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Growth components, fruits nutritional and phytochemical compositions of tomato as influenced by variations in planting depths

Componentes de crescimento, composição nutricional e fitoquímica dos frutos do tomateiro influenciados por variações na profundidade de plantio

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Resumo:

A distribuição incoerente dos nutrientes do solo afeta o cultivo das culturas. Portanto, foram avaliados os efeitos das profundidades de plantio sobre o desempenho vegetativo e as composições bioquímicas dos frutos de tomateiro. As sementes de tomate foram plantadas a 2, 4, 6 e 8 cm em Delineamento em blocos casualizados com quatro repetições. Foram determinados o desempenho vegetativo, o conteúdo nutricional e as composições fitoquímicas dos frutos do tomate. Os dias mínimos de emergência (4 dias), a altura mais elevada (71,00 cm), o número de folhas (31,30), a folha (34,00 m2) e o índice de área foliar (0,80 m2/m2) foram mais elevados nos tomateiros produzidos por sementes plantadas a 4 cm. A taxa líquida de assimilação (0,08 gm-2 dia-1) e a razão de área foliar (0,70 m2kg-1) foram maiores no tomate plantado a 4 cm de profundidade. A fibra bruta (0,14%), a proteína bruta (0,62%) e a gordura (0,17%) foram também mais elevadas nos frutos de tomate plantados a 4 cm. Além disso, vitamina A (0,65 mg/100g), vitamina C (23,80 mg/100g), potássio (17,93%), ferro (5,80%) e magnésio (1,15%) foram maiores nos frutos de tomate produzidos por sementes plantadas a 4 cm seguidas de 6. Observação semelhante foi observada em composições fitoquímicas. 4 a 6 cm melhoraram o desempenho vegetativo, as composições nutricionais e fitoquímicas dos frutos do tomate, pelo que recomenda-se o cultivo de tomate entre 4 e 6 cm

Palavras-chave: Assimilação líquida; conteúdo nutricional; metabolitos secundários; taxa de crescimento relativo; crescimento vegetativo.

Abstract:

Inconsistent distribution of soil nutrients affects cultivation of crops. Therefore, effects of planting depths on vegetative performance and biochemical composition of tomato fruits were assessed. Seeds of tomato were planted at 2, 4, 6 and 8 cm in a randomized complete block design with four replicates. Vegetative performance, nutritional contents and phytochemical compositions of fruits of the tomato were determined. Least days of emergence (4 days), highest height (71.00 cm), number of leaf (31.30), leaf (34.00 m^2) and leaf area index (0.80m^2/m^2) were higher in tomato plants produced by seeds planted at 4 cm. Net assimilation rate (0.08 gm^{-2} day^{-1}) and leaf area ratio (0.70 m^2kg^{-1}) were higher in tomato planted at 4 cm depth. Crude fibre (0.14%), crude protein (0.62%) and fat (0.17%) were also higher in fruits of tomato planted at 4cm. Also, vitamin A (0.65 mg/100g), Vitamin C (23.80 mg/100g), potassium (17.93%), iron (5.80%) and magnesium (1.15%) were higher in tomato fruits produced by seeds planted at 4cm followed by 6. Similar observation was noticed in phytochemical compositions.4 to 6 cm improved vegetative performance, nutritional and phytochemical compositions of tomatoes fruits, therefore cultivation of tomato between 4 and 6 cm is recommended.

Keywords: Net assimilation**;** nutritional contents; secondary metabolites**;** relative growth rate**;** vegetative growth.

1. Introduction

Depth at which seeds are planted can influence physiological processes of seeds such as water imbibition, germination, access to soil nutrients or nutrient absorption rate and radicle and plumule emergence as well as their ability to photosynthesize. It is one of the farming practices that determine yield and quality of crops (ADEYEMI et al., 2017). Based on high consumption of vegetables as common foods, there is need for improving cultivation of vegetables in other to improve diet of people. This is because vegetables contain metabolites of medicinal and nutritional values, making them suitable food and drugs (ADEYEMI et al., 2017). Typical example of such vegetables is tomato (*Solanum lycopersicum L.)*. Tomato belongs to Solanaceae family. It is cultivated for home consumption, processing and export for income generation (F. A.O, 2008).

Despite the relevance of the tomato, there is low production of the vegetable due to various ecological processes such as nutrient leaching, percolation, run off, low nutrient absorption, unequal distribution of nutrients in the soil and planting practice (BIRARA et al., 2016). According to Esteban and Robert (2001), crops including tomatoes often accumulate organic matter beneath their canopies which enhance nutrient pools. These horizontal patterns demonstrate an imprint of spatial distribution of nutrients horizontally. The mechanisms that shape vertical distribution of soil nutrients are influenced by weathering and biological cycling (TRUDGILL, 1988). Leaching and biological cycling also influence vertical transport of nutrients in opposite directions, move nutrients downward and increase nutrient concentrations in depth if acted in isolation (STARK, 1994). In contrast, biological cycling generally moves nutrients upwards because proportion of the nutrients absorbed by plants are transported aboveground and then recycled to the soil surface by litter-fall (STARK,1994). The amount of water that leaches in the soil decreases with depth due to root water uptake causing a peak in nutrient concentrations with maximum rooting depth of plants (STARK,1994). This information therefore underlines the fact that nutrient in the soil is distributed unevenly at different soil levels and that there is an actual depth in which seeds can thrive better.

