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Effects of irrigation frequency and repellent plants on false codling moth (*Thaumatotibia leucotreta)* infestation, growth, yield, and quality of sweet pepper (*Capsicum annuum L.)*

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Summary: Sweet pepper (*Capsicum annum* L.*)* is an important vegetable and spice crop grown worldwide for its pungency, which is derived from high concentrations of capsaicinoids. Despite the economic importance of sweet pepper as an export vegetable in Kenya, its production is currently constrained by the false codling moth (FCM) (*Thaumatotibia leucotreta*) and inadequate management strategies for the pest, among other factors. This study, therefore, evaluated repellent plants (Artemisia (Artemisia absinthium), Lavender (*Lavandula angustifolia*), and Spearmint (Mentha spicata) under different irrigation frequencies to control FCM. A split-plot factorial greenhouse experiment was conducted at Kenya Agricultural and Livestock Research Organization, Muguga (trial 1) and the Horticulture Research and Teaching Field, Egerton University, Kenya (trial 2). Irrigation frequency at three levels (irrigating once a week, irrigating twice a week and irrigating thrice a week) was the main-plot factor, while repellent plants at four levels: sweet pepper (*Capsicum annum* L.), artemisia (*Artemisia absinthium*), lavender (*Lavandula angustifolia*) and spearmint (*Mentha spicata*) constituted the sub-plot factor. Irrigating thrice or twice a week and using lavender as a repellent plant significantly reduced false codling moth infestation by 90%, increased yield by 28% and improved fruit quality in terms of fruit collar diameter and total soluble salts (TSS). The findings demonstrate that integrating lavender repellent plants with frequent irrigation can be adopted as an eco-friendly management strategy for FCM and enhancing sweet pepper yield and quality.

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Key words: false codling moth, irrigation frequency, postharvest quality, repellent plants, sweet pepper, yield

Introduction

Sweet pepper (*Capsicum annuum* L.), also known as bell pepper or paprika, is a significant horticultural crop in Kenya, widely cultivated for both local consumption and export (Oundu, 2023). The crop is valued for its nutritional content, pharmaceutical industry and its contribution to income generation (Muthuswamy et al., 2020). The fruit is a rich source of antioxidants, mineral nutrients, and natural dietary fibres. It contains bioactive compounds, including flavonoids, carotenoids, phenolic acids, capsaicinoids, steam volatile oil, fatty acids, proteins, and vitamins A, C, and E (Brezeanu et al., 2022; Stoleru et al., 2023). It is used in the pharmaceutical industry to treat various ailments, including sore throat, toothache, cough, stomach ailments, wounds, rheumatism, and parasitic infections (Muthuswamy et al., 2020). Currently, peppers have gained commercial interest and are an important vegetable consumed largely by the global population, ranking third (Olutumise, 2022). In Kenya, sweet pepper is cultivated and widely used as a vegetable and spice. It is also used as a food colouring and flavouring agent (Bunde et al., 2021). In the year 2019, about 61 million tons of sweet pepper were produced globally, from a total cultivated land area of approximately 4.5 million ha (Nguyen et al., 2022). Kenya produces approximately 9300 tons of sweet pepper annually from an estimated 990 hectares of land (Bunde et al., 2021).

