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Raw Extracts of Wild Plants Improve the Agronomic and Biochemical Quality of Tomato Fruits (*Lycopersicum esculentum* Mill.)

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Abstract: This study aimed to determine the effect of 10 and 15% concentrations of *Azadirachta indica* oil (v/v) and *Tithonia diversifolia* and *Thevetia peruviana* liquid manure (w/v) on some key characteristics of tomato fruits. For this purpose, the extracts were sprayed on the tomato plants every two weeks until the fruits were harvested. The results show that the 15% *T. diversifolia* mash had the most significant positive impact ($p < 0.05$) on the size, weight, and ability of tomato fruits to protect DNA from denaturation. Indeed, compared to fruits harvested from untreated plants, this treatment increased the surface area by 75.38%, the weight by 72.74%, and the protective capacity of fruits against hydrogen peroxide-induced DNA denaturation by 82.96%. On the other hand, the highest lycopene content was obtained with *A. indica* at 10% (139.13 ± 4.35 µg/g MF), and that of phenols was observed with *T. peruviana* at 10% (31.07 ± 1.06 mg eq catechin/g MF). Also, there is a positive and significant correlation ($p < 0.05$) between phenol content and DPPH (2.2-diphenyl-1-picrylhydrazyl) and FRAP (ferric reducing antioxidant power) free radical scavenging activities of tomato fruits. Thus, this study shows that wild plant extracts are able to improve fruit quality.

Keywords: Wild plant extract, Tomato, Lycopene, Phenols, Antiradical activity, DNA

Introduction

Tomato is widely cultivated in the world for its fruit. In Cameroon, its cultivation occupies a prominent place in the agricultural economy and the consumption of fruits and vegetables [1]. However, the credit to be given to the quality of tomato fruits remains questionable because of the use of synthetic pesticides in the sector. Indeed, analyzing pesticide residues in 12 agricultural products in Cameroon, [2] observed a high rate of contamination, with 34.5% of residues exceeding the European Union's maximum residue limits. This observation reinforces the scientific belief that there is an urgent need to transform tropical agriculture towards an ecological approach.

Among the ecological approaches, the one involving the use of raw extracts of wild plants is probably the simplest to implement, especially since wild plants are freely available, and many of their biological properties are already known (insecticide, fungicide, herbicide, fertilizer, etc.). Among these wild plants with extraordinary biological properties, *Azadirachta indica* A. Juss (Meliaceae), *Tithonia diversifolia* (Hemsl.) A. Gray (Asteraceae) and *Thevetia peruviana* (Pers.) K. Schum (Apocynaceae) were identified as candidates for integrated tomato cultivation (growth, resistance, productivity, and fruit quality). The allelopathic effect of crude extracts of the latter has already been demonstrated on the growth and induction of synthesis of metabolites involved in tomato resistance [3]. Thus, the present study which evaluates the impact of these crude extracts on the agro-biochemical quality of tomato fruits is sufficiently justified. Indeed, the literature reveals that very few studies focus on evaluating the effectiveness of biological control in terms of fruit quality improvement.

In agronomy, fruit quality refers to its size and weight (market value), while in biochemistry, it refers to its phytomicronutrient content and its health benefits. Regarding tomato fruits, they contain a wide variety of health-promoting bioactive compounds such as phenols, lycopene, vitamin C, and β-carotene [4] [5]. These secondary metabolites, in addition to playing an important role in fruit coloration, organoleptic and nutritional quality, and allowing the plant to adapt to its fluctuating environment [6], possess antioxidant and protective properties towards certain degenerative diseases such as cancers and cardiovascular diseases [7] [4]. This explains why many studies on tomatoes aim to increase the phytomicronutrient content in the fruit [6]. This work has thus led to the identification of several factors involved in modulating the content of these bioactive compounds [8] [9] [6]. Thus, while the effect of a genetic program, environment, mineral nutrition and the existing interactions between these three factors are well known, the fact remains that in tropical agriculture, the effect of crude wild plant

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extracts on bioactive compounds accumulation remains a virgin track whose exploration may lead to new development strategies. Therefore, this study seeks to determine the effect of *A. indica* oil and *T. diversifolia* and *T. peruviana* liquid manures on some agronomic and biochemical characteristics of tomato fruits.

Material and methods

The study was conducted from March to June 2019 in an experimental site of the University of Yaoundé I, Yaoundé, Cameroon. The laboratory experimentation was conducted in the Higher Teacher's Training College of the University of Yaoundé I, Cameroon.

