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Effect of deficit irrigation and storage on the nutritional composition of tomato (*Lycopersicon esculentum* Mill. cv. Pectomech)

R. Agbemafle[1*], J.D. Owusu-Sekyere[2], A. Bart-Plange[3]

[1]*Department of Laboratory Technology, School of Physical Sciences, University of Cape Coast, Ghana*
[2]*Department of Agricultural Engineering, School Agriculture, University of Cape Coast, Ghana*
[3]*Department of Agricultural Engineering, College of Engineering, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana*

Abstract

The aim of the study was to determine the effects of deficit irrigation and postharvest storage on nutritional composition of tomatoes. Tomato fruits (Pectomech variety) cultivated under different irrigation treatments (100% ETc, 90% ETc, 80% ETc and 70% ETc) were harvested and analyzed for moisture, ash, protein, fat, fibre, carbohydrate, calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), iron (Fe), copper (Cu) and zinc (Zn) contents. Moisture, ash, protein, fat, fibre, and carbohydrate were determined by standard AOAC methods, calcium and magnesium by EDTA titration, potassium and sodium by flame photometry, iron, copper and zinc by atomic absorption spectrophotometry. Results indicated that fat, fibre and carbohydrate increased with deficit irrigation (water stress) whilst moisture, ash, protein, calcium, magnesium, potassium, sodium, iron, copper and zinc contents decreased. Apart from fibre content which increased significantly during storage for all water treatments, all the other nutritional components (moisture, ash, protein, fat and carbohydrate) decreased significantly. Considering the percentage increases and decreases obtained for nutritional compositions of the tomatoes in this study, it can be concluded that a 10- 20% reduction in the amount or volume of water applied in the cultivation of the Pectomech tomato variety would produce tomato with optimum quality that would compensate for yield losses.

Keywords: *deficit irrigation, nutritional composition, Pechtomech, tomato*

1. Introduction

Tomato is one of the most widely grown vegetables in the world because of the nutritive value of its fruit (rich source of minerals, vitamins, organic acids, essential amino acid, etc.). Therefore, any factor influencing tomato yield has attracted considerable interest. Among environmental factors water availability is a major limiting factor of tomato fruit growth and productivity thus the successful production of tomato requires irrigation (Johnson *et al*., 1992) However, water resources in many parts of the world are limited and thus there is an urgent need to apply effective irrigation strategy to operate under the condition of water scarcity (Fereres and Soriano, 2007). A recent positive approach to attain the goal of improving water use efficiency in agriculture is conventional deficit irrigation. Deficit irrigation is a water-saving strategy under which crops are exposed to a certain level of water stress either during a particular period or throughout the whole growing season (Pereira *et al*., 2002). The expectation is that any yield reduction will be insignificant compared with the benefits gained from the saving of water (Eck *et al*., 1987). The goal of deficit irrigation is to increase crop water use efficiency by reducing the amount of water applied with watering or by reducing the number of irrigation events (Kirda, 2002). The reduction in the amount of water applied to the plant may lead to some physiological and biochemical changes in the plant that may affect its nutritional composition.

Physiological and biochemical changes including carbohydrates, proteins and lipids observed in many plants under various water stress levels have been reported. Among the

major effects are those involving carbohydrate metabolisms, with the accumulation of sugars and a number of other organic solutes (Kameli, 1990).

Short term water stress was reported to stimulate the conversion of starch to sucrose in bean leaves (Fox and Geiger, 1986). The increase of sugar in various plant tissues response to water stress supported the idea of contribution of solutes when the plants are exposed to different stress levels. Studies have shown that soluble sugars accumulate in leaves during water stress (Al-Suhaibani, 1996), and have suggested that these sugars might contribute to osmoregulation (Morgan, 1984), at least under moderate stress.

Changes of amino acids and protein have been mentioned in many reports which have stated that water stress caused different responses depending on the level of stress and plant type. For instance, in *Avena* coleoptiles water stress clearly caused a significant reduction in rate of protein synthesis (Dhindsa and Cleland, 1975). Water stress has a profound effect upon plant metabolism, and results in a reduction in protein synthesis. Several proteins were reduced by stress in maize mesocotyls (Bewley *et al*., 1983). Dasgupta and Bewley (1984) pointed out that water stress reduced protein synthesis in all regions of barley leaf. Although water stress may inhibit protein synthesis (Ho and Sachs, 1989), some specific types of proteins and

Corresponding author: Email: ragbemafle@ucc.edu.gh

mRNA increase in water stressed plants. For instance, free proline accumulation in response to drought in many plant species tissues is well documented (Nair *et al*., 2006).