Many crops including tomatoes produced low yield not necessarily because the soil is nutritionally poor but because the nutrients are not found in the rhizosphere of their roots (WILLIAM et al., 2015). WILLIAM et al. (2015) revealed that sowing tomato seeds too deep may damage radicle and plumule during emergence while insects and high evaporation affected seeds sowed at shallow soil level. Majority of tomato farmers do not take into consideration planting depth before sowing seeds. This usually results into reduced germination, seedling emergence and development of seedling (BIRARA et al., 2016).

In addition, root systems of plants determine access of the plants to soil nutrients and level of nutrient absorption. Tomato has fibrous roots hence the roots may not be able to access deeply leeched nutrients thereby reducing agronomic performance and possibly the nutritional contents of tomato fruits (ESTEBAN; ROBERT 2001). Previous studies on this focus did not consider variations in the soil nutritional contents as affected by sowing depths and their influence on growth components, nutritional and medicinal compositions of fruits of vegetables (BIRARA et al., 2016). The present study therefore characterized the vertical distribution of soil nutrients and evaluated influence of planting depth on growth performance, nutritional and medicinal compositions of tomato fruits.

2. Material and Methods

2.1 *Study Site: This* study was conducted at the open field of botanical garden, Lagos State University, Ojo, Lagos state, Nigeria. The garden lies between latitude 6.4624 to N 6^0 27'58.446'' and longitude 3.19897 to E $3^0$11'56.304.

2.2 Source of Seeds**:**

Tomato **(***Solanum lycopersicum L.*) seeds commonly planted in Abeokuta were collected from a tomato farmer at a farmland located besides Federal Ministry of Agriculture and Rural Development, Kotopo, Abeokuta, Ogun State. The farm lies at latitude 7.18457, **N 7** ^{0}11'4.494 and longitude 3.42816, E 3^0 25'41.31, 5CMH +W3F, Kotopo, 110121, Abeokuta, Ogun State, Nigeria.

2.3 Land preparation and experimental details:

A 120 X 60 m^2 land area was cleared manually and demarcated into four blocks. Each block was subdivided into sub block of four (4) beds of 120 X 60 cm dimension. The experiment was laid using randomized complete block design (RCBD).

2.4 *Soil analysis*:

Procedures of National Soil Characterization Database of the United States Department of Agriculture (USDA ,1994) described by VIJAY et al., (2019) were adopted to determine exchangeable elements (K^+, Ca^{2+}, Mg 2^+, and Na^+) in 300 g of soil samples collected at 2, 4, 6 and 8-cmsoil depth on each bed using soil probe. Soil probe was inserted vertically into the soil and soil core was removed. The soil samples were labeled, air dried and sieved through 2 mm sieve for soil analysis.

2.5 *Planting depth:*

On each bed 2, 4, 6- and 8-cm holes of 3 cm width were dug and four tomato seeds were planted at each depth and covered with soil. Three weeks after emergence, the seedlings were thinned to one seedling per hole (depth). The beds were watered twice daily, and the study was monitored for days of seed emergence, height, number of leaves, number of days before flowering, number of fruits per plants and fresh weight of shoot (KADIRI et al, 2016).

2.6 *Determination of growth components*

(i) The total leaf area was determined using electronic leaf area meter while specific leaf area (SLA) and leaf area index (LAI) were computed following procedure of ALIREZA et al. (2012).

$$Specific\ leaf\ area\ (SLA) = \frac{Leaf\ area\ (LA)}{Corresponding\ weight\ of\ leal\ (WL)}$$

Leaf area Index was computed with the values of SLA and area of litter-fall.

$$LAI = \frac{Leaf\ area (LA)}{Area\ of\ litter\ fall}$$

(ii) Relative growth rate (RGR), leaf area ratio (LAR)and assimilation rate (NGR) were calculated using the method of AGBOOLA, (1996).

RGR was calculated from the measured values of dry weight of plants ($W_1$and W_2) at timet1andt$_2$usingthe mathematical relationship given below.

$$RGR = \frac{LogeW2 - LogeW1}{t2 - t1}$$

W_1= first measured weight (g)
W_2= second measured weight (g)
t_1= initial time (weeks)
t_2= final or second time (weeks)

2.7 Net Assimilation Rate (NAR): The NAR was calculated from the measured values of leaf area ($A_1$and A_2), dry weight of plants ($W_1$and W_2) and time (t1 and t2) using the relationship shown below.

$$NAR = \frac{W3 - W1}{A2 - A1} . \frac{LogeA2 - Loge\ A1}{t2 - t1}$$

A_1= Area of leaf at t_1
A_2= Area of leaf at t_2
W_1= first time measured weight (g)
W_2= second time measured weight (g)
t_1= initial time (weeks)
t_2= final or second time (weeks)

The LAR was also calculated from the measured values of leaf area ($A_1$and A_2), dry; weight of plants ($W_1$and W_2) and time ($t_1$and t_2) using the relationship below.

$$Leaf\ Area\ Ratio = \frac{W3 - W1}{t2 - t1} . \frac{LogeA2 - Loge\ A1}{W2 - W1}$$

2.8 *Determination of nutritional contents of tomato fruits*

Tomatofruitsweredriedandgroundintopowderanddigestedforlaboratory analysis

Proximate contents in the sample were determined according to A. O. A. C. (2000).