Plant growth condition

Vigorous tomato seedlings were transplanted into 5 L plastic pots (one semi/pot) filled 4/5 full of arable soil collected near the experimental site. These pots were then divided into eight blocks (20 pots/block) in a completely randomized design with two replicates. Each block was identified using the spray solution name: one block for the negative control, C (tap water), six blocks for the botanical extracts [*T. diversifolia* 10 and 15% (Td1 & Td2); *T. peruviana* 10 and 15% (Tp1 & Tp2); *A. indica* 10 and 15% (Ai1 & Ai2)] and one block for the chemical treatment, Che (systemic fungicide + systemic insecticide + foliar fertilizer 20-20-20). Every two weeks starting from the second week after transplanting, the treatment solutions were sprayed on the leaves of tomato plants. These different solutions were prepared according to the method described by [3]. Briefly, fresh leaves of *T. diversifolia* and *T. peruviana* were macerated at concentrations of 0.1 and 0.15 kg/L of water (w/v) for six days and the resulting liquid manure was filtered. The 10 and 15% oil solutions of *A. indica* were obtained by emulsifying respectively 0.1 and 0.15 L/L of water (v/v). These treatment solutions were used immediately. The various chemicals were used at the doses recommended. In addition, the chemically treated blocks were kept away from each other to avoid contamination.

Determination of agronomic characteristics of the fruits

The mature fruits were harvested, weighed, and photographed with a digital camera. To facilitate image analysis, the gray background around the fruits was replaced by a white background on https://www.remove.bg/fr/upload. Then, the length, width, and surface area of the fruits were analyzed using ImageJ software developed by Rasband (https://imagej.net/Wayne_Rasband). Five images were taken and analyzed for each block; 10 fruits per treatment.

Determination of the total phenolic compounds content

The extraction of total phenolic compounds from tomato fruit was carried out according to a modified method of [10]. Briefly, 1 g of fresh fruit was crushed at 4°C in 10 ml of 80% methanol; the homogenate was agitated for 10 min, and then centrifuged two times at 10,000 g for 15 min at 4°C. The pellets obtained were re-suspended one time in 5 ml of 80% methanol, agitated, and centrifuge. Then, the supernatant was collected and mixed with the previous to constitute the total phenolic extract. The concentration of phenolic compounds was determined by the method of [11] using the Folin-Ciocalteu reagent. Absorbance was measured at 725 nm, and the total phenolic compound contents were expressed in mg equivalent of catechin per g of fresh weight (mg eq catechin/g FW).

Determination of lycopene content

The extraction of lycopene from tomato fruits was performed by the modified protocol of [12]. Briefly, 1 g of tomato fruit pulp was crushed in 10 ml of the solvent mixture (hexane-acetone-ethanol: 50/49/1), vortexed for 10 min, then centrifuged twice at 10,000 g for 15 min at 4°C. Afterward, 1 ml of the organic phase was diluted in 10 ml of hexane. Absorbance was measured at 472 nm using a UV-1605 Shimadzu spectrophotometer. The lycopene content was expressed in µg per g of fresh material (µg/g FW) and calculated according to the formula below:

$$C = \frac{\mathrm{Abs}_{472} * \mathrm{Fd} * 10^6 * \mathrm{V}}{100 * \varepsilon * \mathrm{W}}$$

Were:

C = lycopene concentration (µg/g MF),

Abs_{472} = Absorbance of the sample measured at 472 nm,

Fd = dilution factor,

V = volume of extraction solvent,

ε = extinction coefficient of hexane (ε = 3450),

W = weight of the test sample.

Determination of antioxidant capacity

The antioxidant capacity of fruits was measured by two methods: (i) 2.2-diphenyl-1-picrylhydrazyl (DPPH) and (ii) ferric reducing antioxidant power (FRAP).

The DPPH assay was performed using a modified colorimetric method proposed by [13]. Briefly, 50 µL of 80% methanol extract were mixed with 1950 µL of 400 µmol/L DPPH in methanol and incubated for 30 min at room temperature in the dark. The reduction of the DPPH radical was estimated by absorbance measurement at 517 nm. Catechin was used as a positive control.

The FRAP assay was performed using a modified colorimetric method proposed by [14]. Briefly, 100 µL of extract were mixed with 1900 µL of FRAP reactive and incubated for 30 min at room temperature in the dark. The reduction of the FRAP radical was estimated by absorbance measurement at 593 nm.