Changes in lipid contents of plants due to water stress have also been reported. Akinci (1997) reported a decrease in total lipids content of cucumber under water stress. Decreases in diacylglycerol, free fatty acid and polar lipid in maize were also reported (Navari-Izzo *et al*., 1989). Other effects of water stress include a reduction in nutrient uptake, reduced cell growth and enlargement, leaf expansion, assimilation, translocation and transpiration. Many nutrient elements are actively taken up by plants, however, the capacity of plant roots to absorb water and nutrients generally decreases in water stressed plants, presumably because of a decline in the nutrient element demand (Alam, 1999). It is well documented that essential plant nutrients are known to regulate plant metabolism even if the plants are exposed to water stress by acting as cofactor or enzymes activators (Nicholas, 1975). Different effects of water stress on nutrient concentrations of different plant species and genotypes were reported and most studies have reported that mineral uptake can decrease when water stress intensity is increased (Singh and Singh, 2004). For instance, nitrogen uptake decreased in soybean plants under water stress conditions (Tanguilig *et al*., 1987) and nitrogen deficiency causes cotton plants to be sensitive to stress with a higher water stress (Singh and Gupta, 1993) and decrease of nutrient presumably because of a decline in the nutrient element demand since the reduced root-absorbing power or capacity to absorb water and nutrients generally declines accompanied by decrease in transpiration rates and impaired active transport and membrane permeability of crop plants (Levitt, 1980). However, water stress has been reported to generally favour increases in nitrogen, K^+, Ca^{2+}, Mg^{2+}, Na^+, and Cl^- but decreases in phosphorus and iron (Abdel, *et al*., 1971) intake in certain plants.

A number of chemical and physical processes take place in vegetables during storage. Apart from physical quality, serious losses also occur in the essential nutrients, vitamins and minerals. The aim of the study was to determine the effects of deficit irrigation and postharvest storage on the nutritional compositions of tomato.

2. Materials and methods

Sample collection

Tomato fruits grown under the various water regimes (100% ETc, 90% ETc, 80% ETc and 70% ETc) were harvested from the School of Agriculture Research Farm, University of Cape Coast and sent to the School of Agriculture Research Laboratory for analysis. Analysis was carried out for nutritional compositions (moisture, ash, protein, fat, fibre, carbohydrate, calcium, magnesium, sodium, potassium, iron, copper and zinc contents). All analysis was carried out in triplicates.

Analysis of nutritional compositions

Moisture content of the tomato fruits was determined using the oven drying method, ash content by incinerating the dry tomato fruit at 550°C in a muffle furnace, protein content by Kjeldahl method, fat content by Soxhlet extraction and fiber content by weighing the acid and alkaline treated defatted sample all as described by AOAC (2000). Carbohydrate content of the tomato fruit was determined by difference. Sodium and potassium contents of the tomatoes were determined by flame photometry, calcium and magnesium contents by EDTA titration, iron, copper and zinc contents by Atomic Absorption Spectrometry as described by AOAC (2000).

Statistical analysis

Results from the study were analyzed using SPSS (Version 20). Descriptive statistics such as mean and standard deviation were also calculated. One way Independent Analysis of Variance (ANOVA) were conducted to measure the significant effect of the different types of irrigation treatment on the various parameters measured. Tukey's HSD multiple comparison was also performed to indicate where the difference exist at $p<0.05$. Simple regression and correlation were conducted to ascertain the relationship between the nutritional components and the amount of water applied.

3. Results and discussions

Effects of deficit irrigation on nutritional composition of the tomato

The effects of deficit irrigation on the nutritional composition of the tomato fruits are shown in Table 1.