(i) Ash content was determined using the following formula stated in OJEWUMI et al. (2021)

(ii) Crude fat was determined following the procedure of A. O. A. C. (2000) using the following formula:

$$Ash\ (\%) = \frac{Weight\ of\ ash - W1}{Weight\ of\ sample} x\ 100$$

Crude fat was determined following the procedure of A.O.A.C. (2000) using the following formula:

$$Crude\ fat\ (\%) = \frac{Weight\ of\ flask\ with\ fat - Weight\ of\ empty\ flask}{Weight\ of\ original\ sample} x\ 100$$

(iii) Moisture was calculated using the following formula:

$$Moisture = \frac{Weight\ of\ sample\ before\ drying - Weight\ of\ sample\ after\ drying}{Weight\ of\ sample\ before\ drying} x\ 100$$

(iv) The crude fiber was determined according to A.O.A.C. (2000) using the following formula:

$$Crude\ fiber = \frac{Weight\ of\ spoutless\ beaker \quad containing\ crude\ fibre - Weight\ of\ spoutless\ beaker \quad and\ crude\ fibre}{Weight\ of\ sample} x$$

(v) Total carbohydrate, total N contents were estimated using the procedure of A.O.A.C. (1980) using the following formula:

Total carbohydrate = 100 - (% moisture + % Ash + % fat + % Protein + % Fibre) A.O.A.C. (1980).

Total nitrogen (N) content: total N content was estimated using the Micro Kjeldahl method cited in A.O.A.C, (1980).

Protein (5) was estimated using the following formula:

$$\Pr o\,tein\,(\%) = \frac{V \times 1.4\,x\,6.25\,x\,0{,}1N\ HCL\ x\ Vol\,(used)}{W \times A \times 1000} x100$$

V = Titter value. 1.4-weight of N expressed in gram in the formula.
6.25 = Protein factor.
W = Weight of sample
. A -Aliquot digested sample used for distillation

2.9 *Contents of mineral, vitamins, and phytochemicals in tomato fruits*:

Mineral elements (calcium, potassium, magnesium, zinc, iron, copper, phosphorus, and sodium) in the digested samples of the tomato fruits were determined using Atomic Absorption Spectrophotometer (Perkin-Elmer Model 2280). Moreover, in each digested sample, vitamin A was measured using Spectrophotometer (Metrohm Spectron 21D Model) at a wavelength of 328nm following the procedure of A. O.A.C, (2000). Vitamin B3 (Niacin) was determined following the methods of HARBORNE, (1973). Vitamin C was measured at 760 nm using atomic absorption Spectrophotometer while Vitamin E was determined using spectrophotometer (A. O.A.C, 2000).

Phytochemicals (alkaloids flavonoids, saponins, steroids, tannin, phenol) in the samples of tomato fruits were determined in percentage while lycopene, carotenoid were determined using following the methods of HARBORNE, (1973), as follows.

(i) $Alkaloids\,(\%) = \%N \times 3.26$

(ii) $Flavonoids\,(\%) = \frac{Absorbance\ of\ sample \times average\ gradient\ factor \times dilution\ factor}{Weight\ of\ sample \times 10000}$

(iii) $Saponin\,(\%) = \frac{Absorbance\ of\ sample \times average\ gradient\ factor \times dilution\ factor}{Weight\ of\ sample \times 10000}$

(iv) $Steroids\,(\%) = \frac{Absorbance\ of\ sample \times average\ gradient\ factor \times dilution\ factor}{Weight\ of\ sample \times 10000}$

(v) $Tannin\,(\%) = \frac{Absorbance\ of\ sample \times average\ gradient\ factor \times dilution\ factor}{Weight\ of\ sample \times 10{,}0000}$

(vi) $Phenol\,(\%) = \frac{Absorbance\ of\ sample \times average\ gradient\ factor \times dilution\ factor}{Weight\ of\ sample \times 10{,}0000}$

2.9.1. *Data Analysis:*

Statistical analysis system, version 9.4 (SAS, 2013) package was used for the analysis of one-way Analysis of Variance and significance of difference between means using Duncan's Multiple Range test at $p < 0.05$.

3. Results and Discussion

3.1 *Soil mineral elements*

Figure 1 revealed significant ($p<0.05$) variations in the quantities of soil mineral elements across the depths. Magnesium and sodium were higher in soil collected at 4 cm compared with other depths; however, calcium was recorded at 6 cm.

3.2 Seeds emergence and morphological characters:

Tomato seeds planted at 2 cm emerged 4 days earlier compared with seeds of the tomatoes grown at other deeper depths (Figure 2). Also, heights (71.0 cm) of tomato planted at 4 cm were significantly higher than height of the plant planted under other depths investigated (WAP) (Figure 3). In addition, tomato plants produced by tomato seeds planted at 4 and 6 cm flowered 32 and 38 days earlier respectively while those planted in deeper soil depth flowered late (Figure, 4). Higher number of fruits (21 fruits) were recorded in tomatoes produced by the seeds planted at4cm followed by at 6 cm (15 fruits) (Figure5). Number of leaves (31.30) of tomato plants produced from seeds plantedat4cm depth was significantly higher compared with other depths at 10 WAP (Table 1).

