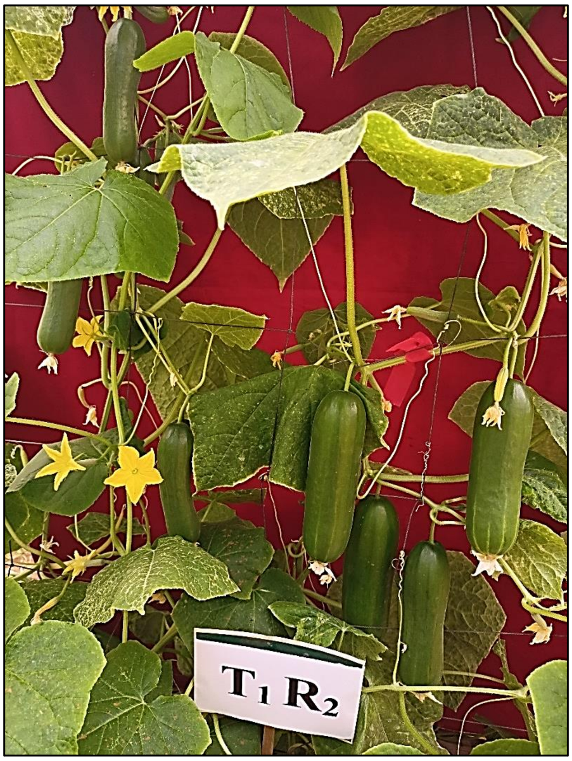
Sl. No.	Treatments	Days to first harvest	Number of harvests
1.	T1 - 100% RDF	40.47	7.33
2.	T6 - 90% RDF	42.07	7.33
3.	T5 - 80% RDF	41.47	7.00
4.	T4 - 70% RDF	42.47	7.67
5.	T3 - 60% RDF	42.80	7.33
6.	T2 - 50% RDF	42.33	7.67
7.	T7 -70% RDF (100% P and 25% N and K were applied as basal)	41.00	8.00
	CV (%)	**4.22**	**9.97**
	CD (0.05)	**NS**	**NS**
	SE (m)	**1.018**	**0.43**

4.1.11 Yield per plant (kg)

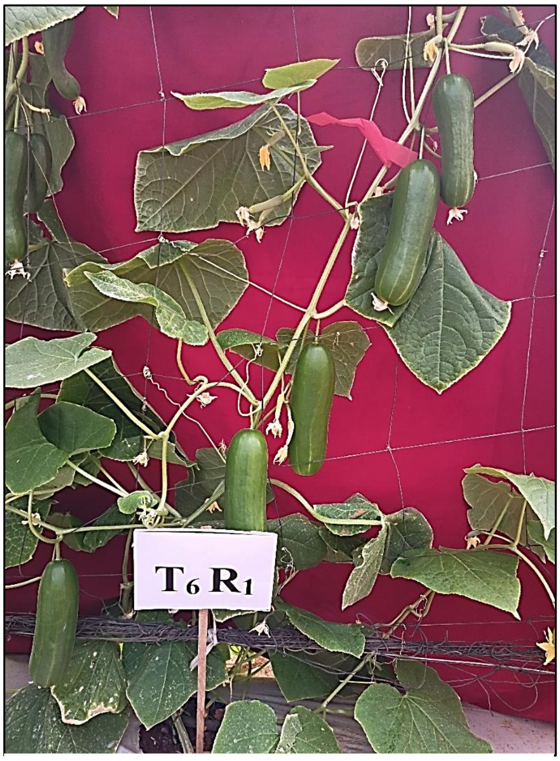
Yield per plant was measured by taking the cumulative yield after each harvest. The results showed that yield per plant was influenced by different fertigation levels (Table 4.6, Plate 4.2). The highest yield per plant was recorded for 100% RDF (2.66 kg) and it was statistically on par with 90% RDF (2.43 kg). Yield per plant was recorded for a crop span of 70 days.

4.1.12 Yield per plot (kg)

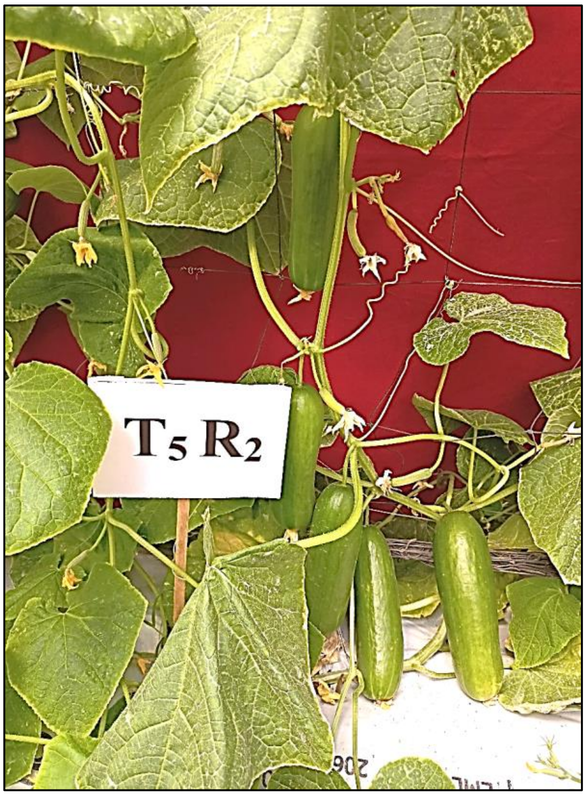
Perusal of the data (Table 4.6) showed that fertigation had significant effect on yield per plot. Yield per plot was maximum for 100% RDF (21.30 kg), which was statistically on par with 90% RDF (19.47 kg). This obtained yield per plot was from eight plants having 70 days of crop duration. The projected yield for 20,000 plants/ha at 1×0.5 m spacing supplied with 100% RDF is 53.2 t/ha for a crop duration of 70 days (Table 4.6). The next highest yield was obtained for T7 which is comparable with the yield obtained from 100% RDF. Yield per plot was minimum for 50%, 60% and 70% RDF.



100% RDF



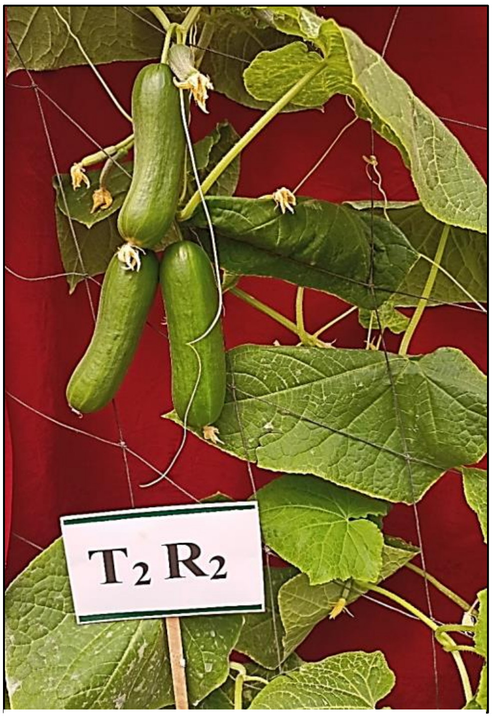
90% RDF



80% RDF

70% RDF

60% RDF



50% RDF

Plate 4.2. Variation in yield at different fertigation levels

Table 4.6. Effect of different levels of fertigation on yield per plant and yield per plot

Sl. No.	Treatments	Yield per plant (kg)	Yield per plot (kg)	Yield per hectare (t)
1.	T1 - 100% RDF	2.66^{a}	21.28^{a}	53.20^{a}
2.	T6 - 90% RDF	2.43^{ab}	19.47^{ab}	48.67^{ab}
3.	T5 - 80% RDF	2.17^{c}	17.38^{c}	43.47^{c}
4.	T4 - 70% RDF	1.92^{d}	15.33^{d}	38.33^{d}
5.	T3 - 60% RDF	1.88^{d}	15.07^{d}	37.67^{d}
6.	T2 - 50% RDF	1.69^{d}	13.55^{d}	33.87^{d}
7.	T7	2.29^{bc}	18.35^{bc}	45.87^{bc}
	CV (%)	**6.206**	**6.206**	**6.206**
	CD (0.05)	**0.237**	**1.899**	**4.748**
	SE (m)	**0.077**	**0.616**	**1.541**

4.2 Qualitative characters

4.2.1 TSS (^{0}B)

Critical analysis of the data on TSS (Table 4.7) indicates that fertigation levels did not have any significant effect on the TSS of fruits. The average TSS of fruits for different treatments varies from 3 to 3.27˚B.

Table 4.7. Effect of different levels of fertigation on TSS

Sl. No.	Treatments	TSS (˚B)
1.	T1 - 100% RDF	3.27
2.	T6 - 90% RDF	3.17
3.	T5 - 80% RDF	3.13
4.	T4 - 70% RDF	3.13
5.	T3 - 60% RDF	3.13
6.	T2 - 50% RDF	3.06
7.	T7 - 70% RDF (100% P and 25% N and K were given as basal)	3.00
	CV	**3.488**
	CD (0.05)	**NS**
	SE (m)	**0.063**

4.3 Incidence of pests and diseases

Details regarding the occurrence of different pests and diseases are summarised in Table 4.8.

4.3.1 Pests

At the time of seed germination, damage caused by rats were noticed inside the rain shelter in which the nursery was raised. Seeds sown in portrays were eaten and the top portion of emerging seedlings were cut down. To control rats, bromadiolone 0.005% bait cakes were placed along with snap traps at different spots inside the rain shelter. Young seedlings were also damaged by snails. The attack was manifested as damage to the roots and collar region of emerging seedlings. To prevent snail damage, metaldehyde baits were kept at the base of plants. Mild infestation of serpentine leaf miner was noticed at the establishment stage and it was controlled by a foliar spray of

Tafgor® (dimethoate 30 EC) at the rate of 1.5 mL/L. Attack of whiteflies, thrips and mites were also noticed at the end of the cropping season when the temperature increased. Yellow sticky traps along with a foliar spray of Confidor® (imidacloprid 17.80 SL) at the rate of 3 mL/10 L were done to manage white flies. Thrips were controlled using two different insecticides – Asataf® 2 g/L (acephate 75 SP) and Pride® 2 g/L (acetamiprid 20 SP). For the management of mites, a foliar spray of Magister® (fenazaquin 10 EC) was done at the rate of 2 mL/L (Plate 4.3).