However, the production of sweet pepper is constrained by insect pests and diseases, false codling moth (FCM) being a major threat. FCM is highly polyphagous and has been recorded on over 50 species of plants in more than 30 families (Bierman, 2023). It feeds primarily on the crop fruits and can attack many wild and cultivated fruit species, including: avocado (*Persea americana*), carambola (*Averrhoa carambola*), cacao (*Theobroma cacao*), citrus species (*particularly Citrus sinensis* and *C. paradise*, guava (*Psidium guajava*), coffee (*Coffea* spp.), peach (*Prunus persica)*, macadamia (*Macadamia ternifolia*), litchi (*Litchi sinensis*), pomegranate (*Punica granatum*), pepper (*Capsicum* spp.), and persimmon (*Diospyros kaki*). *Thaumatotibia leucotreta* is also a pest of field crops such as cotton (*Gossypium hirsutum*), maize (*Zea mays*), beans (*Phaseolus* spp.), and castor bean (*Ricinus communis*) (Grove *et al.*, 2019). Damage to the crop is caused by larvae feeding on affected parts, causing up to 90% losses on some hosts. Besides causing direct damage to the fruit, they are also vectors of diseases or may cause damage to the fruit, making the fruit more vulnerable to disease or fungus contamination (Moore & Manrakhan, 2022). Adom et al. (2021) reported that FCM infestation on *Capsicum* spp. within 5 months after planting, led to a yield loss of 90%. Such loss translates to loss of food, income and increased production costs owing to the instituted control measures (Mwando et al., 2022). Patrick et al. (2021) reported a case of FCM detection in Kenya, which caused a ban on pepper export to the UK and the EU, resulting in up to USD 9 billion economic loss of revenue.

The quarantine restrictions have led to many job losses along the pepper value chain in East Africa, where millions of people work (Floriculture, 2021). Moreover, the direct feeding damage by FCM facilitates entry points for pathogens such as bacteria and fungi (Oundu et al., 2023). The infested produce has low quality as fruit aesthetics primarily determines the market value of the fruits (Lagerkvist et al., 2023).

Current reliance on synthetic pesticides is unsustainable due to pesticide resistance, health concerns, and strict export market restrictions on chemical residues (Attia et al., 2020). Alternative management approaches are urgently required. Repellent plants, such as lavender (*Lavandula angustifolia*), artemisia (*Artemisia absinthium*), and spearmint (*Mentha spicata*), emit volatile compounds that deter insect pests while supporting biodiversity (Vlahova, 2021; Huss et al., 2022). Intercropping with such plants has been shown to reduce pest populations and improve crop yield and quality (Priya et al., 2023).

Irrigation management also influences pest incidence by altering crop vigour and microclimate (Rendon & Walton, 2019; Han et al., 2022). Frequent irrigation enhances plant tolerance to stress and reduces susceptibility to insect damage. However, research on combining irrigation frequency and repellent plants in managing FCM on sweet pepper is limited. The current study investigated the combined effects of irrigation frequency and repellent plants on FCM infestation, growth, yield and postharvest quality of sweet pepper under greenhouse conditions in Kenya.

Materials and methods

Experimental sites

A greenhouse experiment was conducted at Kenya Agricultural and Livestock Research Organization (KALRO)–Muguga (September–December 2023) and Egerton University, Kenya (January–April 2024). Muguga is located at 1°13′S, 36°38′E, 1,675 m altitude, with an average annual rainfall of 1,200 mm. Egerton University lies at 0°23′S, 35°35′E, at an altitude of 2,238 m, with volcanic soils of pH 6.0–6.5.

Experimental design

The study was conducted using a strip-plot or split-block design arrangement in a randomized complete block design (RCBD) with three replications. The main plot factor under study was drip irrigation frequency at three levels: irrigating once a week at 0.008 m^3/m^2 (IF1), irrigating twice a week at 0.008 m^3/m^2 (IF2) and irrigating thrice a week at 0.008 m^3/m^2 (IF3). The different repellent plants were the subplot factor at four levels: artemisia, lavender, spearmint, and a sweet pepper monocrop. The experiment covered an area of 20 m × 8 m. Each block measured 8 m × 6 m while each sub-plot measured 2 m × 2 m. The crop spacing was 75 cm × 45 cm. The blocks were separated by a 1m path, while the sub-plots were separated using a polyfilm cover to limit interaction of the volatile emissions from the repellent plants.

