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Extracts and powders of *Solanum aculeastrum* and *Tithonia diversifolia* induced an improvement of *Solanum lycopersicum* plant growth and development and fruit quality

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Abstract
The conventional tomato cultivation methods require the use of enormous quantities of chemical inputs, which can impair the health-promoting properties of fruits. The present study was undertaken to search for alternatives methods bearing minor risks for human health and environment friendly. Powders of *Solanum aculeastrum* and *Tithonia diversifolia* were applied on the soil and their aqueous, chloroform and hexane extracts sprayed on the aerial parts of tomato plants. Of a total of 19 parameters measured 12 were significantly improved after treatment of tomato plants with chloroform extract of *T. diversifolia*, 10 as a result of foliar sprays of aqueous or hexane extract of *T. diversifolia*, 09 as a result of soil enrichment with the powder of *T. diversifolia*, 05 after foliar application of hexane extract of *S. aculeastrum*, 03 after spraying of aqueous extract of *S. aculeastrum* on aerial parts, 02 as a result of treatment with chloroform extract of *S. aculeastrum* and 01 as a result of soil amendment with the powder of *S. aculeastrum*.

Keywords: *Solanum lycopersicum, Solanum aculeastrum, Tithonia diversifolia*, growth rate, crop yield, fruit quality attributes

1. Introduction
Tomatoes have high potential heath promoting properties due to their contents in flavonoids (Aghofack-Nguemezi *et a*l., 2011; Aghofack-Nguemezi *et al*., 2014, Moco *et al*., 2007) [1, 2, 3] carotenoids and vitamins (Moco *et al*., 2007) [3]. The presence of 9, 12, 13-trihydroy-10(*E*)-octadecenoic acid has also recently been demonstrated in tomato fruits (Aghofack-Nguemezi *et al.*, 2011; Aghofack-Nguemezi and Schwab, 2013) [1, 4]. This eighteen carbons trihydroxylic fatty acid has been shown to have antimicrobial (Masui *et al*., 1989; Walters *et al*., 2004) [5, 6], anti-allergic (Nagai *et al.*, 2004) [7], anti-inflammatory (Choi *et al.*, 2012) [8], prostaglandin-*E*-like (Üstünes *et al.*, 1985; Groenewald and Van der Westhuizen, 1997) [9, 10], adjuvant (Nagai *et al*., 2002; Shirahata *et al*., 2006; Nagai *et al*., 2010) [11, 12, 13] effects; it may also be involved in the development of taste (Baur *et al.*, 1977; Baur and Grosch, 1977; Esterbauer and Schauenstein, 1977; Kuroda *et al.*, 2002) [14, 15, 16, 17]. However, the conventional tomato cultivation methods require great quantities of chemical inputs. The use of chemical fertilizers has even become an absolute requirement particularly in the Cameroon Western Highlands which are some of the most appropriate tomato cultivation zones but where the intensive farming led in the past years to the exhaustion of arable lands (Andrew, 1995; FAOSTAT, 2015) [18, 19]. Such agricultural practices are susceptible to impair the nutritional virtues of tomatoes produced. It has become therefore urgent to search for alternative methods that couldn't have negative consequences on the heath of the consumers and which are environmentally friendly. In this regard, bioregulators or bioeffectors (biological material or their extracts with pesticide and/or fertilizer effects) are promising alternatives to chemical inputs. Leaves of *Tithonia diversifolia* exhibited insecticidal (Adayo *et al*., 1997) [20], antimicrobial (Goffin *et al*., 2002) [21], antioxidant Shyur *et al*., 2005) [22] and plant growth promoting (Olabode *et al*., 2007) [23] activities. *Solanum aculeastrum* fruits have been shown to have antimicrobial (Hutchings *et al*., 1996; Koduru *et al*., 2006) [24, 25] and antioxidant (Koduru *et al*., 2006, Koduru *et al*., 2007) [26, 27] properties. It is worth noting that the efficiency of fertilizers depends on the mode of their application (Taiz and Zeiger, 2006) [28]. Especially during the phase of rapid growth of plants, foliar sprays of fertilizer solutions can circumvent the problem of restricted uptake of the nutrient from the soil by reducing the lag-time between the application and uptake (Taiz and Zeiger, 2006).[28] The present work aimed at testing the efficacy of extracts (obtained using solvents of different polarities) applied as foliar sprays and soil amendment with powders of *Solanum aculeastrum* and *Tithonia diversifolia* on the enhancement of tomato plant growth and development and fruit quality.