The moisture content of the tomato for the various water treatments was in the order 100% ETc > 90% ETc > 80% ETc > 70% ETc. Analysis of variance indicated the variations in the mean moisture content of the tomatoes for all the water treatments were significant ($p<0.05$). There was no significant difference in the moisture contents of fruits from treatments 90% ETc and 80% ETc. However, significant differences existed between the moisture contents of fruits from treatments 100% ETc and 70% ETc, 90% ETc and 70% ETc.

There was a strong positive correlation (R^2 = 0.927) between the amount of water applied to the tomato plant during cultivation and the moisture content of the tomato fruits.

This trend in the percent moisture content is similar to the findings of Abdel-Razik (2012), and Proietti and Antognozzi (1996) who reported that with increasing water treatment, the pulp water content of mango and olive respectively were increased.

The results of the ash content of the tomato showed that ash content decreased with water stress. The ash content of the tomato for the various water treatments was in the range of 0.47% – 0.98% with 100% ETc recording the highest and 70% ETc recording the lowest value. The differences in the ash contents between all water treatments were significant ($p<0.05$).

Regression analysis showed a strong correlation (R^2 = 0.996) between the ash content of the tomato fruits and the amount of water applied to the plant during cultivation.

The ash content of a food substance is a representation of its inorganic components (minerals) (Sobulo *et al*., 1975). Many nutrient elements are actively taken up by plants, however, the capacity of the plant roots to absorb water and nutrients generally decreases in water stressed plants (Akinci and Losel, 2012). Thus the higher ash content of the tomato from the tomato plant treated with 100% ETc may be due to the higher soil water content which led to higher absorption of minerals by the roots.

The protein contents of the tomato for the different water application ranged between 1.80% and 1.84% with treatment 100% ETc recording the highest and 70% ETc recording the least. There were no significant differences in the protein content of the tomato for the various water treatments ($p>0.05$). There was no correlation (R^2=0.070) between the protein content of the tomato fruits and the amount of water applied, implying that the amount of water used during cultivation did not have any influence on the protein content of the tomato fruits.

The range of protein content obtained in this study was higher than the 1.0%-1.1% reported by USDA (2005). The differences may be due to the variety and other environmental conditions during production. Idah *et al*. (2010) also reported a protein content of 0.05% for tomatoes which is lower than that obtained in the current study. Analysis of variance indicated that the treatments did not have any significant effect ($p>0.05$) on the protein content of the tomato. Under water stress conditions changes in the amino acids and proteins (synthesis and utilization) have been mentioned in many reports, which stated that water stress caused different responses depending on the level of stress and plant (Dhindsa and Cleland 1975).

The fat content of the tomato for the different water application ranged between 0.09% and 0.15% with treatment 70% ETc recording the highest and 100% ETc recording the least. There was a strong negative correlation (R^2= 0.901) between the fat content of the tomato fruits and the amount of water applied during cultivation.

The range of fat content obtained in this study fell within the 0.1% and 0.2% reported by USDA (2005). Idah *et al.* (2010) also reported a protein content of 0.22% for tomatoes which is higher than that obtained in the current study. The difference may be due to variety and environmental conditions of cultivation. Analysis of variance indicated that the differences in the fat content of the tomato for the various water treatments were significant ($p<0.05$). This result compares favourably with the findings of Noorka *et al.* (2012) who reported an increase in fat content with increasing water stress. Navari-Izzo *et al.* (1990) reported an increase in diacylglycerol, triacylglycerol and glycolipid content in soybean seedling shoots under water stress.

Fibre is the portion of food that is not digested by the digestive enzymes. However, it is a very important nutrition wise because it helps improve the peristaltic movement of the bowels thereby preventing constipation and colon cancer. The fibre contents of the tomato for the different water applications ranged between 0.70% and 1.10% with treatment 70% ETc recording the highest and 100% ETc recording the least. There was a strong negative correlation (R^2=0.908) between the fibre content of the tomato fruits and the amount of water used.

The range of fibre content obtained in the present study fell within the 0.5% and 0.7% reported by USDA (2005). Analysis of variance indicated that the differences in the fibre content of the tomato for the various water treatments were significant ($p<0.05$). There was a significant difference between treatments 100% ETc and 70% ETc, 90% ETc and 70% ETc but not between 100% ETc and 90% ETc and between 80% ETc and 70% ETc.

