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Bell pepper (*Capsicum annuum*) response to self-regulating low energy clay-based irrigation (SLECI) system, burying depth and fertilizer application dosage

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ABSTRACT

The response of bell pepper (*Capsicum annuum*) to the Self-regulating low energy clay-based irrigation (SLECI) system burying depth and fertilizer application dosage was investigated under open field conditions in the coastal savannah agroecological zone of Ghana. A factorial design with 3 SLECI system depths (5 cm, 10 cm and 15 cm) and 3 fertilizer dosages (100% recommended application dosage RAD, 80% RAD and 60% RAD) was adopted. Data was measured, determined and analyzed at a significant ($P \leq 0.05$) level. Results indicated that the highest yield of 0.7974 t/ha was recorded under a burying depth of 5 cm which is 8.6% and 63.9% more compared to 10 cm and 15 cm. Burying depth of 10 cm exhibited the highest water use efficiency of 0.1435 kg/l, which outperformed the 5 cm burying depth (0.1312 kg/l) and 15 cm burying depth (0.0517 kg/l) by 8.6% and 63.9%, similarly a depth of 10 cm (5,980 kg/kg) exhibited significantly greater fertilizer use efficiency over a depth of 15 cm (2,154 kg/kg) by 64% and 5 cm by (5.465 kg/kg). The highest yield of 0.8772 t/ha was exhibited by 80% RAD which is 29.5% and 63.7% more compared to 100% RAD (0.6179 t/ha) and 60% RAD (0.3181 t/ha) respectively. 80% RAD exhibited significantly superior water use efficiency of 0.1579 kg/l, and fertilizer use efficiency of 6,579 kg/kg. The interaction of burying depth of 10 cm and 80% RAD significantly produced the highest yield of 1,187.7 t/ha, resulted in the highest water use efficiency of 0.214 kg/l, and exhibited the best-performing fertilizer use efficiency of 8,908 kg/kg.

Keywords: SLECI, burying depth, fertilizer, irrigation

INTRODUCTION

Water scarcity is the main natural factor that limits crop cultivation in arid and semi-arid regions (Bozkurt and Mansuroğlu, 2011; Ingrao et al., 2023). Therefore, it is expected that water-saving irrigation techniques could be patronized in the foreseeing years under increased industrialization, intensive horticulture, rapid population increase and increased food demand (Sabli, 2012). Irrigation is crucial to increasing crop yields, as agriculture consumes 70% of the world's available water resources (Li et al., 2020). Agricultural development in Africa has been driven by land expansion rather than productivity, this is further challenged by urbanization, soil degradation, poor farming practices, and climate change which further limit the availability of agricultural lands (Fuglie and Rada, 2013). The rising water and fertilizer costs coupled with environmental issues prompt farmers to adopt fertigation-based crop production systems for better control over water and fertilizer use. According to Bozkurt and Mansuroğlu (2011), Frizzone et al. (2012), Sabli (2012), and Lorenzoni et al. (2016), fertigation is a method of applying fertilizers to plants through irrigation water, thereby maximizing yield and crop quality. Fertigation is more efficient and convenient due to constant flow, less fluctuating nutrient concentrations, precise application, and the ability to be applied in soils that typically prevent conventional application (Kafkafi and Kant, 2005).

Subsurface irrigation systems uniformly deliver water and nutrients to the soil root zone, eliminating wind, evaporation and runoff effects, resulting in high fertilizer use efficiency (Locascio, 2005; Suarez-Rey et al., 2006; Elmaloglou and Diamanto-Poulos, 2009; Kumar et al., 2018). According to Patel and Rajput (2007) and Bozkurt and Mansuroğlu (2011). Proper installation depth of sub-surface irrigation systems is vital as irrigation depth may vary from 0.01 to 0.70 m, depending on both soil and crop type (Elmaloglou and Diamantopoulos (2009); Bozkurt and Mansuroğlu (2011). Soil moisture distribution is important in determining installation depth to achieve an optimal water distribution in the effective root zone of crops Patel and Rajput (2007); Kandelous and Suimunek (2010). Soil evaporation is reduced with moderate lateral depths, but a deep installation may cause water loss due to deep percolation and limited water availability for plant roots (Dukes and Scholberg, 2005).

Self-regulating low-energy clay-based irrigation (SLECI) systems and fertigation have not been adequately investigated as treatment variables, and little is known about the effect on crop growth, yield, water productivity, and fertilizer use efficiency with fertigation and SLECI system burying depth. To address these issues, this study aimed to investigate the effects of the SLECI system burying depth and fertilizer application dosage on the growth, yield and productivity using bell pepper as a test crop.

MATERIAL AND METHODOLOGY

The study area

The experiment was undertaken at the A. G. Carson Technology Centre, School of Agriculture University of Cape Coast, Cape Coast which falls within the tropical savanna climate. The soil is classified as sandy clayey loam of the Benya series (Stagnic Lixisol), with a sub-surface layer of kaolinitic clays.

Pre-planting soil analysis

Soil samples were collected, air-dried, crushed, sieved, and bagged for analysis. The result of the soil properties analysis (Table 1) showed that the soil in the experimental area is a sandy loam, and characterized by soil salinity of 0.37 ds/m, pH of 6.9, CEC of 1.73 mg/g, Organic carbon of 1.17 g/kg, phosphorus of 18.1 ppm, nitrogen of 0.47 g/kg, potassium of 0.24 mg/100 g soil, moisture content of 4.52% and bulk density of 1.25 g/cm^3.