Figure1: Concentration of soil mineral elements at four different soil depths.

Figura 1. Concentração de elementos minerais do solo em quatro profundidades diferentes.

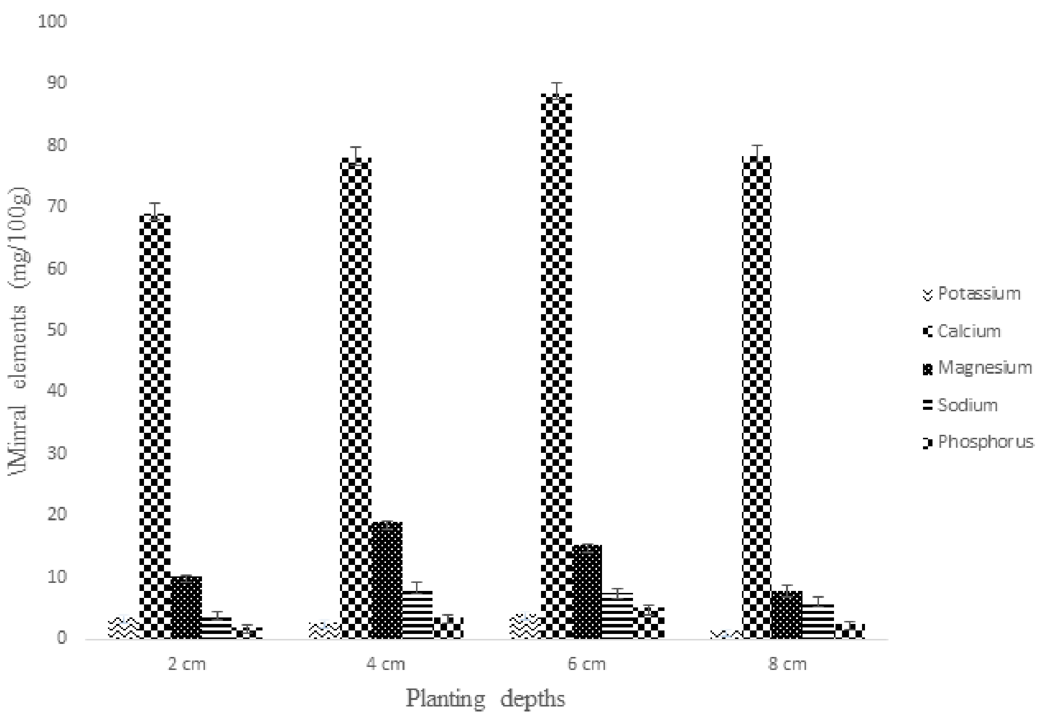

Figure2. Days taken for germination of tomato seeds sown at four different depths.

Figura 2. Dias de germinação das sementes de tomate semeadas em quatro profundidades diferentes.

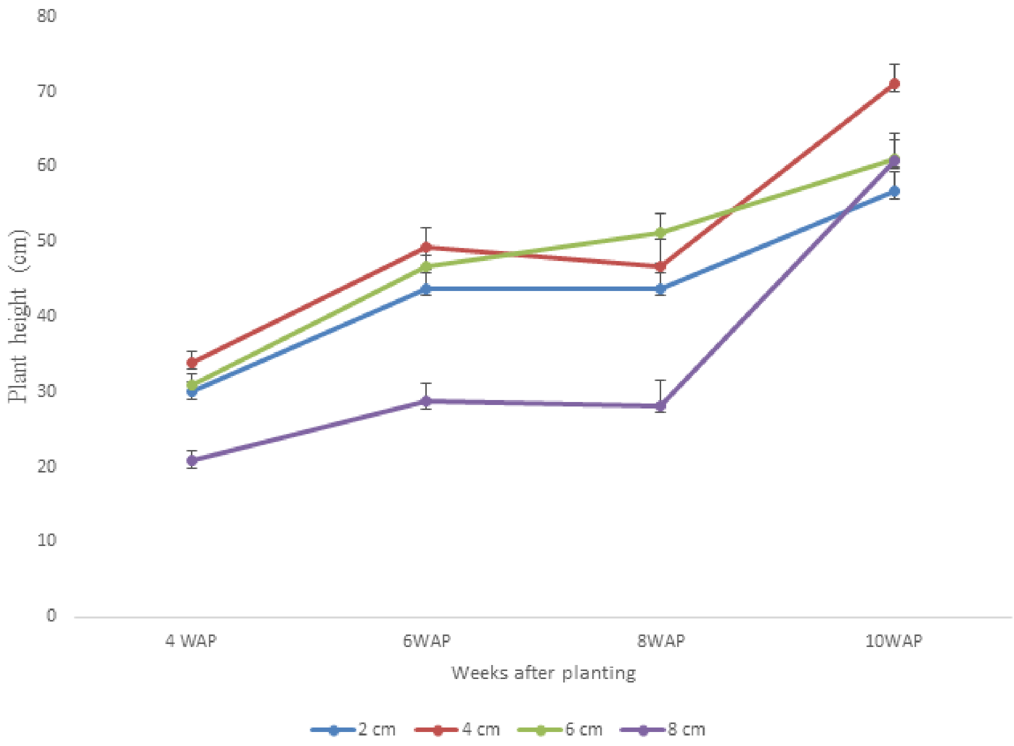

Figure 3. Effects of planting depths on height of tomato seedlings at different weeks.