Crop Establishment and Management

Sweet pepper seedlings were grown in a nursery bed and transplanted when they reached a height of 10–15 cm. They were transplanted into holes manually dug with a hand hoe. NPK 17:17:17 fertilizer was applied at a rate of 110 kg/ha (10 g per plant) to supply the recommended dose of NPK for sweet pepper, 110:45:60 kg/ha of N: P_2O_5: K_2O (Haifa Group, 2023; Kunwar et al., 2024). The fertilizer was thoroughly mixed with the soil before transplanting. The seedlings were drenched with thiamethoxam at 8 g/20 L of water during transplanting to prevent early attacks by aphids, whiteflies, and thrips. Artemisia, lavender, and spearmint cuttings were planted in the experimental plots according to the treatments at the time sweet pepper seeds were sown in the nursery, ensuring they were well established by the time of seedling transplanting. The repellent plants (artemisia (*Artemisia absinthium)*, lavender (*Lavandula angustifolia)*, and spearmint (*Mentha spicata*)) were planted between the sweet pepper seedlings at a spacing of 37.5 cm. Polythene was used to separate the different subplots. All other agronomic and maintenance practices, including weed control, suckering and staking to support the plants and prevent bending, were uniformly applied to all experimental plots as needed.

Data collection

Data were collected from four randomly selected and tagged sweet pepper plants in the middle rows of each subplot to assess false codling moth (FCM) population, plant growth, yield, and fruit quality. False codling moth population was determined by collecting red-ripe malformed fruits exhibiting abnormal growth symptoms typically associated with larval infestation (Moy et al., 2014) from the tagged plants for destructive sampling. Each fruit was carefully sectioned to locate and count the number of larvae present per fruit using a handheld magnifying lens for clarity (Bryan et al., 2010). Growth data were recorded at two-week intervals from 14 days after transplanting (DAT) until the first harvest. Plant height (cm) was measured from the base to the point of new growth using a meter rule. The collar diameter (mm) was taken approximately 4 cm above ground level using a digital vernier calliper (Model 599-577-1/USA), and the data were used to compute weekly averages. In addition, the number and length (cm) of internodes were recorded using a ruler, and weekly averages were calculated to monitor plant development over time.

Yield data were obtained by harvesting fruits at the horticultural maturity stage twice per week. At each harvest, fruits from the tagged plants were counted and weighed using a weighing balance (Advanced Technocracy Inc. Ambala), and the results were used to calculate the average number and weight (kg) of fruits per plant. Total soluble salts (TSS) wFas measured using the same fruits by squeezing juice onto a handheld refractometer (0–30 °Brix) following the procedure of Aguilar et al. (2020), and results were recorded in degrees Brix (°Brix).

Data analysis

The normality and equal variance assumptions for the analysis of variance (ANOVA) were verified before conducting the analysis using the Proc univariate procedure of SAS (Version 9.1; SAS Institute, Cary, NC). The data were then analysed with ANOVA using the GLM procedure of SAS at $P \leq 0.05$. The means for treatments that were significant in the F test were separated using Tukey’s honestly significant difference (HSD) test at $P \leq 0.05$.

Results

Effect of irrigation frequency and repellent plants on false codling moth infestation

The interaction between irrigation frequency and the use of repellent plants significantly influenced the false codling moth incidence ($p \leq 0.05$). Sweet peppers grown with lavender as a repellent plant and irrigated thrice a week had the lowest FCM population in the fruits. In contrast, the highest population was observed in the sweet pepper monocrop, irrigated once a week throughout all sampling dates in both trials (***Table 1***). In trial 1, sweet peppers grown with spearmint and irrigated once a week and those grown with artemisia and irrigated once a week, showed lower FCM populations compared to sweet pepper monocrop and irrigated once a week. The population of FCM was however higher in fruits of sweet pepper grown under these treatments compared to those produced under lavender as a repellent plant and irrigated once a week (***Table 1***). In trial 2, sweet peppers grown with spearmint and irrigated once a week and those grown with artemisia and irrigated once a week, had lower FCM populations in the fruits compared to sweet pepper monocrop and irrigated once a week. Sweet pepper grown with spearmint and artemisia and irrigated twice a week had a lower FCM population in the fruits compared to sweet pepper monocrop irrigated twice, but had a higher population compared to sweet pepper grown with lavender and irrigated twice (***Table 1***).