2. Materials and methods
2.1. Plant material and treatments
Seeds of tomato (*Solanum lycopersicum* L. var. Rio Grande) were from the French firm TECHNISEM. Leaves and fruits respectively from *Tithonia diversifolia* and *Solanum aculeastrum* were collected in the locality.
Leaves of T. *diversifolia* and berries of S. *aculeastrum* were dried in an oven at 40°C until the stabilization of the weight. The dried plant material was then ground using a mill and the powder kept in polythene bags. To prepare hexane and chloroform extracts, 200g of powder were macerated during 2 h in 500 ml hexane and the residue was then soaked during 2 h in 500 ml chloroform (Saidana *et al*., 2007) [29]. Each macerated sample was filtered using a nylon cloth. The extracts thus obtained using hexane and chloroform were dried with a rotary evaporator at 40°C and re-dissolved in 60ml of methanol for better conservation. Aqueous extracts

were prepared three days prior to their field application. 80 g of powder from leaves T. *diversifolia* or berries of S. *aculeastrum* were thus macerated in 300 ml water during 72 h and extracts were filtrated using a nylon cloth.

Tomato seeds were sown in nursery beds in a soil enriched with chicken droppings at the dose of 1 kg m^{-2} and base-fertilized with urea and N-P-K (20-10-10) both at 67 g m^{-2}. The plot used for transplanting tomato seedlings had not been grown with any Solanaceaous crop for the past three years. A split plot experimental design with 42 plots grouped into three blocs was used. Before transplanting the seedlings, 30 holes were dug in each plot in rows spaced by 0.4 m apart with 0.4 m between holes. Each hole was then treated with 1.48 g of the insecticide-nematicide Furaplant 10G (10% carbofuran) and filled with 40 g of chicken droppings. Five days before seedling transplantation each hole received 40 g of powder from T. *diversifolia* leaves or S. *aculeastrum* berries. Seedlings were transferred to experimental plots 35 days after sowing when they had 3-5 true leaves. Thirteen days after transplanting, each seedling was base-fertilized with three grams N-P-K (20-10-10). Foliar sprays with aqueous plant extracts containing two drops of Tween 80 l^{-1} or solutions containing 30 ml methanolic plant extract, 970 ml water and two drops Tween 80 l^{-1} began 18 days after transplanting and continued once a week until one week before the end of the experiment. Control plants received at the same frequencies applications of foliar sprays of either water containing two drops Tween 80 l^{-1} or a solution containing 30 ml methanol and two drops of Tween 80 l^{-1}. Antifungal treatments with Ivory 80 (80% mancozebe) or Beauchamp (8% metalaxy and 64% mancozebe) were applied two days after transplanting and were repeated after each rainfall (Fontem, 2003) [30]. The insecticide Cypercot (cypermethrine 100 EC) was used to fight against insect pests, including whitefly. For efficiency, Tween 80 was added to the pesticide solution at two drops l^{-1} to avoid leaching. Tween 80 enables spray solutions to better adhere to the plant surface (Aghofack-Nguemezi *et al*., 1991) [31]. All plants were staked and watered whenever necessary.

2.2. Growth and development parameters

Data on growth and development parameters were collected on each tomato plant for a total of ten plants per treatment. To characterize the growth, plant height was measured with a ruler from the crown to the collar; stem diameter (at half height) using a vernier caliper with a precision of 0.1cm; and the biomass (of roots, aerial parts and fruits) using a 0.1g precision balance. Growth speed (GS) was determined by the increase in plant height per day whereas the growth rate was determined as $(GS/X_0) \times 100$ where X_0 was the initial value of the plant height. Development parameters were determined considering the time period between transplanting and the appearance of the first flowers (TPTAF), the rate of flower bud abortion (RFBA) [RFBA = (NFB-NFl) / NFB × 100] and the rate of flower abortion (RFA) [RFA = (NFl-NFr) / NFl × 100] (with NFB: number of flower buds; NFl: number of flowers; NFr: number of fruits). The number of fruits per plant or per raceme, and number of racemes per plant were also determined. The percentage of yellowed leaves (PYL) [PYL= (NYL/TNL) x 100] (with NYL: number of yellowed leaves; TNL: total number of leaves) was determined in order to indirectly access the health status of tomato plants.

2.3. Yield and fruit quality related parameters

The yield (t/ha), the vertical and horizontal diameters of fruits, the green life (the time period elapsed between the mature green stage and the red ripe stage of fruits), the ripening speed (number of fruits which reached the red ripe stage per day) of fruits produced in each plot were determined. For the analysis of carbon and nitrogen contents, fruits were sliced and dried nine days in an oven at 60°C. Thereafter, they were further oven dried for 24 h at 105°C. Samples were then ground in a mortar and the powders obtained were kept in polythene bags.