Carbohydrates are very important food nutrients in the body. They are major sources of energy to the body. The carbohydrate contents of the tomato for the different water applications ranged between 5.72% and 9.0% with treatment 70% ETc recording the highest and 100% ETc recording the least. Regression analysis indicated that there was a negative correlation (R^2=0.981) between the carbohydrate content of the tomato fruits and the amount of water applied.

The range of carbohydrates obtained in the present study was higher than the 4.7% reported by USDA (2005). Idah *et al*. (2010) also reported a carbohydrate content of 23.47% for tomatoes which is higher than that obtained in the current study. The difference may be due to variety and environmental conditions of cultivation. Analysis of variance indicated that the differences in the carbohydrate contents of the tomato for the various water treatments were significant ($p<0.05$). The higher carbohydrate content of the tomato treated with 70% ETc may be attributed to the accumulation of soluble sugars in the leaves

Table 1*: Nutritional composition of tomato fruits under the different water treatments at harvest*

Parameter	Treatments			
	100% ETc	90% ETc	80% ETc	70% ETc
Moisture (%)	91.00±0.06 ^{c}	89.65±0.01 ^{b}	88.60±0.05 ^{b}	88.02±0.10 ^{a}
Ash (%)	0.98±0.01 ^{d}	0.78±0.02 ^{c}	0.69±0.01 ^{b}	0.47±0.02 ^{a}
Protein (%)	1.83±0.01 ^{a}	1.82±0.02 ^{a}	1.80±0.02 ^{a}	1.80±0.04 ^{a}
Fat (%)	0.09±0.00 ^{a}	0.10±0.00 ^{b}	0.10±0.00 ^{b}	0.15±0.00 ^{c}
Fibre (%)	0.42±0.03 ^{a}	0.45±0.02 ^{a}	0.51±0.02 ^{ab}	0.56±0.02 ^{b}
Carbohydrate (%)	5.72±0.04 ^{a}	7.20±0.03 ^{b}	8.30±0.14 ^{c}	9.00±0.16 ^{d}
Calcium (ppm)	0.009±0.00 ^{b}	0.009±0.00 ^{b}	0.006±0.00 ^{a}	0.003±0.00 ^{a}
Magnesium (ppm)	0.002 ±0.00 ^{b}	0.002 ±0.00 ^{b}	0.001 ±0.00 ^{a}	0.001 ±0.00 ^{a}
Sodium (ppm)	26.34±0.10 ^{c}	24.11±0.06 ^{b}	23.53±0.02 ^{a}	23.22±0.10 ^{a}
Potassium (pmm)	46.25±0.12 ^{c}	43.48±0.12 ^{b}	42.32±0.05 ^{a}	42.25±0.06 ^{a}
Iron (ppm)	0.54 ±0.01 ^{c}	0.49 ±0.02 ^{b}	0.48 ±0.00 ^{b}	0.30 ±0.02 ^{a}
Copper (ppm)	0.06±0.00 ^{b}	0.05±0.00 ^{ab}	0.05±0.00 ^{ab}	0.04±0.00 ^{a}
Zinc (ppm)	0.17±0.01 ^{c}	0.15±0.00 ^{b}	0.12±0.01 ^{ab}	0.10±0.00 ^{a}

Mean values across each row with similar or same superscripts are not significantly different at $p > 0.05$, n=3 as a result of water stress which contributed to osmoregulation (Al-Suhaibani, 1996). Levitt (1972) also reported a marked increase in reducing sugars, non reducing sugars and total carbohydrates in sunflower leaves under water stress.

The concentration of minerals K, Ca, Mg, Na, Fe, Cu and Zn of tomatoes was observed to decrease with decreasing level of irrigation water from 100% ETc to 70% ETc. The highest mean mineral concentration in tomato fruit was obtained with 100% ETc irrigation treatment and the 70% ETc treatment had the least mineral concentration. The analysis of variance indicated that the different irrigation treatments had significant effects ($p<0.05$) on the concentrations of all the minerals (Ca, Mg, K, Na, Fe, Cu and Zn) in the tomato. Deficit irrigation affects the absorption of nutrient elements due to reduction in vegetative growth of plant (Pascale *et al*., 2001). Reduced irrigation affects the rate of transpiration in plant (Nakijima, 2004). The increase in mineral content of the fruit with increase in the amount of irrigation water may be attributed to the release of more mineral ions in solution as irrigation water increased which in turn increased the rate of absorption by the plant roots. Therefore a decrease in the amount of water in the soil would reduce the amount of minerals absorbed by the roots and hence reduce the mineral content of the fruits (Pascale *et al*., 2001)

Decarvolho and Savaria (2005) reported that water stress caused a decrease in calcium content of plants. According to Taylor *et al.* (2004), reduced irrigation increases evapotranspiration rate and hence reduces calcium uptake by tomato fruit resulting in the incidence of blossom end rot.