Table 1. Soil chemical and physical properties of the experimental site

Soil chemical & physical properties	Value
Salinity (ds/m)	0.37
pH	6.9
CEC (mg/100 g soil)	1.73
Organic carbon (g/kg)	1.17
Phosphorus (ppm)	18.1
Nitrogen (g/kg)	0.47
Potassium (mg/100 g soil)	0.24
Soil moisture content (%)	4.52
Soil bulk density(g/cm^3)	1.25
Clay (%)	13.17
Sand (%)	63.53
Silt (%)	23.30
Texture	Sandy loam

Land and plot preparation

The land was ploughed and harrowed to obtain a fine tilth. It was then lined, pegged and divided into blocks and plots. Healthy and disease-free bell pepper seedlings (Yolo wonder), five weeks old were transplanted onto 2 m x 2 m (4 m²) plots.

Experimental design and treatments

The field experiment was conducted using a factorial design laid out in a Randomized Complete Block Design (RCBD) with three replicates. The field experiment involved nine treatment combinations in three blocks, with three levels of Recommended application dosage (100%, 80%, and 60% RAD) and three levels of SLECI system burying depth (5 cm, 10 cm, and 15 cm). A plant population of 20 crops was recorded on each plot, with 6 plants tagged for data collection. A recommended application dosage of 105 kg/ha RAD was adopted (Kanneh et al., 2017). This was based on the similarity of soil physical-chemical properties, and soil classification of the experimental site as well as the nutritional requirement of bell pepper.

SLECI system

The SLECI system consists of a water tank, valve, filter, clay tubes, connectors, coupling, PE- tubes, and an end cap as shown in Figure 1. The length of the SLECI system clay tube was 9 cm with inner and outer diameters of 10 mm and 12 mm, indicating that each SLECI system can hold 7.1x10^{-6} m^3 of water at a time respectively. The thickness of each SLECI system was 2 mm. The core of the SLECI system was mounted on a PE – hose. This line was completed with a connector to PE-hose --renewal on each end of a clay tube. This was made to allow for the fitting of additional clay tubes. A PE–hose length of 50 cm was allowed between 2 clay tubes. In each plot, clay pipes are joined together or laid end to end to form long tubes of a desired length of 2 m, an end cap was fixed at the end of the PE tube after the desired length was achieved (Figure 2). The clay tubes were buried in the soil at different depths to depict the various treatments.

Water tank, with valve, water filter and hose-connector to irrigation line.