Figura 3. Efeitos das profundidades de plantação na altura das plântulas de tomate em semanas diferentes.

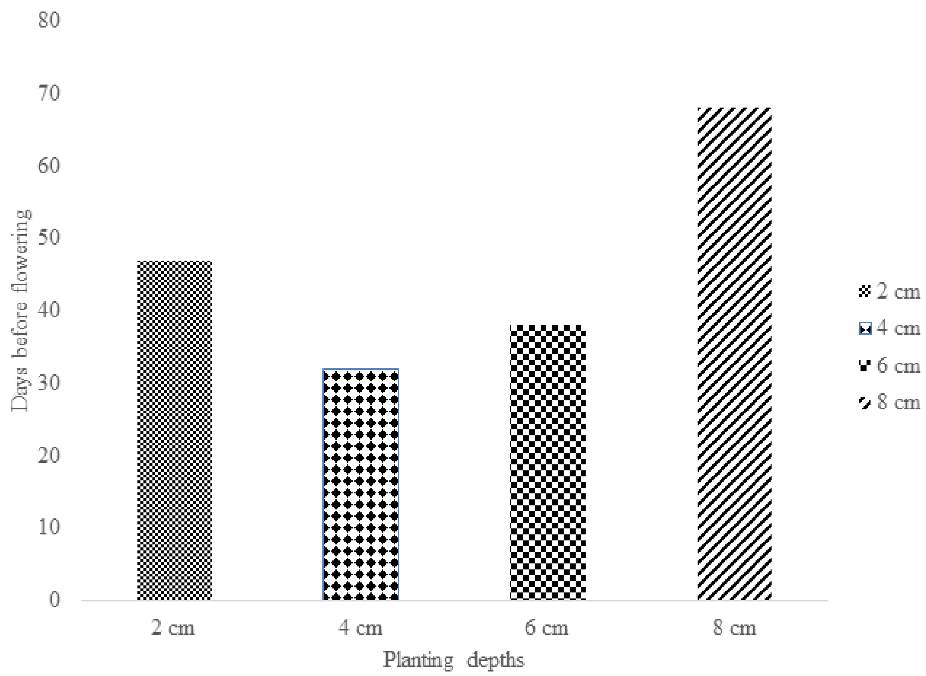

Figure 4. Effects of planting depth on days of flowering of tomato plants.

Figura 4. efeitos da profundidade de plantação nos dias de floração dos tomateiros.

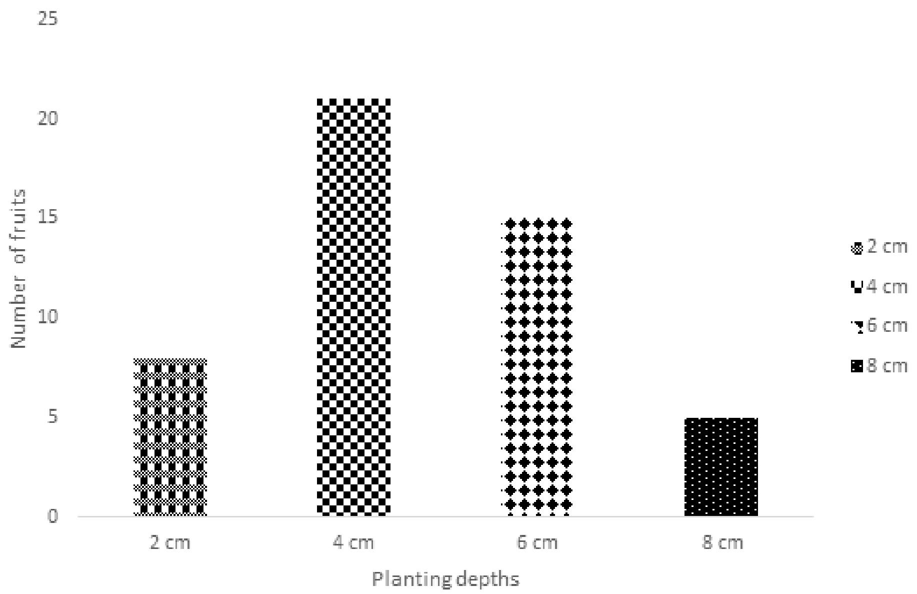

Figure 5. Effects of planting depth on number of fruits of tomato plants at 10 WAP.

Figura 5. Efeitos da profundidade de plantação no número de frutos de tomateiros a 10 pa.