When plants are stressed to low internal water potential, uptake of nutrients usually decrease due to diminishing absorbing power of roots (Dunham and Nye, 1976). According to Nahar and Gretzmachar (2002), the uptake of magnesium by tomato plant was significantly reduced by water stress.

The result of this study is in agreement with Griffith *et al.* (1992) who reported that regulated deficit irrigated fruits contain less potassium than control fruits. According to Nahar and Gretzmachar (2002), the uptake of potassium by tomato plant was significantly reduced by water stress. Osuagwu and Edeoga (2012) also observed a significant decrease in potassium content in the leaves of *Gongrolema latifolium* with decreasing water application. A decrease in potassium concentration with water stress in *Dalbergonia sisso* leaf was also demonstrated by Singh and Singh (2004). They attributed it to translocation of potassium from leaf to stem of stressed seedlings.

In tomato, the ability of roots to exclude sodium from the rest of the plant decreased rapidly as the level of K in the nutrient solutions fell (Besford, 1978). The rate of transpiration can influence uptake and movement of some ions in plants (Weatherly, 1969). These findings confirm the decrease in sodium content of tomato fruits. In contrast, Abdel Rahman *et al.* (1971) reported that water stress generally favours the uptake of sodium in drought tolerant maize crops.

Iron uptake was significantly affected by the different irrigation treatments due to irrigation disruption at different stages of growth of chamomile plants (Pirzard *et al*., 2012). According to Oktem (2008) water stress reduces iron uptake in sweet corn.

According to Singh and Singh (2004) increasing water stress decreased the level of copper in leaf of *Dalbergonia sisso* due to a decrease in biomass accumulation and decrease in ion mobility as a result of increase in impedance in *Dalberon giasisso* seedlings.

The decrease in the concentration of zinc with water stress from this study was not in agreement with the findings of Pirzad *et al*. (2012) whose work showed that different water application had no significant effect on zinc uptake of German chamomile (*Matricaria chamomilla* L).

Effect of storage on nutritional composition of of tomato grown under different water treatments.

The effect of storage on the nutritional compositions of the deficit irrigated tomato plants are shown in Table 2.

The results showed a gradual decrease in the moisture contents of the tomato fruits across the storage period for all treatments. The changes in the moisture contents of the fruits during storage were relatively small. These decreases in the moisture contents of the tomato fruits from day 0 through to day 20, although small, for all the water treatments were significant ($p<0.05$). Analysis of variance indicated also that there were significant differences ($p<0.05$) in the moisture contents of the tomato fruits for the various treatments at each day of storage. These reductions in the moisture contents of the tomato fruits during storage may be due to respiration of the fruits leading to loss of water. As tomato ripens on storage, changes in colour and texture such as development of deep red colour and softening of the tissues affect its quality attributes as they affect tomato sensory quality and determine the end of the shelf life. When loss of water reaches a certain threshold, numerous changes occur such as decrease in turgidity and firmness, shriveling and decline in nutritional value (Nunes and Emond, 2007).

The ash content of the tomato fruits for all the treatments did not change appreciably during storage except treatment 70% ETc which showed a slight decrease at day 15 and 20 of storage. Analysis of variance indicated that there was no significant difference ($p>0.05$) in the ash content of the fruits from 100% ETc treatment. However, there were significant differences ($p<0.05$) in the ash contents of the fruits from treatments 90% ETc, 80% ETc and 70% ETc

The ash content of food substances is an indication of the mineral content of the food. Mineral contents of fruits do not change during storage except due to leakages from fruits (Hui, 2006)). The decrease in the ash content of the fruits at the later days of storage may due to leakages juice of the fruits as storage progressed.