6 * 4 mm PE-hose

Clay tubes mounted on PE hose with connector on each side

Connector

End valve

Figure 1. Components of the SLECI system

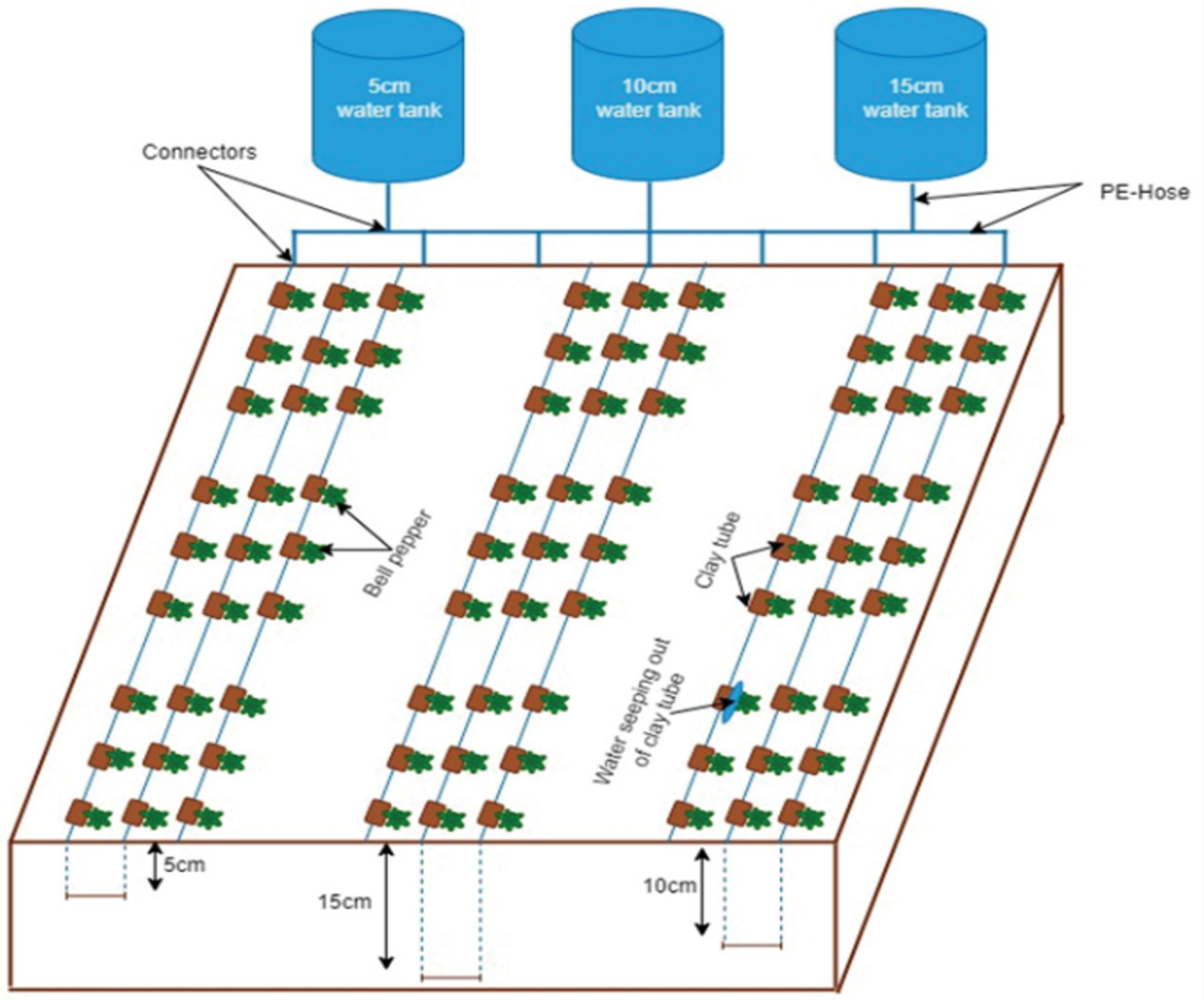

Figure 2. Schematic layout of field experiment indicating varying burying depth

Fertigation scheduling

The fertigation system consisted of a fertilizer tank, valve and PE tubes. The fertigation schedule consisted of a single application of Plantifol NPK 10-50-10, Plantifol NPK 20-20-20 and Plantifol NPK 12-6-36 fertilizer (Atlantica Agricola S. A., Alicante, Spain). Plantifol NPK 10-50-10 was applied 3 days after transplanting at three different application dosages (100% RAD, 80% RAD and 60% RAD of 105 kg/hectare). Plantifol NPK 20-20-20 was applied at three different application dosages (100% RAD, 80% RAD and 60% RAD of 105 kg/hectare) 24 days after transplanting. The last application was carried out when Plantifol NPK 12-6-36 was applied at three different application dosages (100% RAD, 80% RAD and 60% RAD of 105 kg/hectare) 33 days after transplanting.

Figure 3. Transplanted bell pepper plants using SLECI system burying depth of 5 cm

Crop water requirement and irrigation scheduling

Crop water requirement was determined using a weather-sensing irrigation scheduling approach. Four growth stages were considered: initial, developmental, mid-season, and late-season. 100% crop water was applied after evapotranspiration was determined. A variable crop coefficient was applied at each growth stage, Initial stage 0. 60 (25 days), development stage 0. 85 (35 days), mid-season stage 1.05 (40 days), late-season stage 0.90 (20 days) harvesting 0.65 (FAO, 2020: Pepper crop information)

$$ET_c = ET_o \times K_c \qquad (1)$$

where:

- ET_c: Crop evapotranspiration [mm/d],
- ET_o: Reference crop evapotranspiration [mm/d] was determined using the US Class A evaporation pan. To obtain the reference crop evaporation, 0.8 was chosen as the pan factor because the experimental site had a moderate wind speed of 2-3 m/s and high humidity of 75-79% (Darko, 2011).
- K_c: Crop coefficient [dimensionless], was adopted from FAO (2020): Pepper crop information.

Data collection

Measured data

Plant height was measured from the soil surface to the apex of the plant. The mean plant height (tagged plants from each treatment replication) was expressed in centimetres (cm). The longest part along the petiole line of the leaf on the lateral bud beneath the shoot tip and the widest breadth across the leaf were measured as the length and breadth of the leaf. The product was multiplied by a factor of 0.75 to get the leaf area. The number of fruits per plant was determined by counting the number of harvested fruits per plant. The average fruit weight was approximated by weighing harvested fruits and weighing them with an electronic analytical balance.

Derived data

Yield per hectare

The total plant yield was determined by weighing fruits, adding the total fruit weight per plant, and converting the selected area dimensions from square meters to hectares. Yield per hectare was then derived using the formula below.

$$\frac{1\ hectare}{Selected\ area\ containing\ tagged\ plants} x\ total\ yield\ from\ tagged\ plants\ (kg) \qquad (2)$$

Water use efficiency

Water use efficiency was calculated through the proportion of the total plant yield and the total amount of water applied under each treatment.

$$\frac{\text{Total yield per plant (g)}}{\text{The total amount of water applied (mm)}} \qquad (3)$$

Fertilizer use efficiency

Fertilizer use efficiency was calculated through the proportion of the total plant yield and the total fertilizer applied under each treatment.

$$\frac{\text{Total yield per plant (g)}}{\text{The total amount of fertilizer applied (kg)}} \qquad (4)$$

Data analysis

Analyses of variance (ANOVA) of data were performed, using Genstat statistical software (Introduction to GenStat for Windows 18th Ed, VSN International, Rothamsted Experimental Station, Reading University, United Kingdom). Significant mean differences among treatments were compared using Tukey's least significant difference test at a probability level of 5%.

RESULTS AND DISCUSSION

Crop water requirement of bell pepper

Table 2 shows the crop water consumption of bell pepper during the growing season. The seasonal crop water requirement of bell pepper was found to be 558.86 mm (initial growth stage; 77.08 mm, crop developmental stage; 159.75 mm, the middle season stage; 186.69 mm, the late season stage 134.80 mm) (Table 2).

Table 2. Crop water requirement of bell pepper during the growing season

Growth stage	ET_o 100%	K_c	ET_c 100%	5 cm	10 cm	15 cm
Initial stage	122.35	0.63	77.08	74.8	72.8	76.7
Crop development	138.91	1.15	159.75	148.5	135.6	149.2
Middle season	147.58	1.27	186.69	159.7	144.2	161.6
Late season	140.42	0.96	134.80	142.1	136.6	143.9
Total (mm)			558.86	525.1	489.2	531.4

The crop water requirement of bell pepper recorded was similar to observations made by Trivikrama et al. (2018) and Dimple et al. (2018) who reported 562.5 mm and 525.11 mm to be the crop water requirement of bell pepper and were within the range of 300 - 700 mm provided by Agodzo et al. (2003) and FAO (2008). At the initial stage, crop water requirements for 5 cm, 10 cm and 15 cm were 74.8 mm, 72.8 mm and 76.7 mm respectively, with all being less than the crop evapotranspiration of 77.08 mm, this is in line with the findings of Phene (1991) and Phene et al. (1992) reported that a sub-irrigation system reduces the amount of irrigation water, especially in the early development stage of the plants. The highest water consumption (531.4 mm) was found for a burying depth of 15 cm treatment followed by 525.1 mm recorded from a burying depth of 5 cm. The least water consumption of 489.2 mm was recorded from a burying depth of 10 cm. Burying depths of 5 cm, 10 cm and 15 cm reduced crop water requirement by 6%, 12.5% and 4.9%. Water consumption recorded from all the treatments was lower than the crop water requirement. SLECI system reduces the water consumption of bell pepper by ensuring dry soil surfaces and reducing evaporation.