4.3.2 Diseases

Damping off and *Rhizoctonia* rot were observed during the establishment stage and they were controlled by drenching indofil M 45 (mancozeb 75% WP) at the rate of 2 g/L. Mild infestation of downy mildew was observed during the vegetative phase. Foliar spray of curzate M8 (Cymoxanil 8% + Mancozeb 64% WP) at the rate of 1.5 mL/L was done to manage downy mildew. Incidence of bacterial wilt was also seen during the fruiting stage, which was confirmed by the ooze test. Drenching with K-Cycline (Streptomycin sulphate 90% + tetracycline hydrochloride 10% WP) at the rate of two grams in ten litres of water was done to manage bacterial wilt. Mild incidence of the virus, probably due to the melon yellow spot virus was also observed in very few plants at the establishment stage. Virus management was achieved by vector control (thrips) and rouging of diseased plants (Plate 4.4).

Table 4.8. Incidence of pests and diseases

Sl. No.	Common name	Scientific name	Stage of attack	Nature of damage & symptom	Control measures
	Pests				
1.	Rat	*Rattus* spp.	Nursery	Eating cotyledons of germinating seeds and cutting the top portion of germinating seedlings	Bromadiolone 0.005% bait cakes and snap traps
2.	Snails	*Allopeas clavulinum*	Establishment stage	Eating of roots and collar region of young plants	Metaldehyde bait
3.	Serpentine leaf miner	*Liriomyza trifolii*	Vegetative stage	White coloured serpentine mines on the upper surface of leaves	Foliar spray of dimethoate (1.5 mL/L)
4.	White fly	*Bemisia* sp	Fruiting stage	Suck sap from the under surface of leaves resulting in the yellowing of leaves	Yellow sticky traps and foliar spray of imidacloprid (3 mL/10 L)
5.	Thrips	*Thrips* spp.	Establishment and fruiting stage	Cupping, yellowing and shrivelling of leaves	Foliar spray of acephate (2 g/L) and acetamiprid (2 g/L)
6.	Mites	*Tetranychus* sp	Fag end of the crop	Whitish yellow coloured discolouration on the upper surface of leaves	Foliar spray of fenzaquin (2 mL/L)

	Diseases				
Sl. No.	**Diseases**	**Causative organism**	**Susceptible stage**	**Symptoms**	**Management**
1.	Damping off	*Pythium* spp.	Seedling stage	Thinning of collar region and rotting	Drenching of mancozeb (2 g/L)
2.	*Rhizoctonia* rot	*Rhizoctonia solani*	Seedling and vegetative stage	Collar rot, leaf blight and wilting of plants	Drenching of mancozeb (2 g/L)
3.	Melon yellow spot virus	Tospo virus Vector- Thrips	Vegetative stage	Rosetting leaves, stunted plant growth and yellow spots on the upper surface of leaves	Rouging of diseased plants and vector control
4.	Downy mildew	*Pseudoperonospora cubensis*	Vegetative stage	Pale yellow angular spots on the upper surface of leaves	Foliar spray of curzate M8 (1.5 mL/L)
5.	Bacterial wilt	*Ralstonia solanacearum*	Fruiting stage	Rapid and complete wilting of normally grown up plants (confirmed through ooze test)	Drenching with K-Cycline (2 g/10 L)

4.4 Physiological disorders

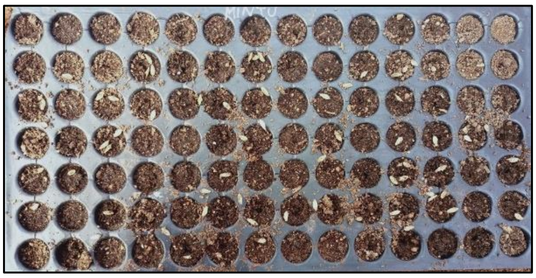
Physiological disorders like crooked fruits and aborted flowers were observed during the last phase of the crop (Plate 4.5). To prevent micronutrient deficiency, foliar spray of Sampoorna KAU multimix for vegetables at the rate of 5 g/L was done at fortnightly intervals. The temperature inside and outside the polyhouse increased alarmingly towards the last stage of the crop. Foggers were operated for 60 seconds each, at one hour interval between 12.00 to 3.00 p.m., during hot sunny days to manage the temperature inside the polyhouse.

4.5 Benefit-Cost ratio

B:C ratio was highest for 100% RDF (Table 4.9). It implies that it is more profitable compared to other treatments. B:C ratio (by considering only variable cost) of all treatments was above one. T7 has a B:C ratio of 2.09, which is almost near to the B:C ratio of 100% RDF (2.18). Details of calculating the B:C ratio are provided in appendix V, VI and VII.

Table 4.9. Benefit-cost ratio

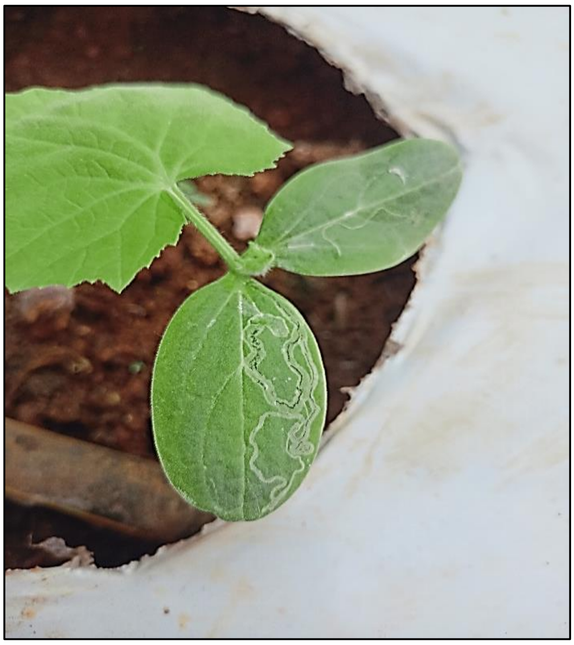
Sl. No.	Treatments	B:C ratio
1.	T1- 100% RDF	2.18
2.	T6- 90% RDF	2.03
3.	T5- 80% RDF	1.86
4.	T4- 70% RDF	1.68
5.	T3- 60% RDF	1.69
6.	T2- 50% RDF	1.55
7.	T7-70% RDF (100% P and 25% N and K as basal)	2.09



Damage caused by rodents in nursery

Roots and collar region damaged by snails

Metaldehyde baits used to control snails



Serpentine mines on leaves caused by leaf miner

Whitish yellow discolouration on leaves caused by mites

Cupping of leaves due to infestation of thrips

Plate 4.3. Incidence of pests

Damping off caused by *Pythium* spp.

Microscopic image of *Pythium* oospores

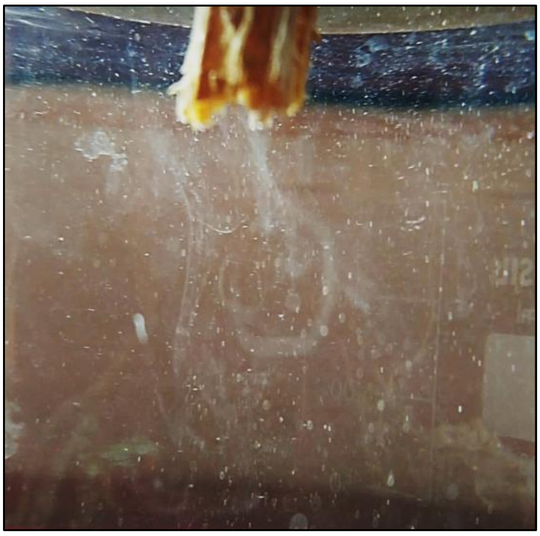
***Rhizoctonia* rot**

Microscopic image of *Rhizoctonia* hyphae

Yellow spots on leaves caused by Melon Yellow Spot Virus

Symptoms of stunting due to virus

Bacterial wilt caused by *Ralstonia solanacearum*



Ooze test to confirm bacterial wilt

Plate 4.4. Incidence of diseases

Crooked fruits

Aborted flowers

Plate 4.5. Occurrence of physiological disorders

4.6 Soil analysis

Soil samples from the polyhouse were analysed for macro and micronutrients before and after the crop. The results of the soil analysis before and after the crop indicate that for all the treatments pH and EC were in the normal range. Organic carbon content was sufficient before the crop and it became high after the crop. Available phosphorus and available potassium were sufficient prior to the crop and the level of both nutrients elevated to a higher range after the crop. Available calcium, available magnesium, and available sulphur were in the 'sufficient' range before cultivation, but after raising the crop the level of calcium became high. Whereas, that of available magnesium and available sulphur remained in the 'sufficient' range. Before raising the crop, the levels of micronutrients like iron and manganese were high, zinc and copper were sufficient and that of boron was deficient. The level of all micronutrients shifted to 'sufficient' level after the crop. The result of soil analysis before raising the crop is given in Table 3.1 and after raising the crop in Appendix I.

4.7 Agro meteorological data

Temperature inside and outside the polyhouse were recorded daily. An average increase in daily maximum temperature of 7.24˚C was observed inside the polyhouse compared to outside temperature (Figure 4.1). The highest daily maximum temperature recorded inside the polyhouse during the study was 45.8˚C.