The protein content of the tomato decreased gradually across the storage period for all water treatments. Analysis of variance indicated that the differences in the protein contents of the tomato across the storage period were significant ($p<0.05$). These changes in the protein content during storage may be attributed to the activities of cell wall enzymes such as α-galactosidase, β-galactosidase, β-mannosidase and β-glucosidase which are also responsible for the softening of the fruit (Emadeldin *et al*., 2012). There were no significant differences ($p>0.05$) in the protein content of the tomato on days 0 and 20 of storage for the various water treatments. However, there were significant differences ($p<0.05$) in the protein contents of the tomato on days 5, 10 and 15 of storage.

The fat content of the tomato decreased across the storage period for all water treatments. Analysis of variance indicated

Table 2: *Changes in the nutritional composition of tomato grown under the different water treatments during storage*

Parameters	Treatments	Storage periods				
		0	5	10	15	20
Moisture (%)	100% ETc	91.00±0.06^{a}	90.81±0.01^{a}	90.55±0.01^{a}	90.33±0.02^{b}	90.19±0.01^{b}
	90% ETc	89.65±0.01^{a}	89.61±0.02^{a}	89.51±0.01^{b}	89.41±0.01^{c}	89.27±0.02^{d}
	80% ETc	88.60±0.05^{a}	88.50±0.05^{b}	88.45±0.03^{c}	87.33±0.02^{c}	88.29±0.02^{d}
	70% ETc	88.02±0.10^{a}	87.90±0.10^{b}	87.86±0.03^{c}	87.64±0.08^{e}	87.58±0.13^{d}
Ash (%)	100% ETc	0.98±0.01^{a}	0.96±0.03^{a}	0.92±0.03^{a}	0.92±0.03^{a}	0.89±0.03^{a}
	90% ETc	0.78±0.02^{b}	0.77±0.01^{b}	0.77±0.01^{b}	0.74±0.01^{ab}	0.71±0.01^{a}
	80% ETc	0.69±0.01^{b}	0.68±0.02^{b}	0.59±0.02^{a}	0.59±0.02^{a}	0.57±0.02^{a}
	70% ETc	0.47±0.02^{b}	0.44±0.02^{b}	0.42±0.01^{b}	0.34±0.02^{a}	0.27±0.01^{a}
Protein (%)	100% ETc	1.83±0.01^{d}	1.70±0.03^{c}	1.65±0.03^{bc}	1.58±0.03^{b}	1.46±0.03^{a}
	90% ETc	1.82±0.02^{c}	1.80±0.03^{bc}	1.74±0.02^{b}	1.72±0.02^{b}	1.67±0.04^{a}
	80% ETc	1.80±0.02^{e}	1.74±0.03^{d}	1.65±0.03^{c}	1.53±0.05^{b}	1.46±0.04^{a}
	70% ETc	1.80±0.04^{c}	1.70±0.03^{c}	1.62±0.04^{b}	1.52±0.03^{ab}	1.45±0.03^{a}
Fat (%)	100% ETc	0.09±0.00^{d}	0.09±0.00^{d}	0.08±0.00^{c}	0.05±0.00^{b}	0.03±0.00^{a}
	90% ETc	0.10±0.00^{c}	0.09±0.00^{c}	0.06±0.00^{b}	0.06±0.00^{b}	0.05±0.00^{a}
	80% ETc	0.10±0.00^{c}	0.10±0.00^{c}	0.09±0.00^{b}	0.08±0.00^{a}	0.08±0.00^{a}
	70% ETc	0.15±0.00^{d}	0.11±0.00^{c}	0.10±0.00^{b}	0.10±0.00^{b}	0.09±0.00^{a}
Fibre (%)	100% ETc	0.42±0.03^{a}	0.80±0.03^{a}	1.20±0.07^{a}	1.60±0.09^{a}	2.00±0.08^{a}
	90% ETc	0.45±0.02^{a}	0.93±0.03^{a}	1.32±0.11^{a}	1.71±0.08^{a}	2.20±0.12^{a}
	80% ETc	0.51±0.02^{a}	0.98±0.03^{a}	1.42±0.10^{a}	1.92±0.07^{a}	2.50±0.05^{b}
	70% ETc	0.56±0.02^{a}	10.5±0.07^{a}	1.50±0.06^{a}	2.30±0.07^{a}	2.80±0.03^{a}