Effect of SLECI system burying depth and fertigation level on the vegetative growth of bell pepper

The leaf area of bell pepper plants is significantly influenced by burying depth, with a 10 cm burying depth resulting in the highest leaf area of 61.96 cm^2 (Figure 4D). The plant height of bell pepper plants was significantly ($P < 0.05$) influenced by the SLECI system burying depth (Figure 4C). At a burying depth of 10 cm, the plant height was significantly higher, indicating a general decrease in height beyond 10 cm (Figure 4C). The result is consistent with the findings of Bozkurt and Mansuroğlu (2011), who indicated that the highest plant height and leaf area was obtained from a depth of 10 cm. According to Siyal et al. (2009), the depth of irrigation pipe installation affects the rate of evaporative losses which in turn affects the shape of the wetted zone in the root zone of the crops. The deepest irrigation depth of 15 cm resulted in the poorest performance of growth parameters. This is in line with the findings of Al-Harbi et al. (2008). Even though, deeper lateral depth leads to the reduction of soil evaporation, water loss due to deep percolation and unavailability of water in the effective root zone of crops can occur, especially in the early growth stages, exposing the crop to water stress. This negatively affects physiological processes such as cell division inhibition & differentiation and reduces photosynthesis rate resulting in poor plant growth.

The impact of fertilizer application dosage on bell pepper plant height is presented in Figure 4B. Bell pepper plants grown under 100% RAD and 80% RAD were statistically better than those subjected to 60% RAD (Figure 4B). The highest leaf area was recorded in plants subjected to 80% RAD, followed by 100% RAD, with the least leaf area being observed at 60% RAD (Figure 4A). Results are in tandem with the findings of Eckas (2005), Umair et al. (2019) and IWS (2022) where best-performing growth parameters were recorded when the fertilizer application rate was reduced by 20-30% and was applied through the sub-surface irrigation system.

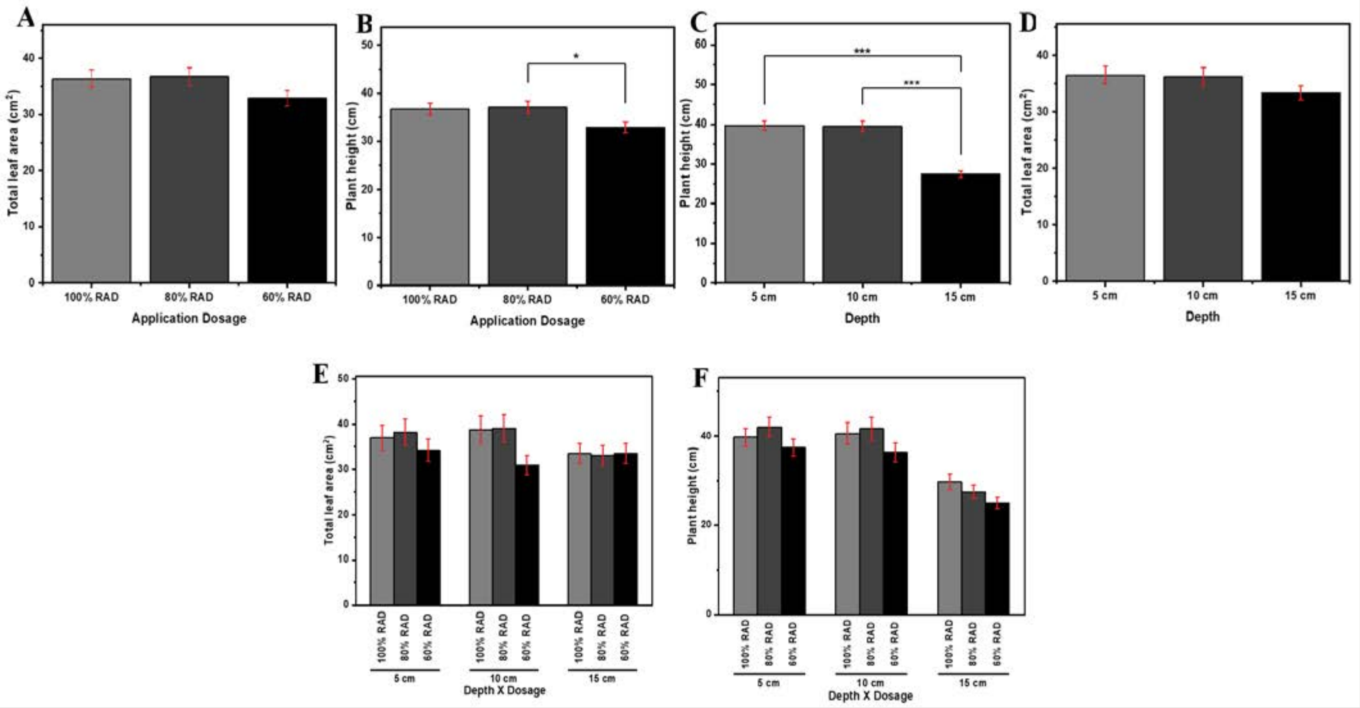

Figure 4. Effect of SLECI system burying depth, recommended fertilizer application dosage and their interaction on the vegetative growth of bell pepper

Singh et al. (2022) emphasized that fertigation through subsurface irrigation is beneficial to crops since there is more efficient usage of nutrients as a result of water being supplied uniformly to the root zone as they are required by the crop, thereby eliminating surface runoff and evaporation from the soil surface.