Data regarding daily maximum temperature and minimum temperature, average relative humidity, rainfall and evaporation rate were collected from the Department of Agricultural Meteorology, COA, Vellanikkara. The results are presented in appendix III. The highest daily maximum temperature of 38.6˚C was recorded on 12^{th} and 14^{th} March 2022 (51 and 53 DAS). The daily maximum temperature ranged between 32.5˚C and 38.6˚C. The daily minimum temperatures ranged between 18.9˚C and 26.6˚C. The mean relative humidity ranged from 23 to 76 per cent. A total rainfall of 1.5 mm was recorded during the cropping period. The maximum daily evaporation rate (8.6 mm) was recorded on 4^{th} March 2022 (43 DAS).

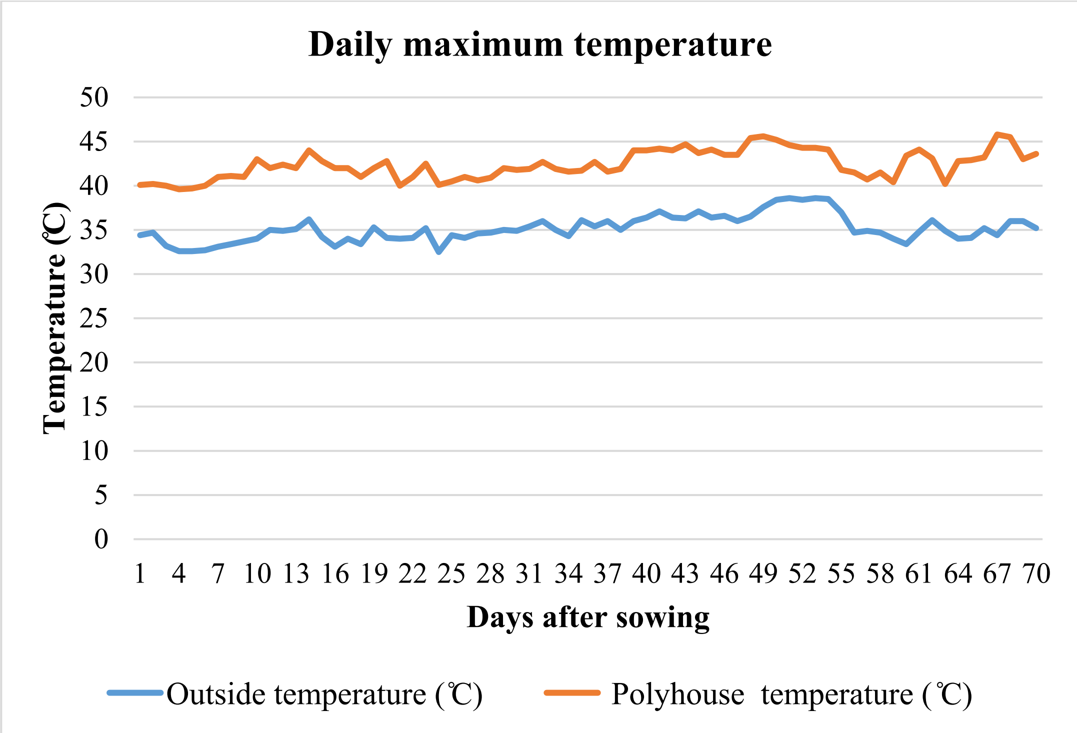


Figure 4.1. Daily maximum temperature inside and outside polyhouse

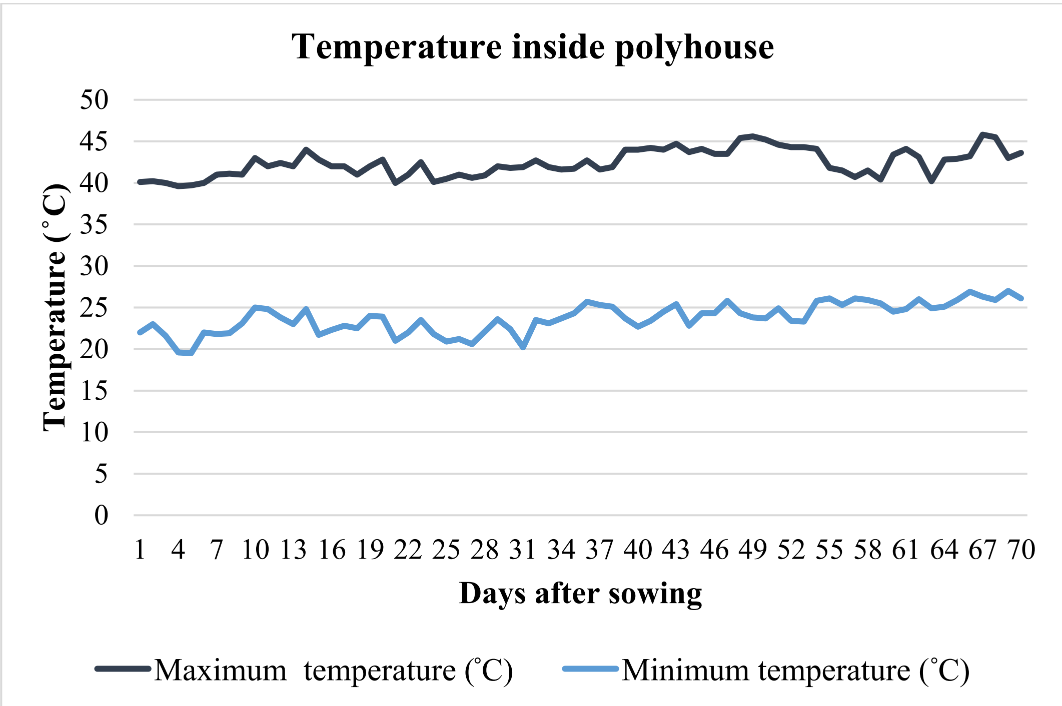


Figure 4.2. Daily maximum and minimum temperature inside polyhouse

Discussion

5. DISCUSSION

In the present study, the effect of fertigation on yield and quality of salad cucumber hybrid, KPCH 1 grown under polyhouse was evaluated. The results of the study indicate that fertigation had a significant effect on the growth, flowering and yield of cucumbers. Whereas, fertigation had no positive influence on the total soluble solids of cucumber grown under polyhouse. The results of the study are discussed below.

5.1 Effect of different levels of fertigation on growth

The results of the study indicate that vine length was influenced by different fertilizer levels. The highest vine length (2.88 m) was observed in 100% RDF and it was on par with 90% RDF, 80% RDF and T7. Increasing fertilizer dose which results in higher availability of major nutrients might be the reason for the increase in vine length in the above treatments. Sumathi *et al*. (2008) stated that the increase in vegetative characters is attributable to increased nutrient availability and the generation of growth-promoting chemicals, which might have increased meristematic activity, and promoted cell elongation and cell multiplication. Jilani *et al*. (2009) claimed that greater nitrogen, phosphorus and potassium application will result in greater vegetative development up to an optimum level, after which growth starts declining. Mohammed *et al.* (2021) reported that the maximum plant height (2.56 m) in cucumber was obtained with 150:120:120 kg NPK/ha, which is comparable with the present study.

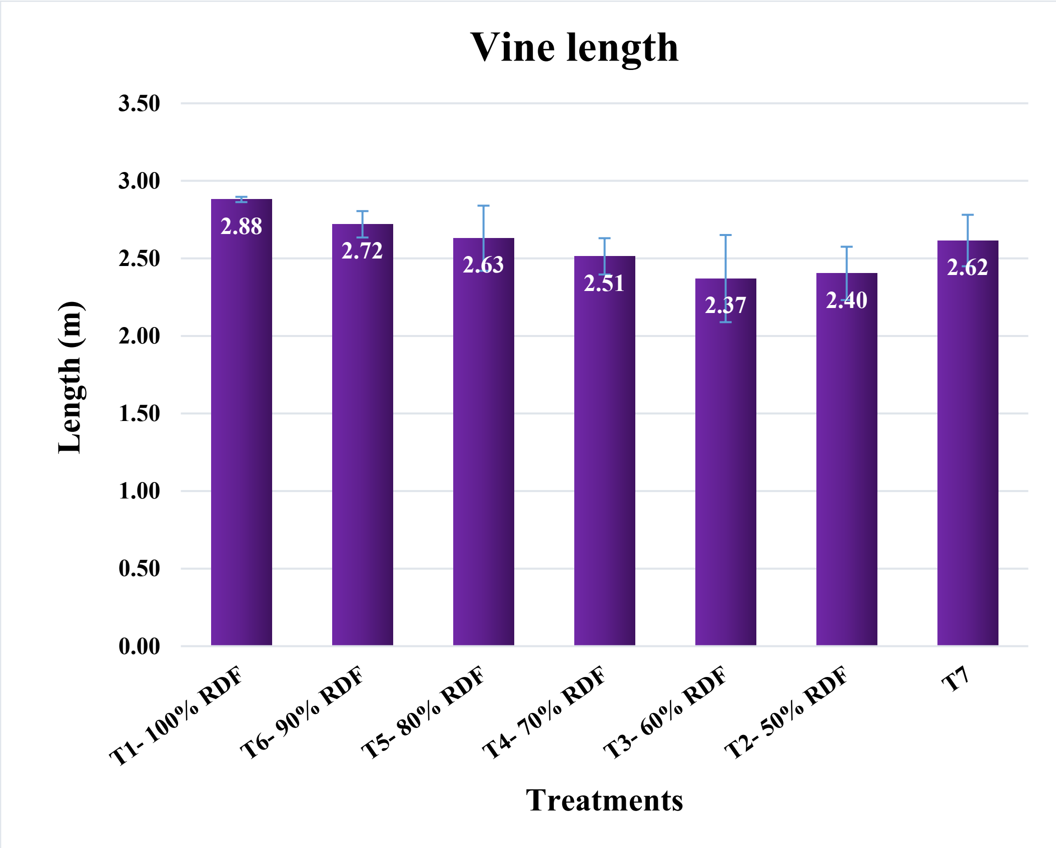


Figure 5.1.1. Effect of different levels of fertigation on vine length

5.2 Effect of different levels of fertigation on flowering and parthenocarpic expression

Treatment T7 registered the least number of days to first flower opening (33 days) and it was on par with treatment one (100% RDF). The plants in treatment seven might have got sufficient nutrients in their early growth stage itself, which resulted in early flowering. Plants in 100% RDF might have met their daily nutrient requirement, which led to early flowering. Flowering takes place when plants attain sufficient nutrient status, both excess and inadequate nutrition delay flowering. According to Kumari *et al*. (2020), the minimum number of days required for flowering in 100% RDF (100:50:75 kg NPK/ha) was 30.13 days whereas, in 80% and 120% RDF it took 32.29 and 30.49 days, respectively. Kumar *et al.* (2020) found out that the mean minimum number of days required for flowering in cucumber is 29.20 days, when supplied with 100:50:50 kg NPK/ha. In the present study, plants supplied with 50% RDF took the maximum number of days to first flower opening. According to Arshad *et al*. (2014) deficiency of major nutrients reduced plant growth and resulted in delayed flowering.