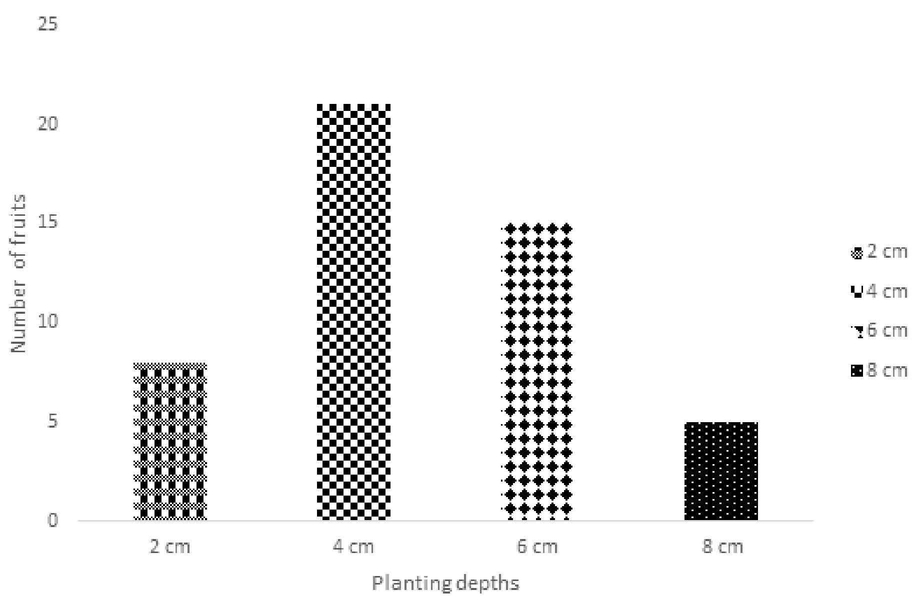

Table 1. Effects of planting depth on number of leaves of tomato plants.

Tabela 1. Efeitos da profundidade de plantação no número de folhas de tomateiros.

Depths (cm)	4WAP	6WAP	8WAP	10WAP
2	11.00±0.70[a]	17.30±1.30[a]	19.50±3.70[b]	26.00±37.50[ab]
4	10.30±0.90[a]	20.30±7.30[a]	28.25±5.20[a]	31.30±6.500[a]
6	12.00±0.70[a]	19.00±3.30[a]	21.00±6.00[b]	19.00±0.00[b]
8k	7.00±4.00[a]	18.50±7.50[a]	21.50±4.50[b]	20.00±68.90[b]

Means with different superscripts within columns are significantly different according to Duncan's Multiple Range Test (DMRT) at p<0.05.

3.3 *Growth components*:

At 8WAP, higher LA (30.30±6.90 $m^2.kg^{-1}$) and LAI (0.60±0.10 m^2/m^2) were recorded in tomato plants produced from seeds plantedat4 cm depth**.** Similar significant increase was observed in SLA of the plants at4cm (5.40±0.90$m^2.kg^{-1}$) and 6 cm (4.90±1.00 $m^2.kg^{-1}$) depth. Observation on the parameters at 10WAP revealed that both LA (34.00±6.70 m^2) and SLA (6.90±1.20 $m^2.kg^{-1}$) were significantly higher in tomato plants produced from seeds plantedat4 cm depth**.** This observation is consistent in LAI values at 4 cm **(**0.80±0.10 m^2/m^2) and 6 cm (0.70±0.10 m^2/m^2) compared with 2 and 8 cm (Table 2). Further, tomato plants from seed planted at 4 cm depth had higher RGR (0.5 mgg^{-1} day^{-1}), NAR (0.08 $gm^{-2}day^{-1}$) and LAR(0.70m^2kg-1) (Table3).

Table 2**.** Effect of planting depth on leaf area, specific leaf area and leaf area index of tomatoes.

Tabela 2**.** Efeito da profundidade de plantação na área foliar, na área foliar específica e no índice de área foliar do tomate.

Depth (cm)	8WAP			10WAP		
	LA(m^2)	SLA ($m^2.kg^{-1}$)	LAI(m^2/m^2)	LA(m^2)	SLA ($m^2.kg^{-1}$)	LAI(m^2/m^2)
2	14.60±1.20[bc]	03.90±0.50[b]	0.22±0.00[b]	9.50±1.90[b]	2.30±0.30[b]	0.20±0.00[c]
4	30.30±6.90[a]	5.40±0.90[a]	0.60±0.10[a]	34.00±6.70[a]	6.90±1.20[a]	0.80±0.10[a]
6	26.30±4.30[ab]	4.90±1.00[a]	0.30±0.00[b]	16.60±4.40[b]	5.40±0.40[b]	0.70±0.10[a]
8	12.20±0.80[c]	1.40±0.80[b]	0.20±0.00[b]	8.60±2.30[b]	3.90±2.30[b]	0.20±0.40[b]

Means with different superscripts within columns are significantly different according to Duncan's Multiple Range Test (DMRT) at p<0.05; LA= Leaf Area, SLA = Specific Leaf Area, LAI= Leaf Area Index

Table 3. Effects of planting depths on relative growth rate, net assimilation rate and leaf area ratio of tomato.

Tabela 3**.** Efeitos da profundidade de plantio sobre a taxa de crescimento relativo, taxa assimilatória líquida e razão de área foliar do tomateiro.

Depths (cm)	(RGR (mgg^{-1} day^{-11})	NAR (gm^{-2} day^{-1})	LAR (m^2kg-1)
2	0.10±0.00[c]	0.20±0.10[b]	0.50±0.20[b]
4	0.50±0.01[a]	0.80±0.01[a]	0.70±0.10[a]
6	0.20±0.00[b]	0.30±0.10[b]	0.50±0.10[b]
8	0.10±0.00[c]	0.20±0.10[b]	0.10±0.10[b]

Means with different superscripts within columns are significantly different according to Duncan's Multiple Range Test (DMRT) at p<0.05. RGR=relative growth rate, NAR=Net assimilation rate, LAR=leaf area ratio.