Significant differences were observed in plant height under different treatment combinations of burying depth and fertigation levels (Figure 4F). The highest plant height of 62.51 cm was observed in plants grown under 10 cm: 80% RAD whereas the lowest plant height of 37.00 cm was observed in plants grown under 15 cm: 60% RAD (Figure 4F). The leaf area of plants grown under 15 cm and 60% RAD (33.05 cm^2), 80% RAD (32.17 cm^2), and 100% RAD (32.72 cm^2) were not statistically different from each other, with the highest leaf area of 35.80 cm^2 recorded in plants grown under 10 cm: 80% RAD, while the least leaf area was 28.04 cm^2 (Figure 4E). The results are in line with earlier findings of Gupta et al. (2009) who indicated that reducing crop water requirement water along with 80% recommended NPK through fertigation was found significantly superior over all other treatment combinations with vegetative growth parameters of bell pepper. A burying depth of 10 cm coupled with 80% RAD of fertilizer through the SLECI system reduces deep leaching of plant nutrients, reduces soil salinity build and ensures the availability of moisture in the effective root zone, creating an ideal environment for growth and development.

Effect of burying depth and fertigation on the yield parameters and yield of bell pepper

The number of fruits per bell pepper plant as influenced by different fertilizer application dosages is presented in (Figure 5A), where the statistically significant (*P* < 0.05), highest number of fruits per plant 8.5 was recorded in 80% RAD followed by 100% RAD and 60% RAD (Figure 5A). The results of average fruit weight show different variations by the application of different recommended application dosages (Figure 5B). Average fruit weight was recorded as 73.88 g, 63.46 g and 51.83 g exhibited by bell pepper plants subjected to 80% RAD, 100% RAD and 60% RAD respectively (Figure 5B).

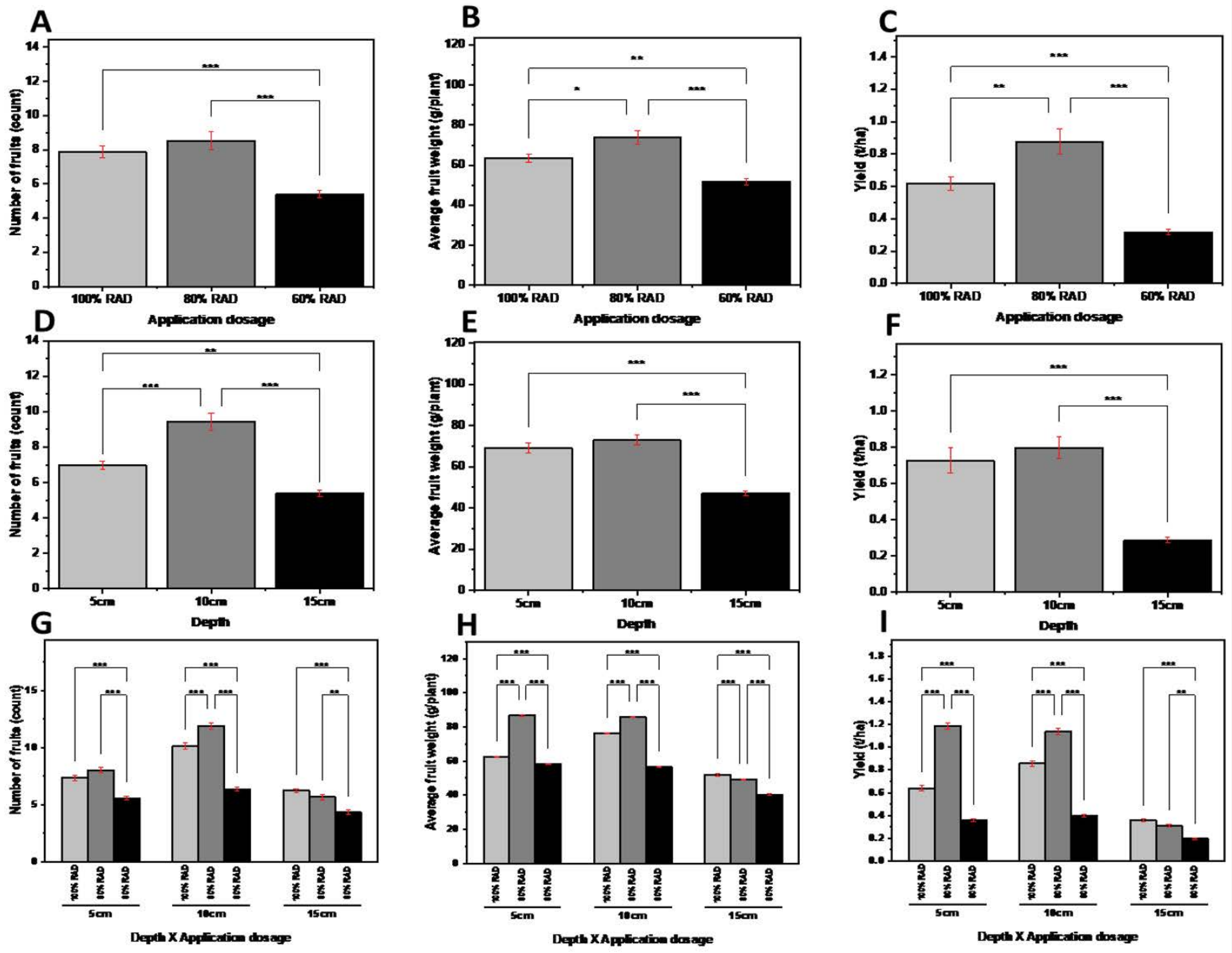

Figure 5. Effect of SLECI system burying depth, recommended fertilizer application dosage and their interaction on the yield parameters and yield of bell pepper