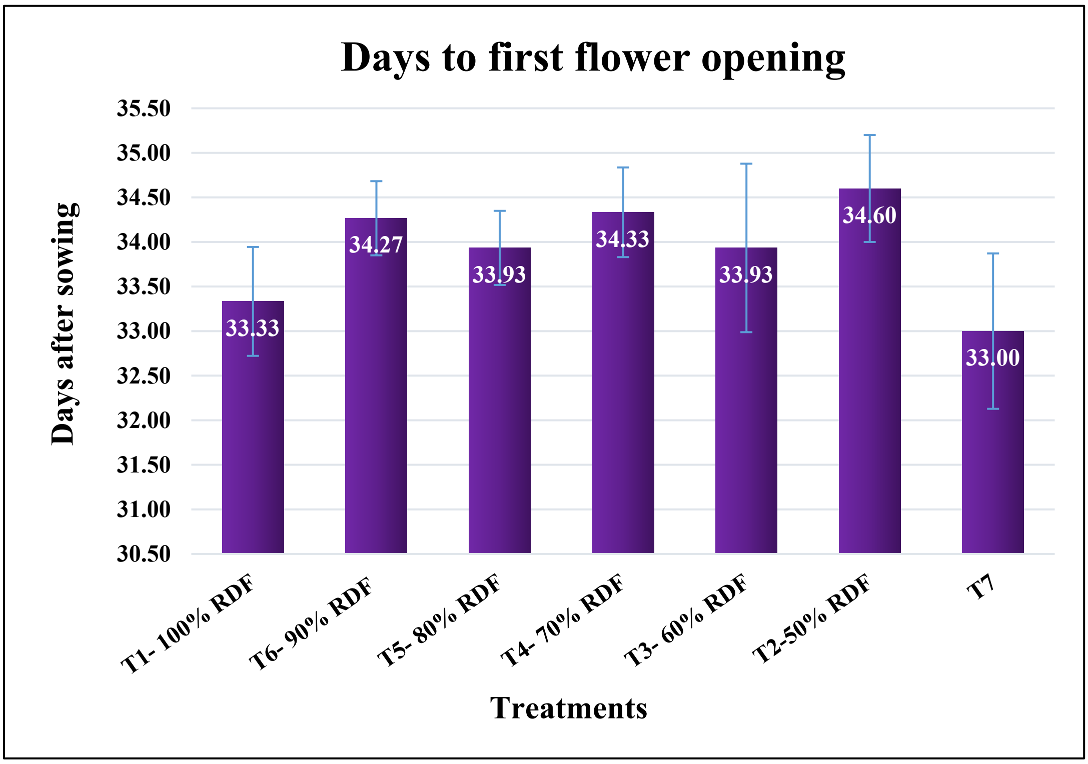


Figure 5.2.1: Effect of different levels of fertigation on days to first flower opening

In general, the ovary ceases its growth and flowers abscise prematurely if pollination and fertilization doesn't happen, but in certain crops, the ovary develops into fruits without pollination and fertilization. Gustafson (1939) reported that the auxin concentration in parthenocarpic fruits is much higher compared to non parthenocarpic fruits. Li *et al.* (2014) suggested that auxin is the primary regulator and cytokinin is the secondary regulator for parthenocarpic fruit set in cucumber. Wang *et al*. (2021) reported that the development of parthenocarpic fruits in cucumber is the combined effect of sugar and plant hormones like auxin and cytokinin. Exogenous application of sugars like fructose and sucrose increased the parthenocarpic fruit set. Genes involved in auxin and cytokinin signalling were more expressed in fruits treated with sugars. Parthenocarpic expression implies the percentage of flowers which developed into full-fledged fruits. Among different levels of fertigation tested in the present study, application of 100% RDF registered the highest parthenocarpic expression. Parthenocarpic expression has shown a linear increasing trend with the amount of nutrients supplied. The increased availability of nitrogen and potassium in the rhizosphere might have enhanced its uptake by plants, which in turn resulted in increased fruit set and development (Feleafel *et al*. 2014). There are reports that among the different nutrients, the level of potassium has a direct relation to parthenocarpic expression. Shafeek *et al.* (2013) found that the application of KNO_3 significantly increased the number of flowers per plant and the percentage of fruit set. Availability of nutrients increases with increasing fertilizer dose, leading to higher parthenocarpic expression thereby eventually leading to increased yield.

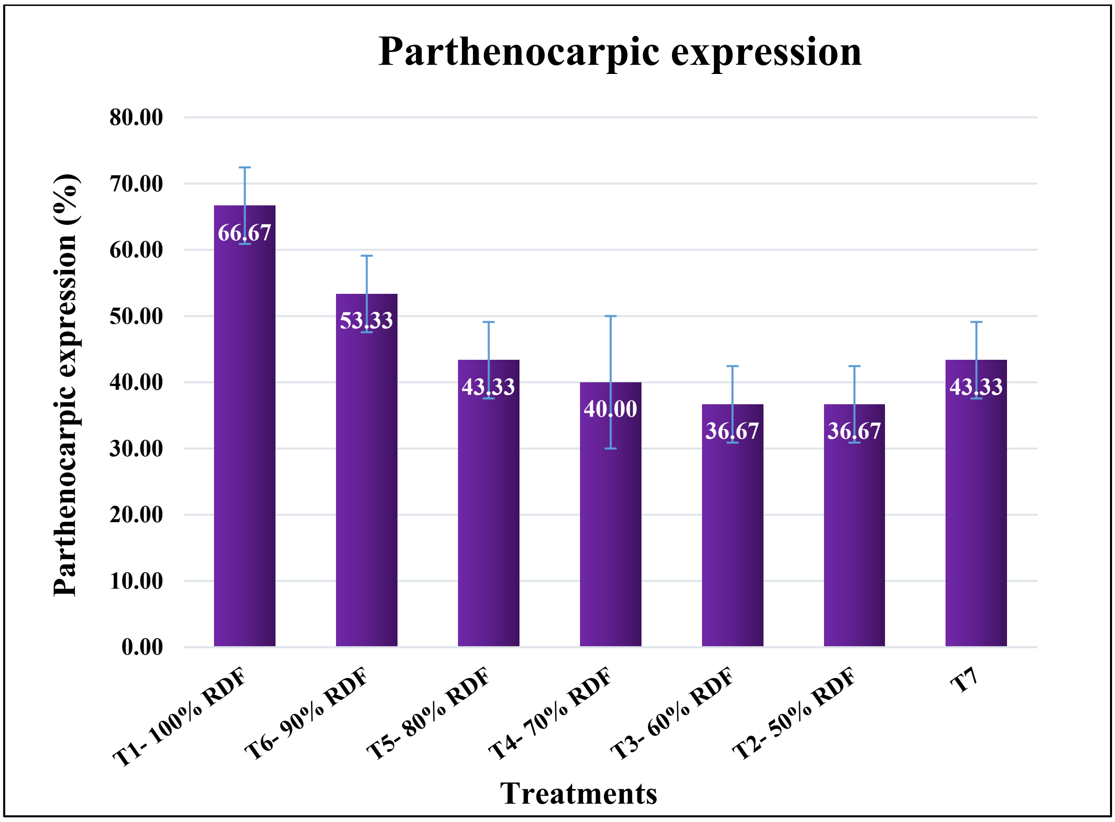


Figure 5.2.2. Effect of different levels of fertigation on parthenocarpic expression

In all the treatments, first flower opened on the second or third node. Results of the present study revealed that fertigation did not have any significant effect on the number of flowers per node, probably because it is primarily a varietal characteristic. Flowering starts when the plants attain sufficient vegetative growth and no much variation in the number of flowers per node was noticed among the treatments. Agbaje *et al*. (2012) reported that increasing NPK fertilizer dose above 100 kg/ha did not significantly influence the number of flowers per plant.

5.3 Effect of different levels of fertigation on yield and yield attributes

The number of fruits per plant varied significantly with different levels of nutrients. The number of fruits per plant was highest at 100% RDF and it was statistically on par with 90% RDF. Growth and production of cucumber might have been boosted by the systematic increase in the dosage of NPK fertilizers. Availability of the right amount of nutrients might have promoted the growth of cucumber plants, which ultimately resulted in an increased number of fruits produced per plant. Application of nutrients at regular short intervals in required quantity resulted in higher nutrient uptake by plants, which led to a maximum number of fruits per vine (Padmaja *et al*., 2021). Similar findings were reported by Arshad *et al*. (2014).