The determination of organic carbon content in tomato fruits was performed according to the slightly modified methods of Walkley and Black (1934) [32]. 100 mg of dried tomato fruits were introduced in a 500 ml Erlenmeyer flask, 10 ml of 0.167 *M* $K_2Cr_2O_7$ and 20 ml of concentrated H_2SO_4 solutions were successively added, and the flask gently swirled. The mixture was then allowed to stand for 30 minutes on an insulation pad to avoid rapid heat loss. Thereafter, the suspension was diluted with 200 ml of water to provide a clearer suspension for viewing the titration endpoint. 10 ml of 85% H_3PO_4 and 200 mg of NaF were sequentially added to complex Fe^{3+} with which could interfere with the titration endpoint. Then, 10 drops of ferroin indicator solution (3.71 g of o-phenathroline and 1.74 g of $FeSO_4 \cdot 7H_2O$ in 250 ml of water) were added to the mixture. The titration was done with a 0.5 *M* Fe^{2+} solution (196.1 g of $Fe(NH_4)_2SO_4 \cdot 6H_2O$ in 800 ml water) to a bright green endpoint. A reagent blank was run using the above procedure without tomato fruit material. The percentage of total organic carbon was calculated using the formulae %C= [(B-S) x 0.5 x 12 x 100]/W x 4000 (where B= ml of Fe^{2+} solution used to titrate the blank; S= ml of Fe^{2+} solution used to titrated the sample; W= weight of the sample used; 12/4000milliequivalent weight of C in g).

The determination of nitrogen content in tomato fruit was performed according to the conventional Kjeldahl method as described in standard text book. Briefly, 100 mg of the powder from dried tomato fruits were digested with concentrate H_2SO_4, $CuSO_4$ and $Na_2S_2O_3$ as catalysts; the resulting ammonia was distilled into boric acid and back titrated with alkali.

2.4. Statistical analyses

Collected data were subjected to variance analysis (ANOVA) and principal component analysis using the softwares SPSS 17 and R, respectively. Comparison of mean values from ANOVA was performed using Student-Newmann-Keuls at the significance threshold of 5%.

3. Results & Discussion

3.1. Effects of treatments with extracts and powders of *Tithonia diversifolia* and *Solanum aculeatrum* on growth and development of tomato plants.

There were improvements; of some growth (Tab. 1) and development (Tab. 2) parameters after treatments with powders and extracts fom *Tithonia diversifolia* and *Solanum aculeatrum*. Soil enrichment with the powder as well as foliar sprays of each of the three extracts from T. *diversifolia* led to a significant enhancement of the stem diameter of treated

tomato plants as compared to controls. A significant improvement of the growth rate after the foliar sprays of aqueous extract from S. *aculeastrum* could also be observed. Treatment of tomato plants by applying an aqueous extract of S. *aculeastrum* on leaves induced a significant increase in the growth rate. There was no significant effect of treatments with powder and extracts from S. *aculeastrum* on the stem diameter of tomato plants. Treatments with powders and extracts from T. *diversifolia* and S. *aculeastrum* could also not significantly positively affect the height and growth speed of tomato plants (Tab.1). Soil enrichment with the powder as well as foliar sprays of each of the three extracts from T. *diversifolia* led to significant improvements of the number of leaves and percentage of yellowed leaves of treated tomato plants as compared to controls. Aerial spray of aqueous extract from T. *diversifolia* was the most effective treatment in reducing the percentage of yellowed tomato plant leaves. Treatments with powder, aqueous and chloroform extracts of T. *diversifolia* positively influenced the time elapsed between the pricking out and the formation of the first flowers by tomato plants. The shortest duration of the period between the pricking out and the formation of the first tomato flowers was obtained as a result of foliar sprays of aqueous and chloroform extracts of T. *diversifolia*. Tomato plants which received foliar applications of hexane extracts of T. *diversifolia* produced more leaves than other treated and control plants. Foliar applications by spraying of hexane extract of S. *aculeastrum* induced a significant increase in the number of leaves and a decrease in the percentage of yellowed leaves (Tab. 2). The principal component analysis (Fig. 1) revealed that treatments with hexane, aqueous and chloroform extracts and the powder from S. *aculeastrum*, in order of increasing efficacy, induced positive effects on tomato plant growth rate and speed. According to this analysis, treatments with chloroform, hexane and aqueous extracts and the powder from T. *diversifolia*, in order of increasing importance, were effective in inducing improvements of the tomato plant stem diameter, number of leaves, percent of yellowed leaves and time elapsed between the pricking out and the onset of fruits.