Carbohydrate (%)	100% ETc	5.72±0.04^{b}	5.64±0.02^{b}	5.60±0.02^{b}	5.52±0.03^{a}	5.43±0.03^{a}
	90% ETc	7.20±0.03^{c}	6.80±0.04^{bc}	6.60±0.02^{c}	6.30±0.07^{a}	6.10±0.07^{a}
	80% ETc	8.30±0.14^{c}	8.00±0.12^{b}	7.80±0.09^{b}	7.55±0.10^{b}	7.10±0.13^{a}
	70% ETc	9.00±0.16^{d}	8.70±0.06^{c}	8.50±0.06^{b}	8.10±0.12^{a}	7.81±0.08^{a}
Calcium (Ppm)	100% ETc	0.009±0.00^{a}	0.009±0.00^{a}	0.009±0.00^{a}	0.008±0.00^{a}	0.007±0.00^{a}
	90% ETc	0.009±0.00^{a}	0.009±0.00^{a}	0.009±0.00^{a}	0.008±0.00^{a}	0.007±0.00^{a}
	80% ETc	0.006±0.00^{a}	0.006±0.00^{a}	0.006±0.00^{a}	0.005±0.00^{a}	0.005±0.00^{a}
	70% ETc	0.003±0.00^{a}	0.003±0.00^{a}	0.003±0.00^{a}	0.003±0.00^{a}	0.003±0.00^{a}
Magnesium (Ppm)	100% ETc	0.002 ±0.00^{a}	0.002 ±0.00^{a}	0.002 ±0.00^{a}	0.002 ±0.00^{a}	0.002 ±0.00^{a}
	90% ETc	0.002 ±0.00^{a}	0.002 ±0.00^{a}	0.002 ±0.00^{a}	0.002 ±0.00^{a}	0.002 ±0.00^{a}
	80% ETc	0.001 ±0.00^{a}	0.001 ±0.00^{a}	0.001 ±0.00^{a}	0.001 ±0.00^{a}	0.001 ±0.00^{a}
	70% ETc	0.001 ±0.00^{a}	0.001 ±0.00^{a}	0.001 ±0.00^{a}	0.001 ±0.00^{a}	0.001 ±0.00^{a}
Sodium (Ppm)	100% ETc	26.34±0.10^{a}	26.34±0.11^{a}	26.33±0.12^{a}	26.10±0.06^{a}	26.00±0.02^{a}
	90% ETc	24.11±0.06^{b}	24.11±0.05^{b}	24.11±0.06^{b}	24.00±0.02^{ab}	23.62±0.21^{a}
	80% ETc	23.53±0.02^{a}	23.52±0.05^{a}	23.54±0.10^{a}	23.50±0.15^{a}	23.42±0.19^{a}
	70% ETc	23.22±0.10^{a}	23.22±0.10^{a}	23.22±0.10^{a}	23.21±0.06^{a}	23.21±0.08^{a}
Potassium (Ppm)	100% ETc	46.25±0.12^{c}	46.01±0.08^{bc}	45.86±0.03^{b}	45.80±0.03^{b}	44.21±0.10^{a}
	90% ETc	43.48±0.12^{b}	43.39±0.07^{ab}	43.41±0.04^{a}	43.38±0.07^{ab}	43.00±0.11^{a}
	80% ETc	42.32±0.05^{b}	42.30±0.02^{b}	42.31±0.02^{b}	42.02±0.05^{a}	41.88±0.07^{a}
	70% ETc	42.25±0.06^{b}	42.20±0.08^{b}	42.24±0.15^{b}	42.00±0.16^{b}	40.86±0.31^{a}
Iron (Ppm)	100% ETc	0.54 ±0.01^{a}	0.53 ±0.01^{a}	0.53 ±0.02^{a}	0.53 ±0.01^{a}	0.50 ±0.01^{a}
	90% ETc	0.49 ±0.02^{a}	0.48 ±0.01^{a}	0.48 ±0.02^{a}	0.47 ±0.01^{a}	0.44 ±0.01^{a}
	80% ETc	0.48 ±0.00^{b}	0.47 ±0.00^{b}	0.47 ±0.00^{b}	0.47 ±0.00^{b}	0.44 ±0.01^{a}
	70% ETc	0.30 ±0.02^{a}	0.30 ±0.02^{a}	0.30 ±0.01^{a}	0.30 ±0.00^{a}	0.27 ±0.00^{a}
Copper (Ppm)	100% ETc	0.06±0.00^{a}	0.06±0.00^{a}	0.05±0.00^{a}	0.05±0.00^{a}	0.05±0.00^{a}
	90% ETc	0.05±0.00^{a}	0.05±0.00^{a}	0.05±0.00^{a}	0.05±0.00^{a}	0.05±0.00^{a}
	80% ETc	0.05±0.00^{a}	0.05±0.00^{a}	0.05±0.00^{a}	0.04±0.00^{a}	0.04±0.00^{a}
	70% ETc	0.04±0.00^{a}	0.04±0.00^{a}	0.04±0.00^{a}	0.04±0.00^{a}	0.04±0.00^{a}
Zinc (Ppm)	100% ETc	0.17±0.01^{b}	0.17±0.01^{b}	0.17±0.01^{b}	0.16±0.00^{ab}	0.14±0.00^{a}
	90% ETc	0.15±0.00^{b}	0.15±0.00^{b}	0.14±0.00^{ab}	0.13±0.003^{ab}	0.12±0.01^{a}
	80% ETc	0.12±0.01^{a}	0.12±0.01^{a}	0.12±0.00^{a}	0.12±0.01^{a}	0.11±0.01^{a}
	70% ETc	0.10±0.00^{a}	0.10±0.00^{a}	0.10±0.00^{a}	0.10±0.00^{a}	0.10±0.00^{a}