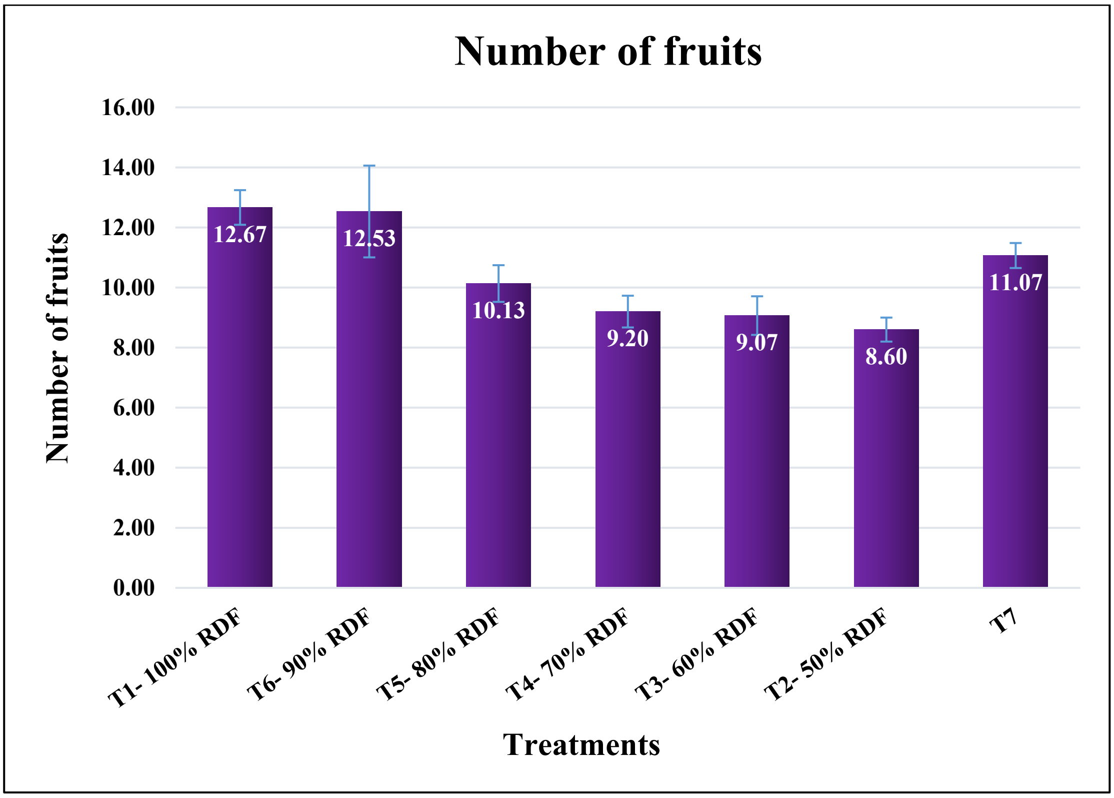


Figure 5.3.1. Effect of different levels of fertigation on number of fruits per plant

Yield attributes *viz.,* number of pickings and days to first harvest did not have any significant difference with different levels of fertigation. Corroborative findings were reported by Pushpendra and Hardaha (2016) and Shafeek *et al*. (2015). According to Kumari *et al*. (2020) in cucumber, it took 38.42 days for first harvest when a fertilizer dosage of 100:50:75 kg NPK/ha was provided.

Different levels of fertigation did not influence the average fruit length, average fruit weight and average fruit girth. Since immature fruits with tender and crisp texture have more consumer preference, fruits were harvested at marketable maturity. Hence average fruit length, fruit weight and fruit girth did not show any significant difference since the fruits were not allowed to develop fully. If they were allowed to remain on the vine for a longer time they might have shown significant differences in their size and weight, but mature fruits have poor keeping quality and low market value.

From the study, it can be inferred that different fertigation levels significantly affected the yield (Table 4.6). Yield per plant and yield per plot were recorded highest in 100% RDF. Fruit yield is the cumulative effect of individual fruit weight, fruit length, fruit girth and number of fruits per plant. It is evident from the study that fruit yield was attributable to number of fruits per plant. Yield has followed a similar trend as shown by vine length towards increase in fertigation dosage. Nisha and Sreelathakumari (2020) reported that increased vegetative growth leads to enhanced chlorophyll content, along with better stomatal conductance, thereby resulting in increased photosynthesis. According to Padmaja *et al*. (2021), uninterrupted application of nutrients in the root zone created a favourable environment for growth and development by way of augmenting metabolic activities in the plant system. Efficient transfer of photosynthates to fruits enhanced dry matter accumulation in fruits, which in turn improved fruit yield (Dawer *et al*., 2019). Sharma *et al.* (2009) examined the effect of fertigation on salad cucumber. The results of the experiment revealed that plants supplied with 300:300:300 kg NPK/ha and planted at a spacing of 1×0.8 m (12,500 plants/ha) recorded highest yield (104 t/ha). Whereas in the present study, fertigation dosage of 116.67:104.2:200 kg NPK/ha and spacing of 1×0.5 m (20,000 plants/ha) were followed. The nitrogen, phosphorus and potassium dosage received per plant in the present study was only 24.17% N, 21.7% P and 41.67% K used in the former study. Hence, it can be inferred that there is still a scope to increase the fertigation dosage per plant and thereby leading to an increase in yield. Al-Jaloud *et al.* (2006) reported that among the different nutrients supplied, potassium has increased the fruit yield linearly indicating that higher K levels may still increase the yield. Whereas, yield get stabilised and then declined after a particular level of N and P supplied *i.e.* N and P showed a typical nutrient response sigmoid curve.

From the study, it can be concluded that a higher dosage of fertilizers will lead to increase in parthenocarpic expression which will result in higher number of fruits per plant and yield per plant.

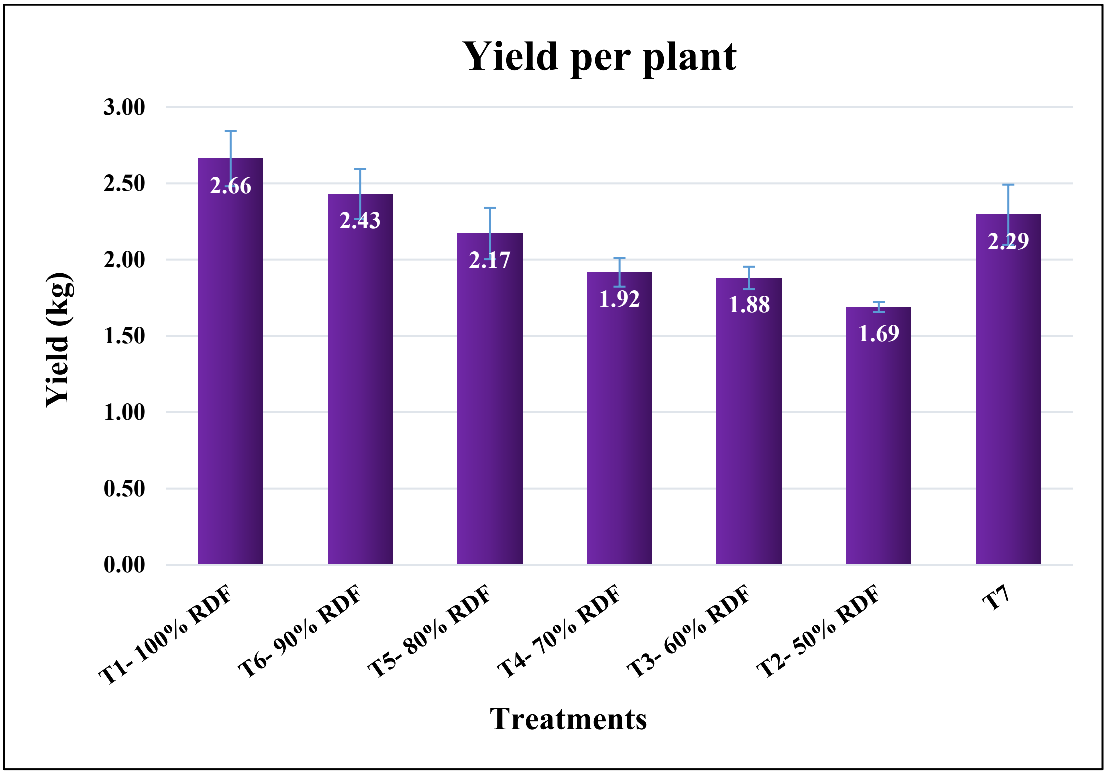


Figure 5.3.2. Effect of different levels of fertigation on yield per plant

5.4 Effect of different levels of fertigation on qualitative characters

Total soluble solid content implies the amount of sugars and soluble minerals present in the fruit juice (Kadam *et al*., 2012). In the present study, levels of fertigation did not have any significant influence on the TSS of fruits. Wang *et al.* (2019) reported that application of excess fertilizers was not beneficial for sugar accumulation in cucumber. This is in conformity with the findings of Kumari *et al*. (2020) in cucumber and Shafeek *et al*. (2015) in muskmelon. Contrary to these results, Brahma *et al.* (2010) reported that TSS improved significantly with different levels of fertilizer application in tomatoes.

5.5 Effect of nutrition on physiological disorders

Indian soils are deficient in mainly two important micronutrients Zn and B. Analysis of soil samples indicated that 33% of Indian soils are deficient in B (Chatterjee *et al*., 2018). Kavitha and Sujatha (2015) reported that B was deficient in all the eight major agro-ecosystem studied in Thrissur district of Kerala. Deficiency of these micronutrients affects the yield and quality of fruits. Crops grown in nutrient deficient soils exhibit major physiological disorders. In the present study, aborted flowers and crooked fruits were observed in all the treatments. The soil prior to the trial was deficient only in boron. It was corrected by applying borax at the rate of 40 g/cent and foliar spray of Sampoorna KAU multimix for vegetables at the rate of 5 g/L at fortnightly intervals, to prevent physiological disorders. Hence, it can be assumed that nutritional deficiency might not be the major reason for observed physiological disorders. Therefore, the probable reason for malformed fruits and aborted flowers may be due to the prevailing high temperature.