The yield per tonne of bell pepper was significantly (*P* > 0.05) affected by the imposition of different fertilizer application dosages (Figure 5C). The yield per hectare was recorded as 0.8772 t/ha, 0.6179 t/ha and 0.3181 t/ha respectively from plants subjected to 80% RAD, 100% RAD and 60% RAD, indicating that the yield of bell pepper showed significant variation due to different fertilizer application dosage. Data available in Figure 5C indicates that even though the recommended application dosage of fertilizer was reduced by 20% (80% RAD) it produced the highest yield of 0.8772 t/ha which was an improvement of 29.5% and 63.7% when compared to bell plants that were subjected to 100% RAD and 60% RAD. Bell pepper crops subjected to a 20% reduction in the recommended application dosage of fertilizer resulted in the best performance in yield. Results are in tandem with the findings of Kaushal et al. (2012) who reported that subsurface irrigation reduces fertilization requirement (20-33%). While ensuring an increase in yield. Tripathi et al. (2017) indicated that the adoption of a SLECI system ensures that the amount of fertilizer required by the crop during its lifecycle can be abridged as much as 25 to 40%. SLECI systems are buried beneath the soil surface, fertigation is uninterrupted. Additionally, the density of roots in a concentrated root zone is substantially higher per unit of soil, thus fertigation is far more effective. The lower application rate of water using a SLECI system averts nutrients from being leached out of the plant's root zone.

The significant ($P < 0.05$) effect of the SLECI system burying depth on the number of fruits of the bell pepper plant is presented in Figure 5D, where a burying depth of 5 cm produced 27% and 42.6% more fruits than a burying depth of 10 cm and 15 cm respectively. The average fruit weight of bell pepper fruits affected by different burying depths is presented in Figure 5E. Average fruit weight shows a significant difference among a burying depth of 5 cm (73.00 g) burying depth of 10 cm (69.08 g) and a burying depth of 15 cm (47.09 g). A significant increase in average fruit weight by 5.3% and 35.3% was attained when plants grown under a burying depth of 5 cm were compared to a burying depth of 10 cm and 15 cm (Figure 5E). The yield per hectare of bell pepper was significantly affected ($P > 0.05$) with the imposition of different SLECI system burying depths (Figure 5F). The yield per tonne was recorded as 0.7974 t/ha, 0.7286 t/ha and 0.2872 t/ha respectively from plants grown under the SLECI system burying depths of 5 cm, 10 cm and 15 cm, indicating that the yield of bell pepper showed significant ($P < 0.05$) variation at the end of the crop growing period. The highest yield of 0.7974 t/ha was recorded in plants grown under a burying depth of 5cm which was 8.6% and 63.9% better than plants grown under 10 cm and 15 cm respectively (Figure 5F). This finding disagrees with earlier findings of Lamm and Trooien (2005) and Al-Damry (2006) who reported high yields from irrigation depths of 25 – 40 cm.

The difference in findings could be ascribed to the type of subsurface system, different geographical temperatures which result in different evaporation losses and different types of soil which influences the potential occurrence of percolation. The best performance of 10 cm is in tandem with the findings of Bozkurt and Mansuroğlu (2011) and Wang et al. (2018) who reported that the highest yield parameters were recorded when crops are grown at 10 cm burying depth. The best performance could be attributed to the fact that at a depth of 10 cm, there was a better balance in the soil moisture, aeration and plant nutrients in the effective root zone depth. The deepest burying depth resulted in a significantly lower yield; this is consistent with the findings of Lamm and Trooien (2005) who indicated that yields were significantly less for the deepest burying depth. The poor performance of the deepest depth and shallowest depth of the SLECI system is in line with the findings of Douh and Boujelben (2011) who indicated that irrigation pipe burying depth results in significantly different yields.

Exposure of bell pepper to burying depth and different fertilizer application dosages caused significant differences concerning the number of fruits per plant produced (Figure 5G). The combination of a burying depth of 10 cm and 80% recommended application dosage irrigation resulted in a significantly higher number of fruits per plant, which was statistically equivalent to, 5 cm: 80% RAD (11.9) and 10 cm: 100% RAD (11.8). The lowest number of fruits per plant (4.3) was recorded in plants subjected to 15 cm and 60% RAD (Figure 5G). The interactive effect of burying depth and fertigation levels on the average fruit weight of bell pepper is presented in Figure 5H. The combination of a burying depth of 10 cm and 80% RAD resulted in a significantly higher average fruit weight of 86.67 g, compared with the rest of the treatment combinations, whereas the lowest average fruit weight of 40.43 g was recorded in plants subjected to 15 cm and 60% RAD (Figure 5H). Figure 5I shows that the yield per hectare of bell pepper was significantly influenced by the SLECI system burying depth and fertilizer application dosage, where 10 cm and 80% RAD significantly produced the highest yield of 1,187.7 t/ha which was statistically equivalent to 5 cm and 80% RAD (1,135.0 t/ha). The lowest yield of 0.1950 t/ha was recorded in bell pepper plants subjected to 15 cm and 60% RAD (Figure 5I). Gupta et al. (2009) indicated that reducing crop water requirement water along with 80% recommended NPK through fertigation results in maximum fruit yield of bell pepper. The better performance of 10 cm burying depth and 80% RAD could be attributed to the availability of water and nutrients in the effective root zone of crops. A concentrated root zone with a SLECI system improves crop performance and yields by supplying fertilizer directly to the roots, resulting in better nutrient absorption. The system's lower application rate and self-regulatory ability prevent nutrient leaching beyond the effective root zone. Furthermore, Eckas (2005), Umair et al. (2019) and IWS (2022) reported that fertilizer requirements can be reduced by as much as 25-40% through fertigation.