Effect of irrigation frequency and repellent plants on growth of sweet pepper

Plant height

The interaction effect of irrigation frequency and repellent plants significantly ($p \leq 0.05$) influenced sweet pepper plants' height at 70 DAT in trial 1 and at 14 DAT and 28 DAT in trial 2. Comparing the effect on plant height of sweet pepper grown under the different combinations of irrigation frequency and repellent plants, sweet pepper grown with lavender as a repellent plant and irrigated twice a week (IF2 +SL) recorded the highest plant height compared to sweet pepper monocrop and irrigated twice a week (S+IF2) in trial 1. There was no significant effect on plant height at 14 DAT, 28 DAT, 42 DAT, 56 DAT and 84 DAT (***Table 3***). In trial 2, the interaction effect of repellent plant and irrigation frequency significantly influenced plant height at $P \leq 0.05$. Sweet pepper plants grown with Artemisia (SA) and lavender (SL) yielded taller plants, although the difference between the two treatments was not statistically significant. At 28 DAT, repellent plants and irrigation frequency were not statistically significant, except for sweet pepper monocrop irrigated once a week (IF1+S). At 42 DAT, 56 DAT, 70 DAT, and 84 DAT, irrigation frequency and repellent plant did not have a significant effect on plant height (***Table 2***).

Collar diameter

The interaction effect of irrigation frequency and repellent plants was not significant on sweet pepper collar diameter in trial 1. Nevertheless, irrigation frequency and repellent plants significantly ($p \leq 0.05$) influenced sweet pepper collar diameter at 14 DAT, 70 DAT and 84 DAT in trial 2 (***Table 3***). Sweet pepper grown with lavender as a repellent plant and irrigated twice a week (IF2 + SL) recorded the largest collar diameter in Trial 2. There was no significant effect on collar diameter at 28 DAT, 42 DAT and 56 DAT (***Table 3***).

Table 1. Effects of irrigation frequency and repellent plants on false codling moth population /plant on sweet pepper in trial 1 (September to December 2023) and trial 2 (January to April 2024).

	False codling moths /plant on various days after transplanting		
Treatment	**90**	**104**	**118**
	Trial 1		
IF1+S	5.5a	5.50a	5.50a
IF1+SA	3.5b	3.83c	3.5b
IF1+SL	2.17c	2.17c	2.17c
IF1+SP	3.5b	3.50b	3.17b
IF2+S	3.5b	3.5b	3.5b
IF2+SA	2.17c	2.83c	2.5c
IF2+SL	1.17d	1.17e	0.83e
IF2+SP	2.5c	1.83d	2.17c
IF3+S	2.5c	2.17c	2.17d
IF3+SA	2.17c	2.83c	1.5d
IF3+SL	0.83e	0.5f	0.5f
IF3+SP	1.5d	1.5d	1.5d
	Trial 2		
IF1+S	4.5a	4.5a	4.5a
IF1+SA	3.5abc	3.8ab	3.1bc
IF1+SL	2.83bcd	2.5cde	2.5cd
IF1+SP	2.83bcd	3.5bc	3.1bc
IF2+S	3.83ab	3.8ab	3.5b
IF2+SA	2.5cd	3.1bcd	3.1bc
IF2+SL	1.5e	1.51f	1.5ef
IF2+SP	2.83bcd	2.5cde	2.5cd
IF3+S	2.5cd	2.5cde	2.5cd
IF3+SA	2.1de	2.1de	2.1de
IF3+SL	0.5f	0.5g	0.5f
IF3+SP	2.5cd	1.83ef	1.5ef

Treatment means followed by the same letter within a column, in trial and in an evaluation date is not significantly different according to Tukey's Honestly Significant Difference at $p \leq 0.05$

IF1 – Irrigating once a week, **IF2** – irrigating twice a week, **IF3** – irrigating thrice a week, **S**- Sweet pepper, **SA**- Sweet pepper + Artemisia, **SL**- Sweet pepper + Lavender, **SP**-Sweet pepper + Spearmint