3.4 *Nutritional contents*:

Crude fibre (0.14 %), fat (0.17 %), ash (0.11 %), crude protein (0.62 %) were significantly higher in tomato fruits produced from seedsplantedat4cm depth followed by 6 cm while Carbohydrate (33.1±0.07%) and Moisture (66.5±0.37%) were higher in tomato fruits produced from seedsplantedat2cm depth (Table4). Furthermore, vitamin A (0.65±0.07 mg/100g), vitamin D (0.08±0.01 mg/100g), vitamin E (0.40±0.29 mg/100g) and vitamin K (0.77±0.00 mg/100g) were significantly higher ($p<0.05$) in the tomato fruits produced by seeds planted at 4 cm depth compared with other depths whose effects were investigated. In addition, higher Vitamin C was observed in tomato fruits produced by seeds planted at 4 (23.80±0.06 mg/100g) and 6 cm (22.11±1.39 mg/100g) (Table 5).

Potassium (17.93±0.49 mg/100g), Phosphorus (11.72±0.34 mg/100g),Iron (5.80±0.04 mg/100g), magnesium (1.15±0.06 mg/100g) and copper (0.92±0.38 mg/100g) were significantly higher in the fruits produced by tomato planted at 4 cm depth unrelation to 2, 6 and 8cm. Calcium was also higher in the fruits of the tomato produced by tomato seeds planted at 4cn(6.95±0.02mg/100g) and 6cm(6.12±0.70mg/100g) depth. Similar observation was obtained for Zinc at 4 and 6 cm while the depths produced no significant deference ($p<0.05$) on quantity sodium (Table 6).

Table 4. Effects of planting depths on concentrations of proximate in tomato fruits.
Tabela 4. Efeitos da lâmina de plantio sobre as concentrações de centesimal em frutos de tomateiro.

Depth (cm)	Proximate contents (%)					
	Crude fibre	Fat	Ash	Carbohydrate	Moisture	Crude protein
2	0.040±0.01^{d}	0.04±0.01^{c}	0.05±0.01^{bc}	33.1±0.07^{a}	66.5±0.37^{a}	0.43±0.01^{c}
4	0.14±0.01^{a}	0.17±0.01^{a}	0.11±0.01^{a}	32.9±0.13^{b}	68.5±0.37^{b}	0.62±0.01^{a}
6	0.11±0.01^{b}	0.15±0.01^{b}	0.07±0.01^{b}	33.1±0.11^{ab}	66.0±0.04^{a}	0.52±0.01^{b}
8	0.07±0.01^{c}	0.03±0.01^{c}	0.04±0.01^{c}	33.1±0.09 ^{ab}	65.9±0.39^{a}	0.40±0.01^{d}

Means with different superscripts within columns are significantly different according to Duncan's Multiple Range Test (DMRT) at $p<0.05$.

Table 5. Effect of planting depths on concentrations of vitamins in tomato fruits.
Tabela 5. Efeito da lâmina de plantio sobre as concentrações de vitaminas em frutos de tomate.

Depths (cm)	Vitamins (mg/100g)				
	vitamin A	Vitamin C	vitamin D	vitamin E	vitamin K
2	0.57± 0.03^{ab}	13.60±0.06^{b}	0.04±0.01^{c}	0.16±0.00^{b}	0.19±0.01^{c}
4	0.65±0.07^{a}	23.80±0.06^{a}	0.08±0.01^{a}	0.40±0.29^{a}	0.77±0.00^{a}
6	0.57±0.12^{ab}	22.11±1.39^{a}	0.06±0.01^{b}	0.17±0.01^{b}	0.47±0.00^{b}
8	0.48±0.03^{b}	10.44±0.06^{c}	0.05±0.00^{c}	0.12±0.01^{c}	0.06±0.01^{d}

Means with different superscripts within columns are significantly different according to; Duncan's Multiple Range Test (DMRT) at $p<0.05$.

Table 6. Effects of planting depths on quantities of mineral elements in tomato fruits.
Tabela 6. Efeito da lâmina de plantio sobre as concentrações de vitaminas em frutos de tomate.

Depths (cm)	Minerals (mg/100g)							
	Sodium	Potassium	Calcium	Phosphorus	Iron	Zinc	Magnesium	Copper
2	6.86±0.83^{a}	15.76±0.29^{b}	4.59±0.04^{b}	9.21±0.34^{c}	0.31±0.45^{d}	0.13±0.03^{d}	0.18±0.01^{c}	0.11±0.01^{b}
4	7.21±0.01^{a}	17.93±0.49^{a}	6.95±0.02^{a}	11.72±0.34^{a}	5.80±0.04^{a}	5.71±0.54^{a}	1.15±0.06^{a}	0.92±0.38^{a}
6	7.78±0.01^{a}	16.41±0.21^{ab}	6.12±0.70^{a}	10.47±0.24^{b}	3.06±0.39^{b}	5.50±0.55^{a}	1.02±0.36^{ab}	0.20±0.35^{b}
8	5.24k±0.63^{b}	5.24±0.63^{b}	4.50±0.35^{b}	7.61±0.05^{d}	1.38±0.16^{c}	1.45±0.68^{b}	0.66±0.23^{b}	0.16±0.01^{b}

Means with different superscripts within columns are significantly different according to Duncan's Multiple Range Test (DMRT) at $p<0.05$.