Relationship between FUE and WUE and SLECI system burying depth

The correlation between SLECI burying depth water use efficiency and fertilizer use efficiency is presented in Figure 6, where a significant negative correlation exists between burying depth and productivity indicators of bell pepper indicating that an increase in the burying depth results in a low or reduced water use efficiency as well as fertilizer use efficiency. At greater depths, excessive water supply can lead to wastage. As water passes through the soil, it carries away nutrients and a large amount of water. This reduces the availability of water for plants and affects their efficiency in using water. Moreover, nutrients are washed out of the soil, depriving crops of the necessary elements for optimal growth. When irrigation is applied at depths beyond the effective root zone, fertilizers cannot function properly at low levels of irrigation. The dissolved nutrients are carried downward and out of reach of the plant's roots, resulting in loss and unavailability for uptake by plants.

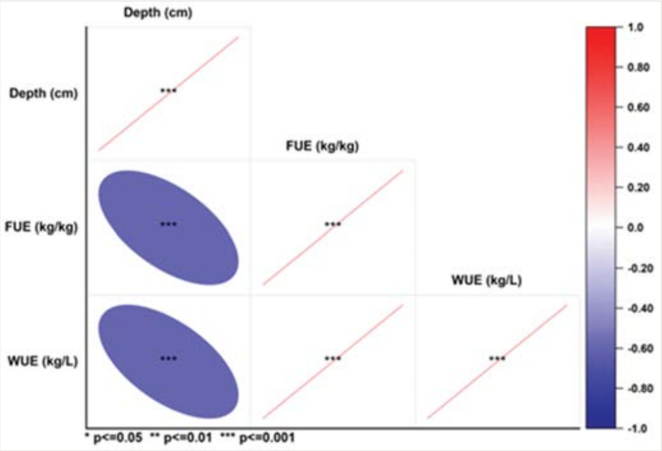

Figure 6. Correlation coefficients of SLECI system burying depth and FUE and WUE of bell pepper

Effect of SLECI system burying depth and fertigation on WUE and FUE

Figure 7A gives the water use efficiency of bell peppers as significantly influenced by different SLECI system burying depths. A burying depth of 10 cm exhibited the highest water use efficiency of 0.1435 kg/l, which outperformed a 5 cm burying depth (0.1312 kg/l) and 15 cm burying depth (0.0517 kg/l) by 8.6% and 63.9%. This is in line with the findings of Wang et al. (2018) where water use efficiency (WUE) burying depth of 10 cm) was higher than those of 5 cm and Bryla et al. (2003) reported that WUE decreased at the deepest buying depth. Low WUE recorded in 5 cm could be attributed to high soil evaporation with crop evapotranspiration resulting in a slow early growth rate in crops. Yazgan et al. (2008) explained that, in the early growth stage, water application does not correspond to crop demand since shallow roots of crops are unable to utilize water beyond the root zone.

The results relating to the water use efficiency of bell pepper as influenced by varying fertilizer application dosages are presented in Figure 7C. Supplying bell pepper plants with 80% RAD was found to be significantly superior with the highest water use efficiency of 0.1579 kg/l, followed by 100% RAD (0.1112 kg/l) and 60% RAD (0.0573 kg/l). This is in line with earlier findings of Li et al. (2021) who reported a 21% reduction in fertilizer requirement in pepper when supplying nutrients through fertigation and subsurface irrigation systems. Shirgure (2013) explained that fertilizing crops through fertigation increases WUE because nutrients are supplied through irrigation water, they are already in soluble forms available for plant uptake.

The results relating to the water use efficiency of bell pepper plants as influenced by the interaction of SLECI system burying depth and fertilizer application dosage are presented in Figure 7E. Bell pepper plants that were grown under SLECI system burying depth of 10 cm and 80% RAD exhibited the highest water use efficiency of 0.214 kg/l, representing a 83.6% increase in comparison to the least water use efficiency of 0.035 kg/l recorded in plants subjected to SLECI system burying depth of 15 cm and 60% RAD. Results are in line with the findings of Gupta et al. (2010) who reported that the highest water use efficiency was observed with the treatment combination of reduced crop water requirement and 80% recommended NPK through fertigation. This could be attributed to the fact that fertigation through the SLECI system synchronizes nutrient supply and crop nutrient requirement, which enhances water-use efficiency and yield.

Figure 7B portrays results related to fertilizer use efficiency as influenced by the SLECI system burying depth. SLECI system burying depth of 5 cm (5,980 kg/kg) exhibited significantly greater (*P* ≤ 0.05) fertilizer use efficiency over a burying depth of 15 cm (2.154 kg/kg) by 64% and 10 cm (5,465 kg/kg) by 9.4%. (Figure 7B). The significantly lower FUE recorded in plants grown under 5 cm burying depth could be attributed to the effect of evaporation on nutrient uptake. Evaporation itself can significantly reduce the quantity or volume of water in the soil, thus subjecting the plant to water stress. Plants absorb nutrients in soil water, when soil is dry, they are unable to absorb soil nutrients. A depth of 10cm ensured that nutrients and water were supplied to the effective root zone of crops regardless of the stage of plant growth, devoid of the negative impact of evaporation as well as leaching. According to Suarez-Rey et al. (2006), Elmaloglou and Diamantopoulos (2009) and Li et al. (2021) subsurface irrigation systems ensure that water is directly applied to the root zone without losses due to evaporation.

Figure 7D portrays results related to fertilizer use efficiency as influenced by fertilizer application dosage. Bell pepper plants that were supplied with 80% RAD exhibited a fertilizer use efficiency of 6,579 kg/kg which was significantly superior compared to the fertilizer use efficiency of bell pepper plants that received 100% RAD (4,634 kg/kg) and 60% RAD (6,579 kg/kg). There were significant differences between 100% RAD and 60% RAD (Figure 7D).