Effect of irrigation frequency and repellent plant on yield of sweet pepper

The interaction effect of irrigation frequency and repellent plants significantly ($p \leq 0.01$) influenced the weight of fruits per plant in both trials. Comparing the effect on yield of sweet pepper grown under the different combinations of irrigation frequency and repellent plants, sweet pepper grown with lavender as a repellent plant and irrigated twice a week (IF2 +SL) recorded the highest weight of fruits per plant compared to sweet pepper grown with artemisia and irrigated twice a week (IF2+SA), sweet pepper grown with spearmint and irrigated twice a week (IF2+SP) and sweet pepper monocrop irrigated twice a week (IF2+S) in both trials. The lowest weight of fruits was recorded in sweet pepper grown with artemisia and irrigated once a week (IF1+SA), sweet pepper grown with artemisia and irrigated thrice a week (IF3+SA), sweet pepper grown with spearmint and irrigated once a week (F1+SP) and sweet pepper grown with spearmint and irrigated thrice a week IF3+SP (***Table 4***).

Table 2. Effect of irrigation frequency and repellent plants on sweet pepper plant height (cm) in trial 1 (September to December 2023) and trial 2 (January to April 2024).

	Plant height (cm) on various days after transplanting					
Treatment	**14**	**28**	**42**	**56**	**70**	**84**
			Trial 1			
IF1 + S	11.23a	12.8a	26a	29.23a	39.83c	45.9a
IF1+ SA	13.13a	15.5a	28.6a	32.13a	43.5ab	46.8a
IF1 + SL	10.6a	16.2a	28.7a	35.4a	44.5ab	49.5a
IF1 + SP	12.23a	12.9a	28.5a	30.7a	41.3ab	47.4a
IF2 + S	12.96a	14.3a	31.0a	37.4a	46.3ab	54.4a
IF2 + SA	13.03a	14.73a	28.1a	34.6a	45.3ab	52.6a
IF2 + SL	12.53a	14.7a	31.2a	36.8a	47.8a	55.1a
IF2 + SP	12.80a	13.46a	28.06a	33.4a	45.0ab	51.8a
IF3 + S	11.86a	16.0a	29.5a	37.6a	45.9ab	53.2a
IF3 + SA	11.93a	13.9a	25.7a	30.7a	43.8ab	50.9a
IF3 + SL	13.2a	14.5a	30.0a	36.1a	47.0ab	54.0a
IF3 + SP	14.0a	16.4a	29.0a	35.2a	46.0ab	52.3a
			Trial 2			
IF1 + S	14.9ab	21.7b	22.6a	31.3a	49.0a	51.2a
IF1+ SA	15.2ab	26.9ab	33.1a	38.7a	51.2a	49.0a
IF1 + SL	15.1ab	27.1ab	30.1a	35.9a	43a	47.2a
IF1+ SP	14.2b	24.6ab	33.1a	40.9a	45.7a	45.7a
IF2 + S	15.8ab	21.8ab	29.8a	38.3a	45.4a	45.4a
IF2 + SA	15.7ab	28.9ab	26.1a	31.1a	42.0a	45.0a
IF2 + SL	16.3ab	27.0ab	29.1a	33.6a	36.7a	44.8a
IF2 + SP	15.5ab	27.5ab	32.4a	38.1a	45.02a	43.0a
IF3 + S	16.8ab	28.6ab	27.7a	34.6a	44.8a	42.0a
IF3 + SA	18.2a	36.7a	24.8a	30.2a	40.9a	41.2a
IF3 + SL	18.1a	28.1a	28.5a	35.8a	41.2a	40.9a
IF3 + SP	17.5a	34.3a	31.5a	38.6a	47.2a	36.7a

Treatment means followed by the same letter within a column, in trial and in an evaluation, date is not significantly different according to Tukey's Honestly Significant Difference at $p \leq 0.05$.
IF1 – Irrigating once a week, **IF2** – irrigating twice a week, **IF3** – irrigating thrice a week, **S**- Sweet pepper, **SA**- Sweet pepper + Artemisia, **SL**- Sweet pepper + Lavender, **SP**-Sweet pepper + Spearmint