Treatments with extracts or powder from T. *diversifolia* were thus more efficacious than those with extracts or powder from S. *aculeastrum* in enhancing the growth and development of tomato plants. It has been reported by Olabode *et al*. (2007) [23] that growth of *Abelmoschus esculentus* was improved after soil enrichment with freshly crushed and dried ground T. *diversifolia*. Also, water extract of T. *diversifolia* shoot and root promoted *Vigna unguiculata* seedling and plant growth (Taiwo and Makinde, 2005) [33]. Moreover, fresh shoot aqueous extract of T. *diversifolia* had stimulatory effects on seedlings growth of *Zea mays* of two weeks age and above whereas inhibitory effects were observed with younger seedlings (Oyerunde *et al*., 2009) [34]. Furthermore, soil fallowed to T. *diversifolia* had higher contents in minerals such as nitrogen, phosphorus, potassium, calcium and magnesium (Ojeniyi *et al*., 2012) [35]. In the present study effects of chloroform extracts from T. *diversifolia* on growth and development of tomato plants were the most pronounced compared to controls and plants that have received other treatments. These results indicated that lipophilic constituents may be some of the most powerful plant growth improving attributes of T. *diversifolia*. Many chemical groups resulting from both primary (e. g. fatty acids, phospholipids and galactolipids) and secondary (e. g. terpenoids and oxylipins) metabolisms are soluble in chloroform. Although some natural growth promoting regulators like diterpenoid, gibberellins could be extracted with chloroform, different T. *diversifolia* chemical constituents soluble in chloroform might synergistically induce an enhancement of tomato plant growth and development. It is well established that T. *diversifolia* contains a great diverse spectrum of chemical compounds including alkaloids, saponins, glycosides, flavonoid, tanins, terpenoid, phenols, alcohols, olefins, six-membered ring lactams and esters (Taiwo and Makinde, 2005; García and Delgado, 2006; Zhai *et al*., 2010; Otusanya and Olasupo, 2012; Zhao *et al*., 2012) [33, 36, 37, 38, 39].

3.2. Effects of treatments with extracts and powders from *Tithonia diversifolia* and *Solanum aculeatrum* on the production and fruit quality

Soil enrichment with the powder as well as foliar sprays of each of three extracts from T. *diversifolia* led to significant improvements of the number of racemes per plant, the flower abortion rate and the number of fruits per plant of treated tomato plants as compared to controls. Similarly, aqueous, chloroform and hexane extracts from T. *diversifolia* induced an enhancement of the floral bud abortion rate. The quantitative fruit yield was significantly increased after application by aerial spraying of chloroform extract T. *diversifolia*. Foliar sprays of hexane extracts from S. *aculeastrum* induced significant increases in the number of racemes per tomato plant. Treatments with aqueous and chloroform extracts from S. *aculeastrum* rather led to a significant decrease in the number of fruits per plant. There was no significant effect of treatments applied on the total number of fruits produced (Tab. 3). Tomato plants grown on soil enriched with powders from T. *diversifolia*, or that received foliar applications of chloroform or hexane extracts from *diversifolia* or S. *aculeastrum* produced fruits with bigger horizontal diameter as compared to fruits produced by controls and plants that received other treatments. The lateral diameter of fruits produced was significantly improved after soil enrichment with powder and foliar sprays of chloroform extract from T. *diversifolia*. All treatments applied in the field led to a significant increase in the duration of green life of tomato fruits harvested at mature-green stage. Soil amendment with the powder and foliar applications of each of the three extracts from T. *diversifolia* also led to significant decreases in the speed of fruit ripening (number of ripe fruit per day). The foliar spray of hexane extract from T. *diversifolia* was the most efficient field treatment in inducing an increase in horizontal diameter, and decreases in de duration of green life and ripening speed of tomato fruits produced (Tab. 4). The principal component analysis (Fig. 1) showed that in order of increasing efficacy foliar sprays of chloroform, hexane or aqueous extracts, or soil enrichment with the powder from T. *diversifolia* induced most significantly marked positive effects on tomato plant production and fruit quality parameters.

On the whole, treatments with hexane extracts of T. *diversifolia* were the most efficacious in improving the horizontal diameter, the duration of green life and the