The DPPH and FRAP radical scavenging effect was calculated as "inhibitory percentage" according to the following formula:

$$\mathrm{IP} = \left(\frac{(\mathrm{A}_0 - \mathrm{A}_1)}{\mathrm{A}_0}\right) * 100$$

Where:

IP = inhibitory percentage,

A_0 = absorbance of the control reaction,

A_1 = absorbance in the presence of the sample.

Evaluation of bioactive properties of fruits by DNA denaturation method

The protective effect of tomato fruit was evaluated on *Plasmodium falciparum* DNA (405 bp). Briefly, 5 µl of pressed tomato juice centrifuged twice at 4°C for 15 min at 10,000 g was introduced into 10 µl of the amplified DNA solution. This mixture was vortexed for 10 s, centrifuged for 2 min at 3,000 g, and the amount of DNA present in the medium was determined with NanoDrop LITE. Then 2 µl of

hydrogen peroxide, H_2O_2 (denaturing agent), was introduced into the medium. After homogenization and centrifugation, the mixture was incubated at 4°C for 1 h and the amount of DNA remaining in the reaction medium was determined. Two controls were set up: a negative control (10 µl DNA + 7 µl double-distilled, H_2O) and a positive control (10 µl DNA + 5 µl H_2O + 2 µl H_2O_2). The ability of tomato fruit to protect DNA from H_2O_2 was determined as the rate of protection relative to the positive control.

Determination of sugar content

The abundance of sugars in the fruit was determined by the modified method of [15]. Briefly, 100 g of fruit was pressed and the resulting juice was centrifuged twice at 10,000 g for 15 min at 4°C. After centrifugation, 50 µl of supernatant was collected. Then 450 µl of 5% phenol and 1 ml of 95% sulfuric acid (H_2SO_4) were quickly added. The reaction mixture was vortexed for 30 s, followed by incubation at 100°C for 10 min and cooling for 30 min at room temperature in the dark. The absorbance of the yellow staining solution was measured at 490 nm against the blank free of tomato juice. Sugar levels were determined regarding a standard range (0; 6.25; 12.5; 25 and 50 µg/ml) of glucose and expressed as mg glucose equivalent per ml of tomato juice (mg Glc eq/ml).

Statistical Analysis

Data analysis was performed using Graphpad Prism 8.0. All results were expressed as means ± standard deviations and subjected to Analysis of Variance (ANOVA). Where significant differences were found, pairs of samples were compared using Tukey's test as a post hoc test at $p < 0.05$. Principal components analysis (PCA) with Pearson correlation between the different variables was also performed with SPAD 5.0.

Results

Agronomic characteristics

Table 1 shows that fruits from plants treated with Td2 showed the best agronomic characteristics: length (6.99 ± 0.21 cm), width (5.44 ± 0.16 cm), area (29.78 ± 0.99 cm²), and weight (94.35 ± 0.52 g). Compared to the fruits of untreated plants (control, C), this extract increased length by 36.26%, width by 34.32%, and area by 75.38%, and weight by 72.74%. Moreover, the effect of the concentration of this manure was only observed on the weight of the fruit. Indeed, the rise of the concentration of the latter increased its effect on the weight of the tomato fruit by 8.3%. Also, none of the extracts showed a phytotoxic effect on fruit growth. Only fruits from blocks treated with Ai2 (50.31 ± 1.01 g) had lower weight values than fruits harvested from chemically treated plants (71.33 ± 0.6 g).

Table 1. Agronomic characteristics of tomato fruits.

	C (Std)	Td1 (Std)	Td2 (Std)	Tp1 (Std)	Tp2 (Std)	Ai1 (Std)	Ai2 (Std)	Che (Std)
Length[1]	5.13b (0.15)	6.07ab (0.28)	6.99a (0.22)	5.35b (0.26)	6.65a (0.27)	5.82ab (0.19)	6.19ab (0.29)	5.79ab (0.34)
Width[1]	4.17c (0.11)	4.91ab (0.13)	5.44a (0.13)	4.52bc (0.17)	4.80bc (0.22)	4.43bc (0.06)	4.36bc (0.14)	5.01ab (0.06)
Area[1]	16.98c (0.81)	24.35ab (1.22)	29.78a (0.99)	19.53bc (1.62)	25.13ab (1.39)	21.0bc (0.44)	21.29bc (1.79)	23.68bc (1.09)
Weight[1]	54.62e (1.39)	87.12b (2.12)	94.35a (0.52)	73.49d (1.09)	77.22cd (0.62)	82.67bc (1.13)	50.31e (1.01)	71.33d (0.6)