5.6 Effect of temperature on aborted flowers, physiological disorders, fruit set and yield

Cucumbers are highly sensitive to high temperature. The optimum day and night temperature required for cucumber are 30℃ and 18 to 21℃ respectively. A minimum temperature of 15℃ is required for the proper growth and development of cucumber plants (Chinatu *et al*., 2017). Increase in both day and night temperature adversely affects flower bud formation in cucumber (Grimstad and Frimanslund, 1993). The findings of the present study showed a similar effect at high temperature, percentage of malformed fruits and number of aborted flowers increased and the percentage of fruit set decreased. The percentage of malformed fruits increased from first harvest to last harvest with the rising temperature *i.e.* towards the end of the crop, temperature increased (Figure 5.6.1). According to Sato *et al*. (2003) increased appearance of malformed fruits in cucumber were recorded at high temperature (45℃). Dax-Fuchs and co-workers (1978), reported that in cucumber the number of aborted female flowers was more in summer planting compared to winter planting. Van Der Vlugt (1983) stated that very few flower buds were formed in gynoecious cucumber at high temperatures, compared to low temperature. Satitmunnaithum *et al*. (2022) reported the occurrence of physiological disorders like blossom end enlargement (BEE) in cucumber at high temperature.

It can be presumed that physiological disorders in cucumber like malformed fruits and aborted flowers are the cumulative effect of many factors like temperature, nutrition, and natural thinning by the plant.

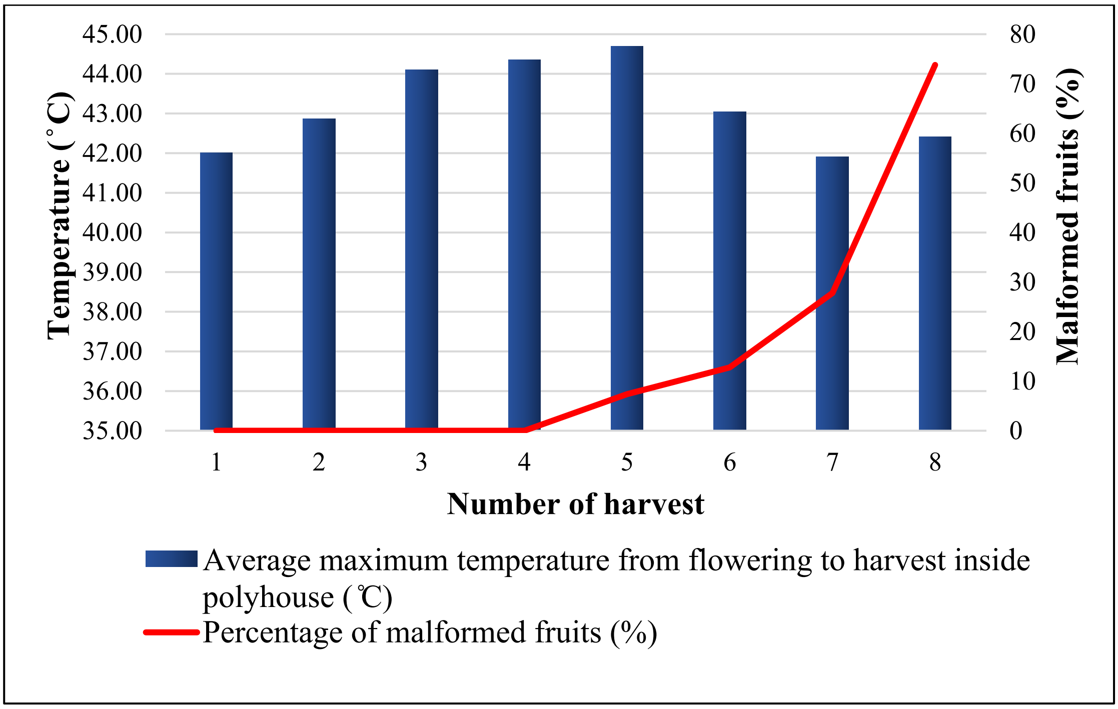


Figure 5.6.1. Percentage of malformed fruits with temperature in 100% RDF

5.7 Economics

The present study revealed that 100% RDF registered the highest income and there is no much variation in the B:C ratio with other treatments. So all the treatments have the potential to give appreciable income to farmers, but in order to achieve the maximum yield of 'KPCH 1' 100% RDF is required. Among all the treatments the production cost was lowest for T7, in which 100% P, 25% N and 25% K were supplied as basal. In T7 full dose of phosphorus was applied basally in the form of rock phosphate. Rock phosphate is one among the cheapest fertilizers available. Use of rock phosphate led to lower cost of production. This method is found to be more economical for farmers in order to avoid the use of costly soluble P fertilizers. In T7, only 70% RDF was applied. If 100% RDF is provided to plants in this manner both productivity and income can be increased with reduced cost of production.

5.8 Soil analysis

Soil analysis reports before and after the crop disclosed that there was an increase in the EC and slight increase in pH of the soil after the crop. The organic carbon content of the soil also increased. Cucumber is a short duration crop of only 90 days. In this study, cropping period was completed in 70 days. Since the crop ended early the nutrients provided in last cycles may not be fully absorbed. So the applied organic (basal application) and inorganic fertilizers might not be fully utilised by the plants.

Future line of work

In the present study, 100% RDF gave best results for the yield and income from a crop of 70 days duration. It is evident that yield increased with increasing fertilizer dose till 100% RDF. Since the yield curve has not stabilised yet, future research has to be carried out with higher doses of fertilizers above 100% RDF till yield stabilises.

The present *ad hoc* recommendation is for a cropping area of one hectare, which can accommodate a population of 20,000 plants if a spacing of 1×0.5 m is followed. Researchers and farmers are adopting different methods like crop geometry, spacing, crop area, bed area *etc.* to calculate per plant fertilizer dose. So it is more advisable to develop fertilizer recommendations on per plant basis rather than on per hectare basis in future, for more uniform results.

In the present study, equal splits of fertilizers were given throughout the cropping period. It is necessary to provide crop stage-specific fertilizer recommendations to meet the stage-specific nutrient demand of the crop. In general, plants require higher quantity of nitrogen and phosphorus during their early stages of growth and more quantity of potassium during flowering and fruiting stages. So more studies have to be conducted to standardise stage-specific fertigation recommendations.

During the present study, various physiological disorders were observed. Hence there is scope for exploring new fertilizer formulations for cucumber, which contain primary, secondary and micronutrients.

Summary

6. SUMMARY

The study entitled 'Standardisation of fertigation schedule for parthenocarpic cucumber (*Cucumis sativus* L.) hybrid KPCH 1 under polyhouse' was carried out at the Department of Vegetable Science, COA, Vellanikkara, during January to March, 2022. The study was conducted with the objectives of standardisation of fertigation schedule and evaluation of different levels of fertigation on yield and quality of 'KPCH 1' grown under polyhouse. The investigation was carried out in a naturally ventilated polyhouse having an area of 384 m^2 in North - South orientation. Soil of the experimental site was lateritic, slightly acidic in nature, normal in organic carbon, high in available phosphorus and potassium, low in boron and medium in calcium, magnesium, sulphur, zinc and copper.

The experiment was conducted in a randomised block design having seven treatments and three replications. The treatments were different levels of fertigation *viz.,* T1 - 100% *ad hoc* recommendation of KAU (175:125:300 kg NPK/ha) for precision farming, T2 - 50% *ad hoc* recommendation, T3 - 60% *ad hoc* recommendation, T4 - 70% *ad hoc* recommendation, T5 - 80% *ad hoc* recommendation, T6 - 90% *ad hoc* recommendation and T7 - 70% *ad hoc* recommendation (100% P, 25% N and 25% K were given as basal dose using rock phosphate, urea and SOP as nutrient source). In all the treatments except T7, 50% P was applied as basal in the form of rock phosphate. *Trichoderma*-enriched farmyard manure at the rate of 15 t/ha and lime at the rate of 2 g/cent were applied uniformly for all the treatments during land preparation. Battery-operated mobile fertilizer injector was used for fertigation in the study. Fertigation was started three days after transplanting and done at three days interval. The *ad hoc* recommendation of KAU for precision farming in cucumber is for a crop duration of 90 days, consisting of 30 equal splits - six splits during establishment stage, 12 splits during vegetative stage and remaining 12 splits in fruiting stage. Water soluble fertilizers *viz.,* urea, KNO_3 and 19:19:19 were used to supply major nutrients. The crop ended early due to extremely high temperature 70 DAS. Hence only 20 splits of fertilizers (116.67:104.2:200 kg NPK/ha) could be applied during the present study.

The data pertaining to biometric observations and TSS were statistically analysed by applying the technique of analysis of variance (ANOVA) for RBD using KAU

Grapes software version 1.0.0. Analysis of the results revealed that vine length was influenced by different levels of fertigation. The highest vine length (2.88 m) was observed for 100% RDF, which was on par with 90% RDF, 80% RDF and T7.

Days to first flower opening and parthenocarpic expression showed significant difference with different levels of fertigation. The highest parthenocarpic expression (66.67%) was recorded in 100% RDF and was superior to other treatments. The treatments 100% RDF and T7 recorded lowest number of days to first flower opening. Whereas, fertigation had no influence on the number of flowers per node.

Average fruit length, fruit weight and fruit girth did not show any significant variation, since the fruits were harvested at marketable maturity. Fertigation had no effect on days to first harvest and number of harvests. However, the number of fruits per plant and yield per plant were highest at 100% RDF and 90% RDF. Increased parthenocarpic expression, enhanced the number of fruits per plant, which in turn increased the yield. Increased availability of nutrients in the root zone resulted in enhanced nutrient uptake by the plants, which eventually enhanced the growth and yield. There was no significant difference between the treatments in total soluble solids of fruits.

Maximum yield (2.66 kg/plant) was obtained from 100% RDF, which also recorded the highest B:C ratio. T7 recorded the second highest B:C ratio. Cost of production was minimum for T7 since it completely replaced the expensive soluble P fertilizers with low-cost rock phosphate. Therefore, both production and income can be increased by supplying 100% RDF to plants by using cost-effective P fertilizers as basal dose.

Incidence of pests like thrips, whiteflies, mites, leaf miners, snails and rats were observed during the study. Rat damage was noticed inside the rain shelter used for raising seedlings in nursery. Downy mildew, bacterial wilt, damping off, *Rhizoctonia* rot and melon yellow spot disease were the important diseases that occurred during the cropping season.