ripening speed of tomato fruits. On the other hand, treatments by spraying of chloroform extracts of T. *diversifolia* were the most performing in the enhancement of the fruit yield and vertical diameter. Obviously, chemical constituents of T. *diversifolia* extracts which triggered an improvement of tomato fruit yield and quality are soluble in apolar solvents like chloroform and hexane, indicating their volatile nature. It is well known that T. *diversifolia* contain many sesquiterpenes (Zhao *et al*., 2012) [39]. There was a better yield of *Abelmoschus esculentus* after treatment of the soil with freshly crushed and dried ground T. *diversifolia* (Olabode *et al*., 2007) [23]. Furthermore, significant increases in the maize yield were obtained during two consecutive years as a result of the incorporation of T. *diversifolia* in the soil when compared to soil fertilized with NPK (Ademiluyi and Omotoso, 2007) [40]. The fact that these previous reported yield promoting properties of T. *diversifolia* were based on soil amendment and results of the present study revealed that chloroform extract of T. *diversifolia* applied by spraying of the aerial parts of tomato plants was the most efficacious treatment in inducing an increase in the fruit yield pointed out the influence of the mode of application of bioregulators/biostimulants/biofertilizers in integrated production management (Taiz and Zeiger, 2006; Coe, 1924) [28, 41]. In this context, it has been reported that simultaneous soil application of organic fertilizers and foliar spray of seaweed extract solution led to significant improvement of growth and yield of *Piper nigrum* as compared to singly soil application organic (Yap, 2012) [42]. Moreover, different effects of soil fertilization with Fe and application of Fe in form of solution spray on yield parameters of *Hordeun vulgare* were observed (Boorboori *et al*., 2012) [43].

4. Tables and Figures

Table 1: Effects of treatments with powders and extracts of *Tithonia diversifolia* and *Solanum aculeastrum* on *Solanum lycopersicum* growth parameters. Values are means±SD (n=3).

Treatments	Growth parameters			
	Height (cm)	Diameter (cm)	GS (cm/day)	GR (%)
T00	66.73±5.60^{a}	0.9±7 0.02^{b}	0.93±0.10^{a}	5.83±1.00^{bc}
T11	69.63±4.32^{a}	1.00±0.04^{b}	0.95±0.05^{a}	5.71±0.60^{bc}
T21	71.33±3.64^{a}	1.16±0.08^{a}	0.99±0.06^{a}	6.04±0.77^{b}
T22	68.43±3.95^{a}	1.16±0.07^{a}	1.02±0.06^{a}	6.32±0.81^{ab}
T23	73.69±5.60^{a}	1.15±0.06^{a}	0.96±0.11^{a}	4.82±1.37^{c}
T24	68.43±3.95^{a}	1.16±0.07^{a}	0.96±0.05^{a}	6.34±0.85^{ab}
T31	70.83±4.93^{a}	0.99±0.06^{b}	1.03±0.07^{a}	6.61±0.96^{ab}
T32	69.33±5.90^{a}	0.96±0.03^{b}	0.99±0.06^{a}	6.09±0.67^{b}
T33	69.33±4.46^{a}	1.02±0.06^{b}	0.99±0.07^{a}	6.76±0.93^{ab}
T34	69.20±7.16^{a}	0.95±0.07^{b}	1.00±0.13^{a}	7.53±1.51^{a}

GS, growth speed; GR, growth rate; T00, control tomato plant which received no treatment; T11, control plants treated with a mixture of 15 ml methanol, 485 ml of water and two drop of Tween 80; T21, treatment by application of the powder of *T. diversifolia* on the soil; T22, foliar spray of an aqueous extract of *Tithonia*. *diversifolia*; T23, foliar spray of a chloroform extract of *T. diversifolia*; T24, foliar spray of an hexane extract of *T. diversifolia*; T31, foliar spray of an hexane extract of *Solanum aculeastrum*; T32, soil enrichment with the powder of *S aculeastrum*; T33, treatment by application of a chloroform extract of *S aculeastrum* on the aerial parts of tomato plants; T34, foliar spray of an aqueous extract of *S aculeastrum*.

Table 2: Effects of treatments with extracts or powders of *Tithonia diversifolia* and *Solanum aculeastrum* on *Solanum lycopersicum* development parameters. Values are means±SD (n=3).

Treatments	Development parameters		
	NL/P	PYL/P	TPFF
T00	50.13±2.14^{bc}	35.69±2.33^{e}	29.43±3.33^{bc}
T11	47.20±1.64^{cd}	34.63±2.63^{de}	30.16±2.81^{bc}
T21	56.06±6.80^{ab}	22.92±2.52^{a}	20.16±3.26^{a}
T22	56.80±2.08^{ab}	22.53±2.35^{a}	20.16±3.26^{a}
T23	54.80±3.87^{ab}	26.41±2.21^{b}	21.50±4.64^{a}
T24	58.90±2.95^{a}	24.02±2.56^{ab}	25.20±6.25^{ab}
T31	55.20±5.54^{ab}	30.01±2.68^{c}	29.03±4.34^{bc}
T32	43.76±6.52^{d}	31.82±2.21^{cd}	29.79±4.17^{bc}
T33	50.63±4.61^{bc}	31.28±2.96^{cd}	29.66±7.83^{bc}
T34	53.96±8.82^{ab}	31.53±5.31^{cd}	32.03±3.58^{c}