[1]The length and width are expressed in cm, area in cm^2 and weight in g.
Means with the same letter are not significantly different at $p < 0.05$. C: control; Td1 (Td2): *T. diversifolia* at 10% (15%); Tp1 (Tp2): *T. peruviana* at 10% (15%); Ai1 (Ai2): *A. indica* at 10% (15%); Che: chemical treatment; Std: standard deviation.

Total sugars content

Except for fruits collected from plants treated with Ai2 (2.65 ± 0.15 mg Glc eq/ml), all treatments, including Che (3.2 ± 0.2 mg Glc eq/ml), showed significantly higher sugars contents than fruits collected from untreated plants, C (2.3 ± 0.2 mg Glc eq/ml) (**Figure 1**). On the other hand, fruits collected from plants treated with Ai1 (5.45 ± 0.15 mg Glc eq/ml) showed the highest sugar content. This treatment indeed boosted the content of this primary metabolite in tomato fruits by 136.96%.

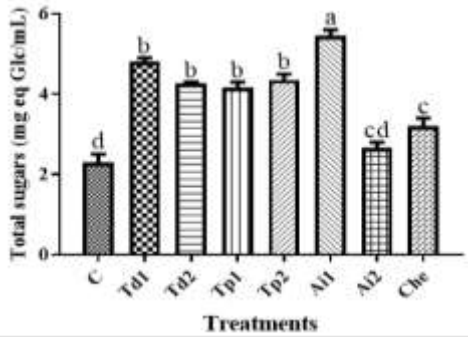

Figure 1. Variation in sugar content in tomato fruit. Means with the same letters are not significantly different at $p < 0.05$. C: control; Td1 (Td2): *T. diversifolia* at 10% (15%); Tp1 (Tp2): *T. peruviana* at 10% (15%); Ai1 (Ai2): *A. indica* at 10% (15%); Che: chemical treatment.

Lycopene and phenol content

Chemical treatment, Che (68.7 ± 1.67 µg/g FW) and aqueous extracts at 10%, Tp1 (69.71 ± 2.46 µg/g FW) and 15%, Tp2 (60.68 ± 1.06 µg/g FW) of *T. peruviana* did not significantly influence ($p > 0.05$) the accumulation of lycopene in tomato fruits (**Figure 2**). However, the fruits of plants treated with Ai1 (139.13 ± 4.35 µg/g FW) showed the highest content of this carotenoid; an increase of 99.58% compared to the fruits of the control block. On the other hand, the increase of *A. indica* concentration reduced its effect on the accumulation of lycopene in tomato fruits by 40.83%.

Regarding phenols accumulation in fruits, Tp1 (31.07 ± 1.06 mg catechin eq/g FW) showed the best effect compared to the control, C (20.71 ± 0.71 mg catechin eq/g FW) and other treatments (18.4 to 26.1 mg catechin eq/g FW) (**Figure 3**). However, increasing the concentration of *T. peruviana* reduced its effect on phenols accumulation in fruit by 19.44%. Finally, *A. indica* oil did not have a significant effect ($p > 0.05$) on the phenols content of tomato fruits. The

same was true for chemical treatment, Che (21.13 ± 0.5 mg catechin eq/g FW).

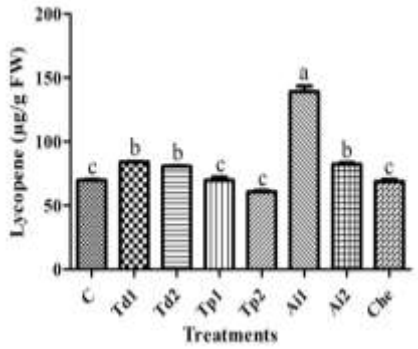

Figure 2. Variation of lycopene content in tomato fruits. Means with the same letter are not significantly different at $p < 0.05$. C: control; Td1 (Td2): *T. diversifolia* at 10% (15%); Tp1 (Tp2): *T. peruviana* at 10% (15%); Ai1 (Ai2): *A. indica* at 10% (15%); Che: chemical treatment.