Table 3. Effect of irrigation frequency and repellent plants on sweet pepper collar diameter (mm) in trial 2 (January to April 2024)

	Fruit collar diameter (mm) on various days after transplanting					
Treatment	**14**	**28**	**42**	**56**	**70**	**84**
			Trial 2			
IF1 + S	2.16cd	3.9a	6.8a	9.06a	9.8bc	10.6bc
IF1+ SA	2.30bcd	5.11a	8.3a	11.1a	9.9bc	10.7bc
IF1+ SL	2.8abcd	4.5a	8.2a	9.8a	26.nov	11.8abc
IF1+ SP	3.2abc	4.3a	6.8a	8.3a	10bc	10.8bc
IF2+ S	3.03abcd	4.3a	8.14a	9.5a	11.3abc	12.1abc
IF2+ SA	3.08abdc	4.7a	7.6a	10.1a	12.8a	13.5a
IF2+ SL	3.7a	4.4a	7.2a	8.6a	11.7ab	12.6ab
IF2+ SP	3.4ab	4l6a	7.8a	8.7a	11.5abc	12.2ab
IF3+ S	3.2abc	3.8a	7.4a	9.2a	11.36abc	12.6ab
IF3+ SA	2.6abcd	4.4a	8.6a	9.7a	11.3abc	12.2ab
IF3+ SL	1.9d	4.3a	7.9a	9.3a	9.3c	10.03c
IF3+ SP	2.7abcd	3.4a	7.3a	8.9a	11.13abc	11.8abc

Treatment means followed by the same letter within a column, on an evaluation date is not significantly different according to Tukey's Honestly Significant Difference at ($p \leq 0.05$).
IF1 – Irrigating once a week, **IF2** – irrigating twice a week, **IF3** – irrigating thrice a week, **S**- Sweet pepper, **SA**- Sweet pepper + Artemisia, **SL**- Sweet pepper + Lavender, **SP**-Sweet pepper + Spearmint

Table 4. Effect of irrigation frequency and repellent plants on the weight (kg) of sweet pepper fruits per plant in trial 1 (September to December 2023) and trial 2 (January to April 2024).

Treatment	Weight of fruits (kg/plant)
Trial 1	
IF1 + S	2.9ab
IF1+ SA	2.2b
IF1+ SL	1.8b
IF1+ SP	2.1b
IF2+ S	2.2b
IF2+ SA	2.2b
IF2+ SL	4.3a
IF2+ SP	2.05b
IF3+ S	2.4b
IF3+ SA	2.5b
IF3+ SL	1.8b
IF3+ SP	2b
Trial 2	
IF1 + S	2.6c
IF1+ SA	3.6c
IF1+ SL	5.6a
IF1+ SP	3.3c
IF2+ S	4bc
IF2+ SA	3.6c
IF2+ SL	6.6a
IF2+ SP	3c
IF3+ S	3.3c
IF3+ SA	3.3c
IF3+ SL	5.9a
IF3+ SP	4.4ab

Treatment means followed by the same letter within a column and in a trial is not significantly different according to Tukey's Honestly Significant Difference at $p \leq 0.01$

IF1 – Irrigating once a week, **IF2** – irrigating twice a week, **IF3** – irrigating thrice a week, **S-** Sweet pepper, **SA-** Sweet pepper + Artemisia, **SL-** Sweet pepper + Lavender, **SP**-Sweet pepper + Spearmint

Table 5. Effect of irrigation frequency and repellent plants on total soluble salts (TSS) in trial 2 (January to April 2024).