NL/P, number of leaves per plant; PYL/P, percent of yellowed leaves per plant; TPFF, time elapsed between the pricking out and the formation of first flowers; T00, not treated control tomato plants; T11, control plants treated with

a mixture of 15 ml methanol, 485 ml of water and two drop of Tween 80; T21, treatment by application of the powder of *T. diversifolia* on the soil; T22, foliar spray of an aqueous extract of *Tithonia. diversifolia*; T23, foliar spray of a chloroform extract of *T. diversifolia*; T24, foliar spray of an hexane extract of *T. diversifolia*; T31, foliar spray of an hexane extract of *Solanum aculeastrum*; T32, soil enrichment with the powder of *S aculeastrum*; T33, treatment by application of a chloroform extract of *S aculeastrum* on the aerial parts of tomato plants; T34, foliar spray of an aqueous extract of *S aculeastrum.*

Table 3: Effects of treatments with powders or extracts of *Tithonia diversifolia* and *Solanum aculeastrum* on *Solanum lycopersicum* production parameters. Values are means±SD (n=3).

Treatments	Production parameters				
	RAFB	RAF	NR/P	NF/P	Yield (t/ha)
T00	32.93±13.42^{bc}	51.04±11.21^{bc}	12.93±0.77^{c}	21.18±1.28^{bc}	12.01±4.32^{b}
T11	30.20±8.13^{bc}	54.31±7.04^{c}	13.63±2.03^{c}	21.90±1.37^{b}	11.80±4.33^{b}
T21	24.77±5.67^{b}	44.58±7.59^{b}	17.63±2.03^{a}	18.90±1.89^{cd}	23.48±2.00^{ab}
T22	10.17±9.41^{a}	44.80±7.24^{b}	17.63±2.38^{a}	35.83±1.78^{a}	16.87±3.69^{ab}
T23	10.55±7.27^{a}	45.74±6.69^{b}	17.39±1.81^{a}	33.93±1.52^{a}	27.07±5.42^{a}
T24	10.59±12.07^{a}	34.05±10.77^{a}	15.69±0.91^{b}	35.10±1.61^{a}	22.61±11.18^{ab}
T31	26.85±11.37^{b}	57.51±2.28^{c}	14.46±1.16^{ab}	21.74±2.02^{b}	20.58±2.04^{ab}
T32	42.09±5.67^{c}	56.48±2.56^{c}	13.39±1.06c	20.93±3.05^{bc}	18.89±6.17^{ab}
T33	36.19±9.60^{bc}	59.14±1.36^{c}	13.56±1.15c	17.33±3.03^{d}	17.99±1.11^{ab}
T34	33.12±11.72^{bc}	59.43±2.90^{c}	13.70±2.35c	17.16±2.85^{d}	17.43±2.64^{ab}

RAFB, rate of abortion of floral buds; RAF, rate of abortion of flowers; NR/P, number of racemes per plant; NF/P, number of fruits per plant; T00, not treated control tomato plants; T11, control plants treated with a mixture of 15 ml methanol, 485 ml of water and two drop of Tween 80; T21, treatment by application of the powder of *T. diversifolia* on the soil; T22, foliar spray of an aqueous extract of *Tithonia. diversifolia*; T23, foliar spray of a chloroform extract of *T. diversifolia*; T24, foliar spray of an hexane extract of *T. diversifolia*; T31, foliar spray of an hexane extract of *Solanum aculeastrum*; T32, soil enrichment with the powder of *S aculeastrum*; T33, treatment by application of a chloroform extract of *S aculeastrum* on the aerial parts of tomato plants; T34, foliar spray of an aqueous extract of *S aculeastrum*

Table 4: Effects of treatments with powders or extracts of *Tithonia diversifolia* and *Solanum aculeastrum* on *Solanum lycopersicum* fruit ripening and quality parameters. Values are means±SD (n=3).