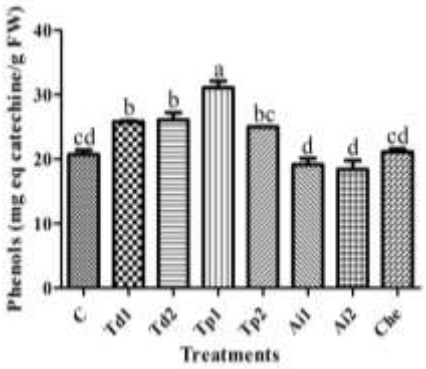

Figure 3. Variation of total phenolic content in tomato fruits. Means with the same letter are not significantly different at $p < 0.05$. C: control; Td1 (Td2): *T. diversifolia* at 10% (15%); Tp1 (Tp2): *T. peruviana* at 10% (15%); Ai1 (Ai2): *A. indica* at 10% (15%); Che: chemical treatment.

DPPH and FRAP radical-scavenging activity

Except for fruits from plants treated at concentrations of 10, Ai1 (57.46 ± 0.5%) and 15%, Ai2 (61.81 ± 1.75%) of *A. indica*, all biological treatments showed DPPH radical trapping values (68.97 to 78.87%) higher than fruits from plants of the control block, C (59.62 ± 1.16%) at the threshold $p < 0.05$ (**Figure 4**). Also, fruits from plants treated chemically, Che (69.02 ± 0.51%) and with Ai2 (69.77 ± 0.59%) did not have significant FRAP radical scavenging activity ($p > 0.05$) compared to fruits from plants in the control block, C (69.27 ± 0.94%) (**Figure 5**). Finally, the fruits of plants treated with Tp1 showed the best DPPH (78.88 ± 1.71%) and FRAP (77.72 ± 0.04%) radical scavenging activity. However, these antiradical activities were lower ($p < 0.05$) than that of catechin at 50 µg/mL (DPPH = 96.46 ± 1.08%; FRAP = 100%) used as standard.

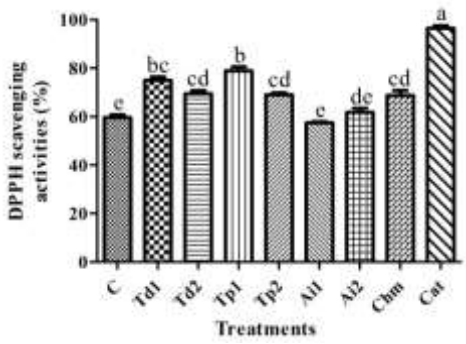

Figure 4. DPPH-free radical scavenging activities of tomato fruits. Means with the same letter are not significantly different at $p < 0.05$. C: control; Td1 (Td2): *T. diversifolia* at 10% (15%); Tp1 (Tp2): *T. peruviana* at 10% (15%); Ai1 (Ai2): *A. indica* at 10% (15%); Che: chemical treatment.

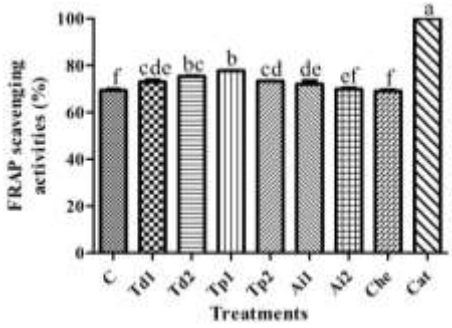

Figure 5. FRAP-free radical scavenging activities of tomato fruits. Means with the same letter are not significantly different at $p < 0.05$. C: control; Td1 (Td2): *T. diversifolia* at 10% (15%); Tp1 (Tp2): *T. peruviana* at 10% (15%); Ai1 (Ai2): *A. indica* at 10% (15%); Che: chemical treatment.

DNA protection

Td2 (71.39 ± 4.86%), Tp1 (49.01 ± 2.21%), and Ai1 (56.65 ± 1.16%) were the only biological treatments that significantly ($p < 0.05$) improved the ability of tomato fruits to protect DNA against H_2O_2-induced denaturation (**Figure 6**). On the other hand, the chemically treated fruits, Che (21.75 ± 1.43%) showed the lowest effect on DNA protection compared to the fruits of the control block, C (39.02 ± 2.92%) and the other blocks. In addition, increasing the concentration of *T. diversifolia* increased the ability of tomato fruits to protect DNA from denaturation by 83.95%, while that of *A. indica* reduced this ability by 26.55%. **Figure 7** shows the DNA migration profile on 1.5% agarose gel after incubation in the presence of H_2O_2.