Treatment	**TSS** (°Bx)
Trial 2	
IF1 + S	5.1ab
IF1+ SA	4.8ab
IF1+ SL	5.6a
IF1+ SP	4.3c
IF2+ S	5.2ab
IF2+ SA	4.8ab
IF2+ SL	5.3ab
IF2+ SP	5.0ab
IF3+ S	4.5ab
IF3+ SA	5.1ab
IF3+ SL	5.9ab
IF3+ SP	4.7ab

Treatment means followed by the same letter within a column and in trial is not significantly different according to Tukey's Honestly Significant Difference at $p \leq 0.05$

IF1 – irrigating once a week, **IF2** – irrigating twice a week, **IF3** – irrigating thrice a week, **S-** Sweet pepper, **SA-** Sweet pepper + Artemisia, **SL-** Sweet pepper + Lavender, **SP**-Sweet pepper + Spearmint

Effect of irrigation frequency and repellent plants on quality of sweet pepper

Total soluble salts (TSS)

The interaction effect of irrigation frequency and repellent plants did not influence total soluble salts (TSS) in trial 1, while in trial 2, it significantly influenced TSS at ($p \leq 0.05$). Sweet pepper grown with lavender as a repellent plant and irrigated once a week (IF1+SL) recorded the highest TSS compared to sweet pepper grown with artemisia and irrigated thrice a week (IF3+SA), sweet pepper grown with spearmint and irrigated thrice a week (IF3+SP) and sweet pepper monocrop and irrigated thrice a week (IF3+S). Sweet pepper grown with lavender and irrigated twice a week (IF2+SL) recorded a higher TSS compared to sweet pepper grown with artemisia and irrigated twice a week (IF2+SA), sweet pepper grown with spearmint and irrigated twice a week (IF2+SP) and sweet pepper monocrop and irrigated twice a week (IF2+S) but lower than sweet pepper grown with lavender and irrigated once a week (IF1+SL). Sweet pepper grown with spearmint and irrigated once a week (IF1+SP) resulted in the lowest TSS (***Table 5***).

Discussion

There was a decrease in false codling moth population under the interaction of sweet pepper with lavender and irrigation frequency, which could be a result of unfavourable conditions for moth infestation and favourable conditions for plant growth and development. In addition, correct spacing of sweet pepper and lavender reduces the larval spread to the host plants (Shelton et al., 2006). These results agree with the findings that the practice of intercropping with repellent plants increases the distance between plants of the same species, which complicates migration of pests from one plant to another in the same field (Onamu et al., 2024). The authors further found that the use of repellent plants plays an important role in controlling pests and protecting beneficial insects relevant to enhancing biodiversity in an agroecosystem. The results agree with Mutyambai et al. (2020), who found that repellent plants planted as a companion crop for capsicum can reduce false codling moth population. Reduction of the false codling moth population on sweet pepper intercropped with lavender could be due to strong volatile organic compounds, which could have masked the scent of sweet pepper or repelled the moth. Similarly, the results are consistent with Priya et al. (2023), who found that when lavender is intercropped with sweet pepper, it deters false codling moths by keeping them at bay. Essential oils of lavender are known to repel and control a wide range of insect pests. Lavender has a strong fragrance, which could have interfered with the ability of the false codling moth to locate sweet pepper plants, thus reducing its infestation**.**

Sweet pepper grown with lavender as a repellent plant and irrigated twice a week (SL+IF2) recorded higher plant height compared to sweet pepper monocrop irrigated twice a week (S+IF2) in Trial 1, 70 days after transplanting but it was not significantly different for the other days. While in trial 2, lavender and irrigating twice resulted in plant height increase in 14 and 28 days after transplanting but not significantly different in 42,56,70 and 84 DAT. This was in contrast to the sweet pepper monocrop irrigated once a week, which could be attributed to the presence of repellent plants and sufficient water availability, allowing sweet pepper plants to access more water and nutrients. When irrigation frequency is combined with repellent plants, these practices synergistically improve growth outcomes by ensuring adequate water supply and reducing pest-related damage. A study by Kumar and Patel (2023) demonstrated that moderate irrigation frequency paired with pest-repellent companion plants significantly enhanced plant height and collar diameter compared to traditional practices alone. The integration of repellent plants such as marigolds (*Tagetes spp.)* and basil (*Ocimum basilicum*), has been shown to mitigate pest pressure, thereby indirectly promoting healthier and taller sweet pepper plants (Kumar & Patel, 2024). A study by Rodriguez et al. (2025) further indicated that combining irrigation frequency with repellent plants intercropping synergistically improved plant height, suggesting that an integrated approach can enhance sweet pepper productivity. An increase in plant height could have resulted from consistent soil moisture levels, which may have promoted better nutrient uptake, leading to healthier growing conditions.