Treatments	Fruit quality parameters					
	NC (%)	OCC (%)	DGL (days)	RS (days)	HD (cm)	VD (cm)
T00	6.53±0.80^{a}	29.96±0.66^{a}	17.67±1.57^{b}	1.04±0.08^{bc}	3.94±0.25^{b}	3.84±0.17^{b}
T11	6.95±0.17^{a}	30.41±0.26^{a}	17.67±1.52^{b}	1.07±0.06^{c}	3.96±0.39^{b}	3.93±0.31^{ab}
T21	6.81±1.03^{a}	30.31±0.31^{a}	24.33±1.52^{a}	0.82±0.05^{ab}	4.55±0.14^{a}	4.49±0.18^{a}
T22	7.37±0.58^{a}	29.99±0.85^{a}	24.67±3.05^{a}	0.81±0.09^{ab}	4.21±0.19^{ab}	4.25±0.23^{ab}
T23	6.25±1.72^{a}	29.25±0.75^{a}	24.67±1.15^{a}	0.81±0.03^{ab}	4.53±0.07^{a}	4.55±0.10^{a}
T24	6.41±1.27^{a}	29.96±0.54^{a}	25.00±1.00^{a}	0.67±0.18^{a}	4.70±0.16^{a}	4.41±0.38^{ab}
T31	7.70±0.56^{a}	29.55±1.06^{a}	22.67±1.15^{a}	0.88±0.04^{abc}	4.51±0.13^{a}	4.43±0.16^{ab}
T32	7.49±0.68^{a}	29.50±1.49^{a}	23.33±2.51^{a}	0.86±±0.09^{abc}	4.39±0.21^{ab}	4.33±0.27^{ab}
T33	7.70±0.61^{a}	29.86±0.63^{a}	23.33±0.57^{a}	0.85±0.02^{abc}	4.46±0.03^{a}	4.41±0.13^{ab}
T34	7.32±0.45^{a}	26.52±5.49^{a}	22.33±1.52^{a}	0.89±0.06^{abc}	4.40±0.13^{ab}	4.38±0.13^{ab}

NC, nitrogen content; OCC, organic carbon content; DGL, duration of the green life; RS, ripening speed; HD, horizontal diameter; VD, vertical diameter; T00, not treated control tomato plants; T11, control plants treated with a mixture of 15 ml methanol, 485 ml of water and two drop of Tween 80; T21, treatment by application of the powder of *T. diversifolia* on the soil; T22, foliar spray of an aqueous extract of *Tithonia. diversifolia*; T23, foliar spray of a chloroform extract of *T. diversifolia*; T24, foliar spray of an hexane extract of *T. diversifolia*; T31, foliar spray of an hexane extract of *Solanum aculeastrum*; T32, soil enrichment with the powder of *S aculeastrum*; T33, treatment by application of a chloroform extract of *S aculeastrum* on the aerial parts of tomato plants; T34, foliar spray of an aqueous extract of *S aculeastrum*