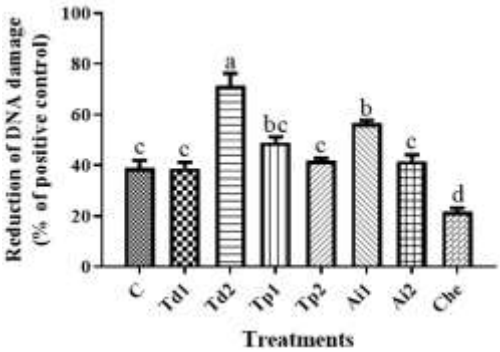

Figure 6. Protective effect of tomato juice on hydrogen peroxide-induced DNA denaturation. Means with the same letter are not significantly different at $p < 0.05$. C: control; Td1 (Td2): *T.*

diversifolia at 10% (15%); Tp1 (Tp2): *T. peruviana* at 10% (15%); Ai1 (Ai2): *A. indica* at 10% (15%); Che: chemical treatment.

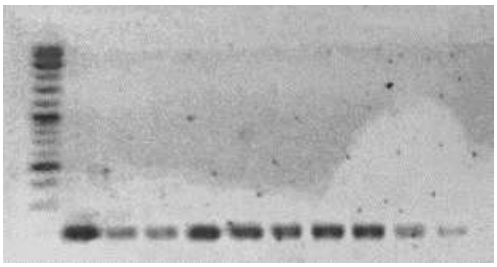

Figure 7. DNA migration profile on 1.5% agarose gel after incubation in the presence of H_2O_2. From left to right: molecular weight markers; negative control; control (C); *T. diversifolia* at 10% (Td1); *T. diversifolia* at 15% (Td2); *T. peruviana* at 10% (Tp1); *T. peruviana* at 15% (Tp2); *A. indica* at 10% (Ai1); *A. indica* at 15% (Ai2); chemical treatment (Che); and positive control.

Principal Component Analysis (PCA)

Table 2 shows that there was no significant correlation ($p > 0.05$) between the lycopene content and other variables. Concerning the agronomic parameters of the fruits, only length and weight ($r = 0.527$) do not correlate significantly ($p > 0.05$). On the other hand, the phenol content showed a strong positive correlation with free radical scavenging DPPH ($r = 0.902$) and FRAP ($r = 0.89$). Also, total sugars content shows a significant positive correlation with fruit weight ($r = 0,835$).

Table 2. Correlation matrix of Pearson (in bold: significant correlation at p >0.05).

	Length	Width	Area	Weight	Sugar	Lycopene	Phenol	DPPH	FRAP	DNA
Length										
Width	**0.728**									
Area	**0.915**	**0.941**								
Weight	0.527	**0.758**	**0.725**							
Sugar	0.332	0.346	0.399	**0.835**						
Lycopene	-0.001	-0.154	-0.049	0.296	0.590					
Phenol	0.083	0.389	0.255	0.496	0.346	-0.398				
DPPH	0.102	0.477	0.317	0.420	0.251	-0.480	**0.902**			
FRAP	0.224	0.337	0.304	0.595	0.568	-0.031	**0.890**	0.698		
DNA	0.445	0.265	0.383	0.519	0.466	0.418	0.269	-0.044	0.614	

The PCA factorial map shows an inertia rate of 71.45%, of which 48.78% is explained by principal component 1 and 22.76% by principal component 2 (**Figure 8**). Furthermore, the treatments are arranged in the same order as the variables. Thus, Td2 is the treatment that shows the best effect on all agronomic characteristics of tomato fruits and their ability to protect DNA from denaturation, while Tp1 has a better impact on phenol accumulation and DPPH and FRAP antiradical activities. Also, Ai1 has the best influence on lycopene content in fruits.