3.5 *Phytochemical contents*

Alkaloids (2.84 %), flavonoid (2.84 %), saponins (2.06 %) and tannins (1.46%), lycopenes (5.17 mg/100g) and carotenoid (3.24 mg/100g) were significantly higher in the fruits produced by tomato planted at 4 cm depth followed by 6cm while least of the parameters were observed in the fruits produced by tomato planted at 6 cm (Table 7)

Table 7. Effects of planting depths on concentrations of phytochemicals in tomatoes fruits.

Tabela 7. Efeitos da lâmina de plantio sobre as concentrações de fitoquímicos em frutos de tomate.

Depth (cm)	Phytochemicals					
	(%)				(mg/100g)	
	Alkaloid	Flavonoid	Saponin	Tannin	Lycopene	Carotenoid
2	1.44±0.09[c]	1.54±0.52[b]	1.58±0.11[c]	1.29±0.01[b]	3.15±0.01[c]	2.23±0.04[c]
4	2.84±0.27[a]	2.84±0.27[a]	2.06±0.03[a]	1.46±0.01[a]	5.17±0.01[a]	3.24±0.032[a]
6	1.54±0.12[b]	1.54±0.12[b]	1.94±0.06[b]	1.30±0.01[b]	4.08±0.01[b]	2.54±0.79[b]
8	1.24±0.15[d]	1.24±0.15[d]	1.16±0.12[d]	0.92±0.061[c]	2.15±0.04[d]	1.14±0.01[d]

Means with different superscripts within columns are significantly different according to Duncan's Multiple Range Test (DMRT) at $p<0.05$.

Poor yield of farm produce sustained because of inconsistent planting depth is one of the farming challenges encountered in agriculture. In the present study, higher mineral elements recorded in the soil collected at 4 and 6 cm could influence variations in the distributions of soil minerals at different soil levels as influenced by erosion, leaching or mobility of the elements (SCHOONOVER AND CRIM, 2015; GASPAR et al, 2021).

Early seed emergence observed in tomato seeds planted at 2 and 4 cm informs that the planting depth improves soil aeration, greater water retention (MENTGES et al., 2016) and exposes seeds to higher amount of soil minerals and that planting depth can encourage early or late seeds emergence (MACEDO et al., 2017; DE SOUZA MORAES et al., 2020). Also, the observation may be attributed to higher concentrations of soil mineral elements recorded at the depth (CHAICHI et al., 2022). On other hand, the observation implies that soil nutrients move into the subsoil and drain away along with plant nutrients in the soil profile. This agrees with submission of BIRARA et al. (2016) and MANIK et al. (2019) who reported early seed emergence in tomato seeds at shallow depth.

Higher tomato height and early flowering observed in the vegetable planted at 4 and 6 cm may be traceable to access of the tomato to higher soil nutritional contents at the depths. The nutritional contents of the soil might have enhanced cell division, enlargement and cell differentiation, stem elongation, flower bud formation as well as appreciable increase observed in the vegetative parameters of the tomato plants compared with other sowing depths (HARPER, & OBEID, 1967. SIKUKU et al., 2010; SINGH; GIRISH, 2013; FARMAN et al 2019; AJAYI et al., 2022). This result is in line with findings of BIRARA et al. (2016) and SHARMA et al. (2009) who reported lower days of flowering and rapid flower formation in in tomato plants under favorable growth conditions within the available range of soil profile.

In the similar trend, high number of leaves recorded in tomato planted at 4 cm may suggest that seeds that emerged earlier started leaf formation prior to the others and the leaves formed increased numerically due to faster exposure of plumules to photosynthetic activities and light reactive pigments (JACOBY et al., 2017; MUNTEAN et al, 2021, BEGUM et al. 2021).

Higher leaf area, specific leaf area and leaf area index observed in the leaves of tomato planted at 4 cm followed 6 cm may be due to increase in the nutritional contents recoded in the soil sample collected at the depths and that light sensitive pigments have increased leaf area of the vegetable for higher metabolic activities and assimilation of photosynthates produced (YANG et al., 2009; AKHTAR et al.,2019; YANG et al 2009; MUSA et al, 2020; AJAYI et al., 2022).

Significant amount of proximate, vitamin and minerals as well as phytochemicals recorded in; the fruits of the tomato planted at 4 as well as 6 cm indicates that soil depths influenced the nutritional and medicinal compositions of the fruits (RAO, 2006; MUSA et al 2020) and that synergy between the growth components of the tomato might have enhanced the metabolic performance of the fruits.

However, presence of the metabolites might have enhanced the metabolic functioning, cellular and environmental interactions and protected the tomatoes against pathogenic attack BIRARA et al. (2016). The general decrease observed in nutritional and phytochemical contents of the tomato fruits as well as growth components of the tomato plants with variation in sowing depth could be attributed to the decrease in agronomic attributes of the plants (SINGH; GIRISH, 2013; Yang et al., 2020; AJAYI et al., 2022).

4. Conclusion

Soil nutritional contents showed significant variations across soil depths, however, higher proportion of the minerals were observed at 4- and 6 cm depths.

4 cm emerged as the best planting depth followed by 6 cm as they produced significant positive influence on morphological parameters, growth components and yield of tomato shoot as well as nutritional and medicinal compositions of fruits of the vegetable hence cultivation of tomato between 4 and 6 cm depths is recommended.

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