Mean values across each row with similar or same superscripts are not significantly different at $p > 0.05$, $n=3$

that the differences in the fat contents of the tomato across the storage period were significant ($p<0.05$). The differences in the fat content of the tomato from day 0 to day 20 for all the treatments were significant.

The fibre content of the tomato increased gradually across the storage period for all water treatments. Analysis of variance indicated that the differences in the fiber contents of the tomato across the storage period were significant ($p<0.05$).

The results showed a gradual decrease in the carbohydrate contents of the tomato fruits across the storage period for all treatments. The changes in the carbohydrate contents of the fruits during storage were relatively small. These decreases in the carbohydrate contents of the tomato fruits from day 0 through to day 20, although small, for all the water treatments were significant ($p<0.05$). Analysis of variance indicated also that there were significant differences ($p<0.05$) in the carbohydrate contents of the tomato fruits for the various treatments at each day of storage. These reductions in the carbohydrate contents of the tomato fruits during storage may be due to respiration of the fruits since carbohydrates are substrate of respiration.

In general, there were no changes in the minerals contents of the tomato fruits for all the water treatments from day 0 to days 10 and 15 across the storage. However, the minerals contents of the tomato fruits decreased slightly at day 20. These decreases were, however, not significant ($p>0.05$). The decreases may be due to the fact minerals are not metabolized and therefore do not undergo any major change during storage of fruits except due to leakages as a result of rotting (Hui, 2006). There were, however, significant differences ($p<0.05$) in the minerals contents for the various water treatments at various days of storage.

Conclusions

Based on the results obtained from this study, it can be concluded that deficit irrigation has both positive and negative effects on the nutritional and mineral compositions of the Pectomech variety of tomato.

Deficit irrigation caused increases in fat, fibre and carbohydrate contents of the tomato fruits. However, decreases in moisture, ash, protein, calcium, magnesium, potassium, sodium, iron, copper and zinc contents of the tomato fruits with decreasing water applications were recorded. There were significant differences ($p<0.05$) in the moisture, ash, fat, fiber, carbohydrate and all the mineral (Ca, Mg, K, Na, Fe, Cu and Zn) contents of the tomato for the various water treatments. However, the differences in the protein contents of the tomato fruits were not significant.

Considering the percentage increases and decreases obtained for nutritional compositions of the tomatoes in this study, it can be concluded that a 10-20% reduction in the amount or volume of water applied in the cultivation of the Pectomech tomato variety in the coastal savannah zone of Ghana would produce tomato with optimum quality that would compensate for yield losses.

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