Physiological disorders like aborted flowers and crooked fruits occurred during the present study. Nutrient deficiency of the soil was corrected before raising the crop and foliar spray of Sampoorna KAU multimix for vegetables was done at the rate of 5 g/L in-order to prevent micronutrient deficiency. Hence, it can be presumed that high temperature could be the reason for occurrence of malformed fruits in the present study. The percentage of malformed fruits increased after each harvest with rising temperature and it was nil during the initial four harvests.

From the present study, it can be inferred that for parthenocarpic cucumber 'KPCH 1' planted inside the polyhouse at a spacing of 1×0.5 m, accommodating 20,000 plants/ha, 116.67:104.2:200 kg NPK/ha is the best fertigation dosage for a crop duration of 70 days.

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Appendices

Appendix I

Soil test data after the cropping period

Sl. No.	Parameters	100% RDF	90% RDF	80% RDF	70% RDF	60% RDF	50% RDF	T7
1.	pH	6.62	7.01	6.96	6.85	6.91	6.86	6.99
2.	Electrical conductivity (dS/m)	0.50	0.46	0.47	0.62	0.41	0.51	0.28
3.	Organic carbon (%)	1.99	1.95	2.05	1.99	1.71	1.97	1.67
4.	Available phosphorus (kg/ha)	219.16	217.89	240.55	221.96	224.00	242.84	116.97
5.	Available potassium (kg/ha)	1531.61	1400.00	1387.46	1859.20	1453.20	1541.46	686.00
6.	Available calcium (mg/kg)	1446.88	2021.88	1741.25	1876.88	1661.25	1642.50	1820.63
7.	Available magnesium (mg/kg)	249.63	250.00	262.44	288.69	223.88	266.38	253.00
8.	Available sulphur (mg/kg)	40.63	43.23	8.33	67.19	43.75	85.42	8.33
9.	Iron (mg/kg)	20.16	15.97	15.11	14.63	15.30	13.75	10.70
10.	Manganese (mg/kg)	29.32	25.84	25.26	27.62	24.02	24.82	19.63
11.	Zinc (mg/kg)	12.67	14.02	11.42	13.59	10.68	11.56	12.28
12.	Copper (mg/kg)	9.17	8.09	7.59	9.49	7.98	9.24	9.06
13.	Boron (mg/kg)	1.32	1.20	3.00	2.90	2.77	3.20	1.47

Appendix II

Varietal characters of KPCH 1 (Pradeepkumar *et al*., 2015)

Sl. No.	Characters	Description
1.	Plant growth habit	Vigorous, viny
2.	Average vine length	6.5 m
3.	Days to first female flower opening (days)	18.8
4.	Node at which first female flower formed	3.3
5.	Days to first harvest (days)	35.83
6.	Parthenocarpy (%)	92.18
7.	Number of fruits / plant	21.83
8.	Average weight of fruit (g)	240.75
9.	Fruit length (cm)	20.98
10.	Fruit perimeter (cm)	15.88
11.	Density of prickle on fruit at harvestable stage	Nil
12.	Colour of fruit rind at tender harvestable stage	Dark green
13.	Crispness	High
14.	Flesh thickness (cm)	1.13
15.	TSS (^{0} Brix)	2.95
16.	No. of seeds/fruit	Nil
17.	Average yield/ plant (kg)	5.26
18.	Average yield/plot ((Mg 100/m^2)	1.052
19.	Potential yield/plot (Mg 100/m^2)	1.397

Appendix III

Weather data (21-01-2022 to 31-03-2022)

Date	Daily maximum temperature (℃)	Daily minimum temperature (℃)	Daily average relative humidity (%)	Daily rainfall (mm)	Daily evaporation rate (mm)
21-Jan	34.4	22.3	71.0	0	3.2
22-Jan	34.7	22.7	73.0	0	3.0
23-Jan	33.2	21.7	75.0	0	3.0
24-Jan	32.6	18.9	65.0	0	3.6
25-Jan	32.6	20.2	63.5	0	3.4
26-Jan	32.7	20.7	71.0	0	2.9
27-Jan	33.1	20.9	66.5	0	4.1
28-Jan	33.4	24.1	53.0	0	5.0
29-Jan	33.7	25.4	51.5	0	7.8
30-Jan	34.0	23.7	59.0	0	6.7
31-Jan	35.0	24.0	63.5	0	3.6
01-Feb	34.9	23.9	60.0	0	3.8
02-Feb	35.1	23.3	61.0	0	4.5
03-Feb	36.2	23.6	70.5	0	3.7
04-Feb	34.2	21.7	72.0	0	3.7
05-Feb	33.1	19.5	68.0	0	3.7
06-Feb	34.0	21.4	72.5	0	4.1
07-Feb	33.4	22.4	59.0	0	3.4
08-Feb	35.3	22.5	64.5	0	4.1
09-Feb	34.1	22.5	53.5	0	4.4
10-Feb	34.0	22.3	54.0	0	6.5
11-Feb	34.1	20.9	51.0	0	5.0
12-Feb	35.2	25.6	63.0	0	6.0
13-Feb	32.5	23.8	51.5	0	5.6
14-Feb	34.4	24.0	55.5	0	5.6
15-Feb	34.1	24.1	55.0	0	5.3
16-Feb	34.6	24.2	52.5	0	5.1
17-Feb	34.7	24.4	47.0	0	4.3
18-Feb	35.0	23.4	50.0	0	5.1
19-Feb	34.9	23.1	56.5	0	5.3
20-Feb	35.4	24.6	57.0	0	5.8
21-Feb	36.0	24.5	74.0	0	4.4
22-Feb	35.0	24.1	69.5	0	3.4
23-Feb	34.3	22.2	50.0	0	5.5

24-Feb	36.1	24.1	52.0	0	7.1
25-Feb	35.4	23.7	53.0	0	6.6
26-Feb	36.0	23.7	52.0	0	6.8
27-Feb	35.0	23.2	55.0	0	5.8
28-Feb	36.0	24.7	50.5	0	6.0
01-Mar	36.4	22.8	44.0	0	6.0
02-Mar	37.1	24.0	23.0	0	8.2
03-Mar	36.4	24.4	26.5	0	8.2
04-Mar	36.3	24.7	35.5	0	8.6
05-Mar	37.1	22.4	56.5	0	5.7
06-Mar	36.4	23.7	45.5	0	5.7
07-Mar	36.6	24.0	45.5	0	6.3
08-Mar	36.0	25.2	55.5	0	7.8
09-Mar	36.5	24.2	44.0	0	5.5
10-Mar	37.6	24.0	36.0	0	6.2
11-Mar	38.4	22.7	56.0	0	6.0
12-Mar	38.6	24.4	53.5	0	5.8
13-Mar	38.4	23.4	37.5	0	5.5
14-Mar	38.6	23.5	31.5	0	7.2
15-Mar	38.5	25.3	69.0	0	5.7
16-Mar	37.0	25.5	72.0	0	3.8
17-Mar	34.7	25.0	72.0	0	3.9
18-Mar	34.9	25.7	76.0	0	3.7
19-Mar	34.7	25.4	71.5	0	3.9
20-Mar	34.0	24.7	70.0	0	3.4
21-Mar	33.4	24.0	73.0	0.8	3.4
22-Mar	34.8	24.7	70.0	0	3.6
23-Mar	36.1	26.4	74.0	0	4.7
24-Mar	34.9	24.4	72.5	0	3.0
25-Mar	34.0	24.9	74.5	0	2.6
26-Mar	34.1	25.7	74.5	0	3.0
27-Mar	35.2	26.6	74.0	0.7	3.6
28-Mar	34.4	25.9	72.5	0	3.6
29-Mar	36.0	25.3	73.5	0	3.8
30-Mar	36.0	26.4	75.5	0	3.7
31-Mar	35.2	25.7	69.0	0	3.6

Appendix IV

Fertigation schedule at 3 days interval for a single plant for 90 days duration

Item	Period (DAT)	Fertilizers used for fertigation (g)			No: of splits	Basal fertilizers (g)		
		19:19:19	KNO_3	Urea		Rock phosphate	Urea	SOP
T1 100% RDF	3 to 18	3.29	6.67	0.56	6	17.36		
	21 to 90	13.16	26.67	2.25	24			
T2 50% RDF	3 to 18	1.64	3.33	0.28	6	8.68		
	21 to 90	6.58	13.33	1.12	24			
T3 60% RDF	3 to 18	1.97	4.00	0.34	6	10.42		
	21 to 90	7.89	16.00	1.35	24			
T4 70% RDF	3 to 18	2.30	4.67	0.39	6	12.15		
	21 to 90	9.21	18.67	1.57	24			
T5 80% RDF	3 to 18	2.63	5.33	0.45	6	13.89		
	21 to 90	10.53	21.33	1.80	24			
T6 90% RDF	3 to 18	2.96	6.00	0.51	6	15.63		
	21 to 90	11.84	24.00	2.02	24			
T7	3 to 18	0.00	3.50	2.43	6	24.31	3.33	5.25
	21 to 90	0.00	14.00	9.74	24			

Appendix V

Cost of fertilizers

Sl. No.	Fertilizers	Cost (Rs/kg)
1.	Rock phosphate	8.57
2.	SOP	140.00
3.	Urea	5.71
4.	19: 19: 19	123.81
5.	KNO_3	161.90

Appendix VI

Cost of inputs (for 400 m^2)