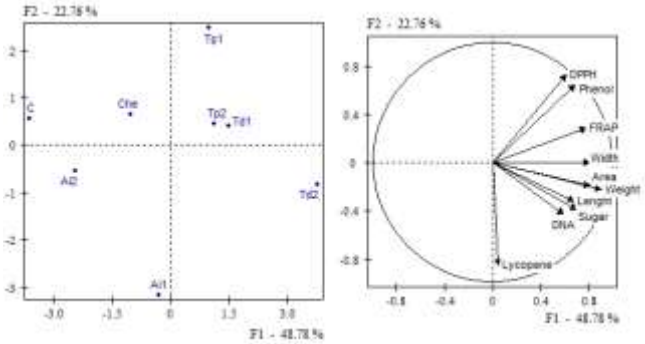

Figure 8. Factor map of PCA. C: control; Td1 (Td2): *T. diversifolia* at 10% (15%); Tp1 (Tp2): *T. peruviana* at 10% (15%); Ai1 (Ai2): *A. indica* at 10% (15%); Che: chemical treatment.

Discussion

The results of this study show that the treatment of tomato plants with the 15% aqueous extract of *T. diversifolia* (Td2) had a beneficial effect on the agronomic characteristics of the fruits. Indeed, this extract significantly enhanced the size and weight of fruits compared to those harvested from untreated plants (control). Several studies have shown that *T. diversifolia* is rich in important fertilizing elements (phosphorus, potassium, calcium, magnesium, nitrogen) [16] [17] [18] and organic matter [16] [18], all of which can explain the phenotype observed in tomato fruits. Thus, this study showed that in addition to promoting good aerial and root growth of tomato plants [3], *T. diversifolia* manure had a positive stimulatory effect on fruit growth. Other botanical extracts have also a positive effect on certain agronomic characteristics of the fruit, such as weight increase.

Regarding the biochemical quality of the fruits, it appears that the 10% aqueous extract of *T. peruviana* (Tp1) was the one that maximized the biochemical potential of tomato fruits. Indeed, it had a good influence on the accumulation of phenols and the antiradical activity of the fruits. Furthermore, the phenol content was showed a strong and positive linear correlation with the antiradical activity of scavenging free radicals DPPH and FRAP. In the same, the works of [19], and [20] respectively on the evaluation of the antioxidant activity of *Piliostigma thonningii* Schumach, and 112 Chinese medicinal herbs showed the existence of positive and significant linear correlations between antioxidant activity and phenolic compounds content of the tested plants. Thus, it appears from the present study that the strong antiradical capacity of the harvested fruits of the plants treated with Tp1 is related to their phenol content.

In the particular case of lycopene content of fruits, investigations showed that there was no significant correlation between this carotenoid content of fruits and their antiradical activity. However, lycopene was cited in the literature for its antioxidant properties [21] [22] [23]. The results of the present study are close to those of [5] working on the effect of salt stress on the antioxidant quality of tomato fruits. The latter did show a significant correlation between the phenol content of tomato fruits and their DPPH and FRAP antiradical activities, but no correlation between these antiradical activities and the lycopene content of the fruits. Nevertheless, as tomato is the primary source of lycopene for humans [8] [21] [5], results of this study showed that *A. indica* at 10% (Ai1) had a good effect on its accumulation in fruits. This extract also promotes the accumulation of sugars in the fruit.

Finally, fruits harvested from plants treated with Td2 was showed the best effect on DNA protection against H_2O_2 used in this study as a denaturing agent. However, there was no significant correlation between this biological activity and the lycopene and/or phenol content of the fruit. However, [24] working on phenolic compounds extracted from a grape variety had shown that the resistance of DNA to H_2O_2-induced denaturation was proportional to the quantity of phenolic compounds present in them. Similarly, the work of [25] was showed that tomato sauce supplemented with lycopene (30 mg/day) significantly reduced DNA damage in prostate cancer patients. Thus, this work showed the involvement of phenols and lycopene in the resistance of DNA to denaturation. But in the case of the present study, it is established that the observed protective effect must be the result of the combined action of antioxidant molecules present in tomato fruits.

Conclusion

This study showed that 15% *T. diversifolia* and 10% *T. peruviana* liquid manure can be used by growers to enhance the commercial characteristics and biochemical properties of tomato fruits. Moreover, *T. diversifolia* manure had already shown a good effect on root and aerial plant growth, and *T. peruviana* manure on the synthesis of metabolites involved in tomato plant resistance. Nevertheless, other studies must be carried out to complete the knowledge on the use of extracts of these wild plants on integrated cultivation of tomato, including (i) the determination of their effect on the epidemiology and field productivity of tomato; (ii) the appropriate times for their application on plants (taking into account the developmental cycle of the plant and the results already obtained); (iii) the molecular understanding of the mechanisms that explain the observed biological properties.

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Conflict of interest

The authors have not declared any conflict of interests.

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