Combining irrigation frequency and the use of repellent plants increased collar diameter at $p \leq 0.05$. Sweet pepper grown with artemisia and irrigated twice a week (IF2+SA) recorded the largest collar diameter. This can be attributed to the ability of lavender to repel pests, thus reducing pest pressure on sweet pepper, hence more energy of the plant is channelled towards growth and development. From the study, in 3 (28, 42 and 56 DAT) out of 6 measurements there was no significant difference and in the other cases there was no visible trend in the data. From the 3 (14, 70 and 84 DAT) increasing irrigation frequency from irrigating once a week to irrigating twice a week led to a marked increase in collar diameter across all treatments. Increased irrigation frequency can enhance plant growth by ensuring adequate water availability, which may lead to a larger collar diameter (Smith & Johnson, 2020).

According to Martin et al. (2023), an integrated approach that includes irrigating peppers based on soil moisture levels while employing pest-repelling companion plants can yield more robust harvests and improve resource efficiency. Belman and Ozuna (2023) found that the push–pull system that exists in intercropping has a high potential of controlling pests and improving crop yields and quality. This is achievable since crop protection against infestations and diseases enhances crop yields and quality. Combining sweet pepper with repellent plants significantly increased the weight of fruits. Lavender produced high fruit weight under irrigating twice a week. This suggests that the integration of biocontrol methods and efficient water management can greatly enhance both growth and yield (Olaniyi et al., 2023). Moreover, the interactive effect of irrigation and the use of repellent plants have been shown to improve plant resilience. It fosters healthier growth cycles, reduces the need for chemical pesticides and ultimately leads to more sustainable sweet pepper production practices (Zhang et al., 2024).

Optimizing irrigation frequency is crucial for minimizing post-harvest losses and extending fruit shelf life. Repellent plants can influence microclimate conditions, possibly moderating humidity and temperature around the sweet pepper plants, which affects weight loss and firmness (Mendes et al., 2024). These results are supported by Villa et al. (2020), who demonstrated that peppers grown under optimal irrigation regimes and accompanied by repellent plants exhibited reduced postharvest losses and retained their firmness and colour significantly better than those exposed to stress conditions. Intercropping with repellent plants, such as marigolds or basil, has been documented to effectively deter pests, thereby reducing physical damage and minimizing post-harvest weight loss (Johnson & Lee, 2022).

Sweet pepper grown with lavender as a repellent plant and irrigated once a week (IF1+SL) recorded the highest TSS compared to sweet pepper grown with artemisia and irrigated three times a week (IF3+SA), sweet pepper grown with spearmint and irrigated three times a week (IF3+SP), and sweet pepper monocrop irrigated three times a week (IF3+S) in trial 2 (***Table 5***). These results agree with Smith et al. (2019), who reported that combining optimal irrigation scheduling with the strategic use of repellent plants can help manage soluble salt concentrations in the root zone, thereby improving sweet pepper growth and fruit quality. It is important to carefully balance irrigation frequency with repellent plant selection to prevent excessive salt buildup, which can interfere with plant development and reduce yield. The interaction between irrigation frequency and repellent plants indicates that optimizing irrigation at lower frequencies, combined with strategic intercropping, can enhance TSS content. This aligns with sustainable production practices where both water use efficiency and fruit quality are maximized (Khalid et al., 2020).

Conclusions

This study demonstrates the effectiveness of integrating repellent plants, particularly lavender, with optimized irrigation frequency in managing false codling moth (FCM) in sweet pepper production. The results revealed that planting sweet pepper with lavender and irrigating twice or thrice a week significantly reduces FCM infestation, increases fruit collar diameter yield and to some extent plant height of sweet pepper. Therefore, using lavender as a repellent plant alongside frequent irrigation is recommended as a viable and eco-friendly integrated pest management (IPM) option for FCM management in sweet pepper.

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