Sl. No.	Particulars	Rate (Rs)	Amount used	Cost (Rs)
1.	Seed	1/seed	1000 seeds	1000.00
2.	Trichoderma enriched FYM	70/pack	25 pack	1750.00
3.	Sampoorna	115/500g	1000g	230.00
4.	Paecilomyces	85/kg	5 kg	425.00
5.	Pseudomonas	100/kg	1 kg	100.00
6.	**Labour charge**			
	Land preparation and liming	650	6 no:	3,900.00
	Basal application	650	2 no:	1300.00
	Sowing and gap filling	650	1 no:	650.00
	Weeding	650	2 no:	1300.00
	Spraying	650	2 no:	1300.00
	Floriculture net laying	650	2 no:	1300.00
	Harvesting	650	4 no:	2600.00
7.	**PP chemicals**			
	Formaldehyde	900/ 5L	24 L	4320.00
	Rat poison	40/ pack	5 no:	200.00
	Yellow sticky trap	60/ trap	3	180.00
	Imidachloprid	400/100mL	30 mL	120.00
	Snail kill	660/kg	200 g	132.00
	Dimethoate	276/250mL	30 mL	33.12
	Acephate	282/250g	40 g	45.12
	SAAF	900/kg	500 g	450.00
	Mancozeb	500/kg	500 g	250.00
	Curzate M8	202/100g	30 g	60.60
	K-Cyclin	60/60g	40 g	40.00
	Magister	385/100mL	100 mL	385.00
	Acetamiprid	310/100g	40 g	124.00
8.	**Electricity and water charge**			500.00
9.	**Miscellaneous**			500.00
	Total			**23194.84**

Appendix VII

B:C ratio (for 400 m^2 polyhouse)

Sl. No.	Treatments	Fertilizer cost (Rs)	Total variable cost (Rs)	Returns (Rs)	B:C ratio
1.	T1	6078.26	29273.10	63840.00	**2.18**
2.	T2	3039.13	26233.97	40560.00	1.55
3.	T3	3646.96	26841.80	45360.00	1.69
4.	T4	4254.79	27449.63	46080.00	1.68
5.	T5	4862.61	28057.45	52080.00	1.86
6.	T6	5470.44	28665.28	58320.00	2.03
7.	T7	3092.06	26286.90	54960.00	**2.09**

Appendix VIII

Maximum and minimum temperature inside the polyhouse

Date	Maximum temperature (˚C)	Minimum temperature (˚C)
21-Jan	40.1	22.0
22-Jan	40.2	23.0
23-Jan	40.0	21.6
24-Jan	39.6	19.6
25-Jan	39.7	19.5
26-Jan	40.0	22.0
27-Jan	41.0	21.8
28-Jan	41.1	21.9
29-Jan	41.0	23.1
30-Jan	43.0	25.0
31-Jan	42.0	24.8
01-Feb	42.4	23.8
02-Feb	42.0	23.0
03-Feb	44.0	24.8
04-Feb	42.8	21.7
05-Feb	42.0	22.3
06-Feb	42.0	22.8
07-Feb	41.0	22.5
08-Feb	42.0	24.0
09-Feb	42.8	23.9
10-Feb	40.0	21.0
11-Feb	41.0	22.0
12-Feb	42.5	23.5
13-Feb	40.1	21.8
14-Feb	40.5	20.9
15-Feb	41.0	21.2
16-Feb	40.6	20.6
17-Feb	40.9	22.1
18-Feb	42.0	23.6
19-Feb	41.8	22.4
20-Feb	41.9	20.2
21-Feb	42.7	23.5
22-Feb	41.9	23.1
23-Feb	41.6	23.7
24-Feb	41.7	24.3
25-Feb	42.7	25.7
26-Feb	41.6	25.3
27-Feb	41.9	25.1

28-Feb	44.0	23.7
01-Mar	44.0	22.7
02-Mar	44.2	23.4
03-Mar	44.0	24.5
04-Mar	44.7	25.4
05-Mar	43.7	22.8
06-Mar	44.1	24.3
07-Mar	43.5	24.3
08-Mar	43.5	25.8
09-Mar	45.4	24.3
10-Mar	45.6	23.8
11-Mar	45.2	23.7
12-Mar	44.6	24.9
13-Mar	44.3	23.4
14-Mar	44.3	23.3
15-Mar	44.1	25.8
16-Mar	41.8	26.1
17-Mar	41.5	25.3
18-Mar	40.7	26.1
19-Mar	41.5	25.9
20-Mar	40.4	25.5
21-Mar	43.4	24.5
22-Mar	44.1	24.8
23-Mar	43.1	26.0
24-Mar	40.2	24.9
25-Mar	42.8	25.1
26-Mar	42.9	25.9
27-Mar	43.2	26.9
28-Mar	45.8	26.3
29-Mar	45.5	25.9
30-Mar	43.0	27.0
31-Mar	43.6	26.1

Appendix IX

Leaf analysis results of 50% RDF and 100% RDF

Sl. No.	Particulars	50% RDF		100% RDF	
		Value	Rating	Value	Rating
1.	Nitrogen (%)	3.62	Sufficient	3.69	Sufficient
2.	Phosphorus (%)	0.28	Deficient	0.31	Sufficient
3.	Potassium (%)	3.37	Sufficient	3.83	Sufficient
4.	Calcium (%)	2.87	Sufficient	3.53	High
5.	Magnesium (%)	0.77	Sufficient	0.75	Sufficient
6.	Iron (ppm)	442.40	High	425.60	High
7.	Manganese (ppm)	54.40	Sufficient	49.20	Deficient
8.	Zinc (ppm)	42.80	Sufficient	31.60	Sufficient
9.	Copper (ppm)	14.00	Sufficient	12.60	Sufficient
10.	Boron (ppm)	261.80	Excessive	152.00	Excessive

Appendix X

Abbreviations

%	Percentage
°B	Degree brix
°C	Degree Celsius
B	Boron
B:C	Benefit-cost
cm	Centimetre
COA	College of Agriculture
Cu	Copper
DAS	Days after sowing
dS	Deci-siemens per metre
EC	Electrical conductivity
Fe	Iron
g	Gram
g/L	Gram per litre
Ha	Hectare
IPM	Integrated pest management
K	Potassium
KAU	Kerala Agricultural University
Kg	Kilogram
KNO_3	Potassium nitrate
KPCH 1	KAU parthenocarpic cucumber hybrid 1
L	Litre
LPH	Litre per hour
M	Metre
m^2	Square metre
mg/kg	Milligram per kilogram

mL/L	Millilitre per litre
Mn	Manganese
MT	Metric tons
N	Nitrogen
NHB	National horticulture board
P	Phosphorus
Ph	Potential of hydrogen
PFD	Pillowy fruit disorder
Ppm	Parts per million
RDF	Recommended dose of fertilizers
RTL	Radio tracer laboratory
S	Sulphur
SOP	Sulphate of potash
T	Tonnes
t/ha	Tonnes per hectare
T7	Treatment seven
TSS	Total Soluble Solids
Zn	Zinc

STANDARDISATION OF FERTIGATION SCHEDULE FOR PARTHENOCARPIC CUCUMBER (*Cucumis sativus* L.) HYBRID KPCH 1 UNDER POLYHOUSE

By

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ABSTRACT OF THE THESIS

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ABSTRACT

Cucumber is an annual cucurbitaceous crop. It is grown throughout the world for its tender, crisp and immature fruits. It is mainly used as a salad crop. Parthenocarpic cucumber has more consumer preference as they are seedless. KPCH 1 is a parthenocarpic cucumber hybrid developed by Kerala Agricultural University. Parthenocarpic cucumber varieties are preferred for cultivation under polyhouse, since pollination is not required for fruit set.

Fertigation is a technique in which water-soluble fertilizers are supplied through irrigation water. It is preferred over conventional fertilizer application methods due to its high nutrient and water use efficiency. Different studies have shown that fertilizer recommendation for cucumber varies drastically across India. At present, KAU has an *ad hoc* recommendation for precision farming in vegetables. The optimum dose of fertilizers has to be standardised for obtaining the highest yield and thereby increasing the income of farmers. Hence the present investigation was conducted with the objective of standardisation of fertigation schedule and evaluation of different levels of fertigation on yield and quality of KPCH 1 grown under polyhouse.

The study was conducted at Department of Vegetable Science, College of Agriculture, Vellanikkara during January to March, 2022. The experiment was conducted in a randomised block design with seven levels of fertigation *viz.,* 100% RDF, 90% RDF, 80% RDF, 70% RDF, 60% RDF, 50% RDF and 70% RDF (100% P + 25% N + 25% K as basal). Fertigation was given at three days interval. *Trichoderma*-enriched FYM was applied at the rate of 15 t/ha uniformly to all the treatments. Fifty percent dose of recommended P was applied as basal in all the treatments except T7. In T7 100% P, 25% N and 25% K were applied as basal. Hundred percent recommended dose of fertilizers was 175:125:300 kg NPK/ha (30 splits). In the present study, only 20 splits of fertilizers were applied because the crop ended early, 70 days after sowing due to high temperature. The actual quantity of fertilizer (20 splits) applied was at the rate of 116.67:104.2:200 kg NPK/ha (100% RDF).

Findings of the study revealed that fertigation had significant effect on growth and yield of cucumber. Hundred percent RDF recorded the highest vine length (2.88 m)

and it was statistically on par with 90% RDF, 80% RDF and T7. Fertigation had significant effect on the number of days to first flower opening and parthenocarpic expression. Hundred percent RDF recorded the highest parthenocarpic expression and 100% RDF along with T7 registered least number of days to first flower opening. However, the number of flowers per node did not exhibit any significant difference between treatments. The highest number of fruits per plant was observed in 100% RDF and 90% RDF. Moreover, highest yield was recorded in 100% RDF (2.66 kg/plant) and 90% RDF (2.43 kg/plant). Average fruit length, average fruit girth and average fruit weight did not show any marked difference with different levels of fertigation. Similarly, number of harvests and days to first harvest were not influenced by nutrition level. Fertigation had no significant effect on TSS of fruits.

Benefit-cost ratio was found to be highest for 100% RDF (2.18) and the second highest B:C ratio was obtained for T7 (2.09). Incidence of pests like rodents, snails, serpentine leaf miners, white flies, thrips and mites were observed during the study. The crop was affected by diseases such as damping off, *Rhizoctonia* rot, melon yellow spot virus, downy mildew and bacterial wilt. Physiological disorders like crooked fruits were also observed during the study.

Thus, based on the present study it can be concluded that 100% RDF (116.67:104.2:200 kg NPK/ha) is the best fertigation dosage for obtaining maximum yield and B:C ratio for parthenocarpic cucumber KPCH 1 grown inside polyhouse.