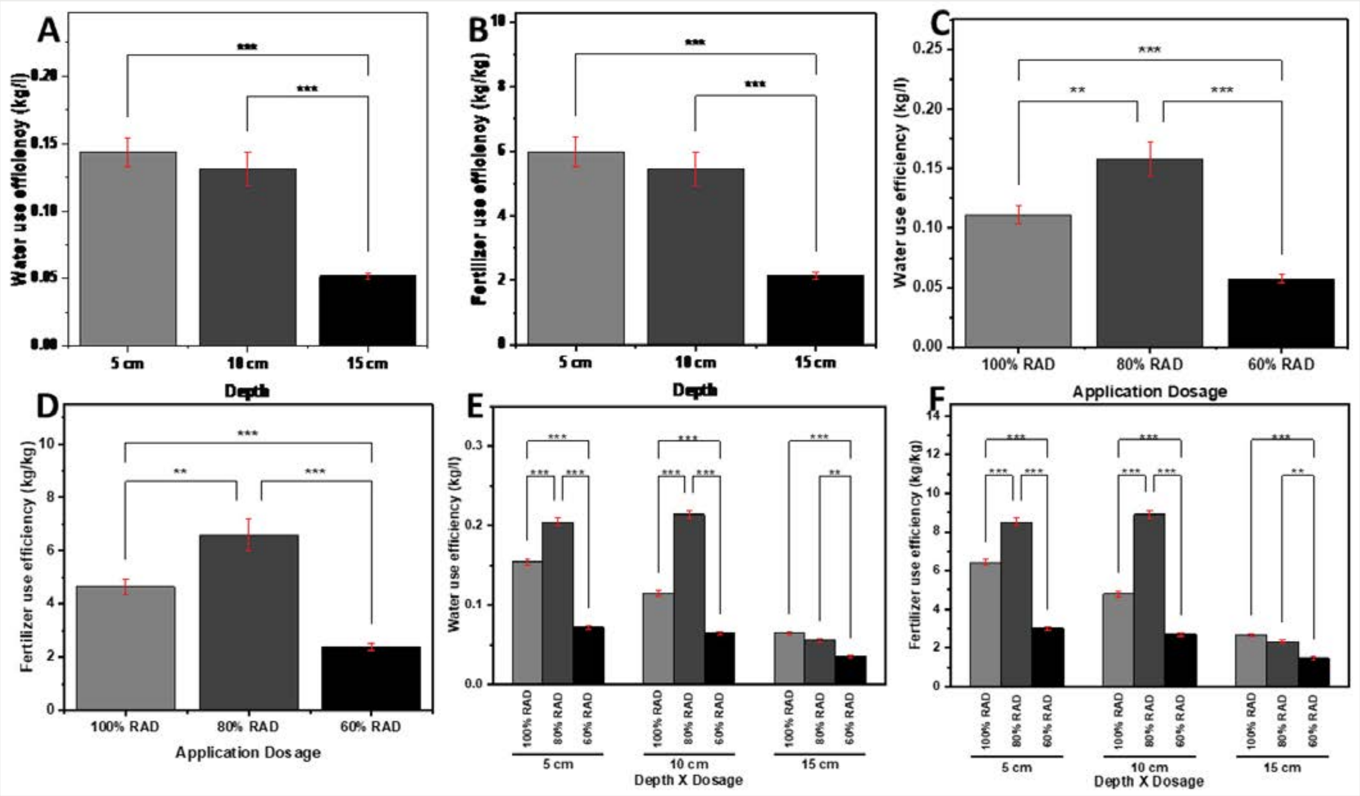

Figure 7. Effect of SLECI system burying depth, recommended fertilizer application dosage and their interaction on the water use and fertilizer use efficiency of bell pepper

Lower FUE obtained from crops subjected to 100% RAD compared to FUE obtained from crops subjected to 80% RAD could be attributed to the increase in EC soil water resulting in soil salinity. Bano and Fatima (2009) reported that soil salinity enacts osmotic stress, ion toxicity, oxidative stress and nutrient deficiency on plants, thus limiting water uptake from soil. Lower FUE obtained from crops subjected to 60% RAD compared to crops subjected to 80% RAD could be attributed to poor growth due to a well low quantity of nutrients supplied to the crops. As the quantity of supplied nutrients is reduced, the yield of crops is reduced, thus a lower FUE.

The results of fertilizer use efficiency of bell pepper concerning the interactive effect of SLECI system burying depth and fertilizer application dosage is presented in Figure 7F. It indicates that the bell pepper plants grown under a burying depth of 10 cm: 80% RAD (8,908 kg/kg) recorded the highest fertilizer use efficiency which was significantly superior to the remaining treatment combinations. This could be attributed to the form of fertilizer application, that is fertigation. Badr and El-Yazied (2007) and Dhotre et al. (2017) explained that fertigation can reduce fertilizer usage due to the absence of leaching, ammonia volatilization and denitrification.

CONCLUSION

This study was conducted to investigate the effects of SLECI system burying depth and fertilizer application dosage on the growth, yield and productivity of bell pepper plants. The best growth parameters for bell pepper plants were achieved with a burying depth of 10 cm and 80% recommended application dosage. This combination resulted in the highest plant height and leaf area. For yield, using the SLECI system with a burying depth of 10 cm produced more fruits per plant, higher average fruit weight, and greater yield per hectare compared to burying depths of 5 cm and 15 cm. Additionally, reducing the recommended application dosage of fertilizer by 20% (80% RAD) also increased the number of fruits per plant, average fruit weight, and yield per hectare compared to treatments with 100% RAD and 60% RAD.

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