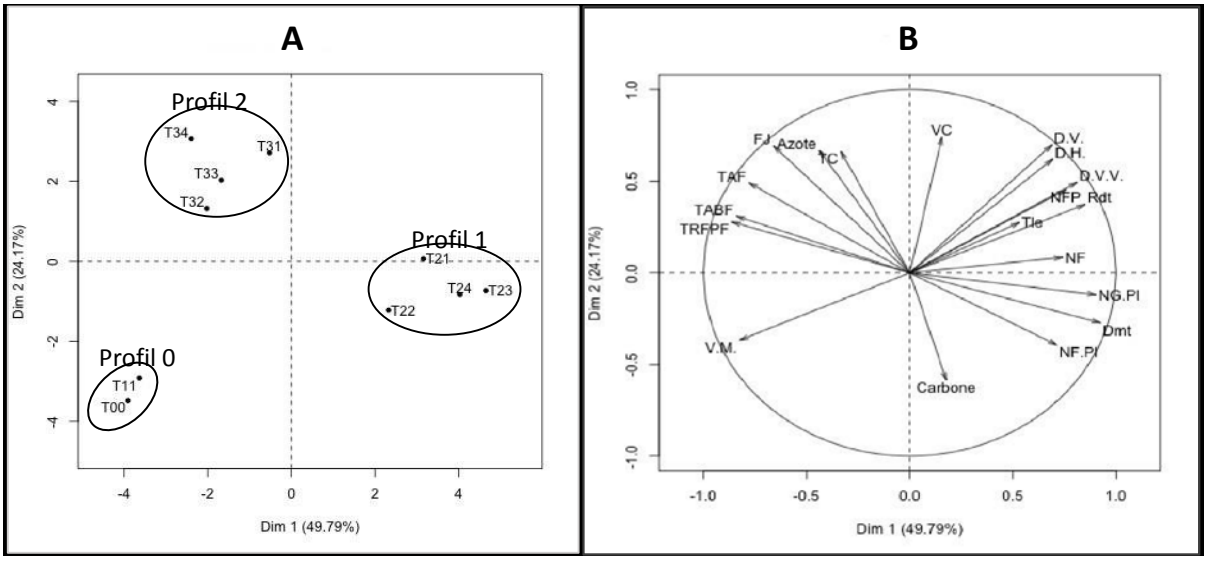

Fig 1: Principal component analysis of the Effects of treatments with powders or extracts of *Tithonia diversifolia* and *Solanum aculeastrum* on *Solanum lycopersicum* fruit ripening and quality parameters. VC, growth speed; TC, growth rate; NF.Pl, number of leaves per plant; FJ, percent of yellowed leaves per plant; TRFPF, time elapsed between the pricking out and the formation of first flowers; TABF, rate of abortion of floral buds; TAF, rate of abortion of flowers; NG.Pl, number of racemes per plant; NFP, number of fruits per plant; Azote, nitrogen content; Carbone, organic carbon content; DVV, duration of the green life; VM, ripening speed; DH, horizontal diameter; DV, vertical diameter; T00, not treated control tomato plants; T11, control plants treated with a mixture of 15 ml methanol, 485 ml of water and two drop of Tween 80; T21, treatment by application of the powder of *T. diversifolia* on the soil; T22, foliar spray of an aqueous extract of *Tithonia*. *diversifolia*; T23, foliar spray of a chloroform extract of *T. diversifolia*; T24, foliar spray of an hexane extract of *T. diversifolia*; T31, foliar spray of an hexane extract of *Solanum aculeastrum*; T32, soil enrichment with the powder of *S aculeastrum*; T33, treatment by application of a chloroform extract of *S aculeastrum* on the aerial parts of tomato plants; T34, foliar spray of an aqueous extract of *S aculeastrum*

5. References

1. Aghofack-Nguemezi J, Fuchs C, Yeh S-Y, Huang F-C, Hoffmann T, Schwab W. An oxygenase inhibitor study in Solanumlycopersicum combined with metabolite profiling analysis revealed a potent peroxygenase inactivator. Journal of Experimental Botany. 2011; 62(3):1313-1323.
2. Aghofack-Nguemezi J, Schwab W. Differential accumulation of flavonoids by tomato (*Solanum lycopersicum*) fruits tissues during maturation and ripening. Journal of Applied Biosciences. 2014; 84:7674-7681.
3. Moco S, Capanoglu E, Tikunov Y, Bino RJ, Boyacioglu D, Hall RD. *et al.* Tissue specialization at the metabolite level is perceived during the development of tomato fruit. Journal of Experimental Botany. 2007; 58(15-16):4131-4146.
4. Masui H, Kondo T, Kojima M. An antifungal compound, 9, 12, 13-trihydroxy-(*E*)-10-octadecenoic acid, from *Colocasia antiquorum* inoculated with *Ceratocystis fimbrata*. Phytochemistry. 1989; 28:2613-2615.
5. Aghofack-Nguemezi J, Schwab W. Spatiotemporal changes in the content and metabolism of 9, 12, 13–Trihydorxy-10 (*E*)-Octadecenoic acid in tomato (*Solanum Lycopersicum* L. CV Balkonsar) fruits. Journal of Science and Technology. 2013; 33(1):12-22.
6. Walters DR, Cowley T, Weher H. Rapid accumulation of trihydroxy oxylipins and resistance to bean rust pathogen *Uromyuces fabae* following wounding in *Vicia Faba*. Annals of Botany. 2004; 97:779-784.
7. Nagai T, Arai Y, Emori M, Nunome SY, Yabe T, Yakeda T. *et al.* Anti-allergic activity of kampo (Japanese herbal) medicine "Sho-seiryu-to (SST, Xia-Qing-Long-Tang in Chinese)" on airway inflammation in a mouse model. International Immunopharmacology. 2004; 4(10-11):1353-1365.
8. Choi HG, Park YM, Lu Y, Chang HW, Na M, Lee SH. Inhibition of prostaglandin (D2) production by trihydroxy fatty acids isolated from *Ulmus davidiana* var. Japonica. Phytotherapy Research. 2012; 23:113-123.
9. Üstünes L, Claeys M, Laekeman G, Herman AG, Vlietinck AJ, Özer A. Isolation and identification of two isomeric trihydroxy octadecenoic acid with prostaglandin E-like activity from onion bulbs (Allium cepa). Prostaglandins. 1985; 29(5):847-865.
10. Groenewald EG, Van der Westhuizen AJ. Prostaglandins and related substances in plants. The Botanical Review. 1997; 63(3):199-220.
11. Nagai T, Kiyohara H, Munakata K, Shirahata T, Sunazuka T, Harigaya Y. *et al.* Pinellic acid from the tuber of *Pinellia ternata* Breitenbach as effective oral adjuvant for nasal influenza vaccine. International Immunopharmacology. 2002; 2:1183-1193.
12. Shirahata T, Sunazuka T, Yoshida K, Yamamoto D, Harigaya Y, Kuwajima I. *et al.* Total synthesis, elucidation of absolute stereochemistry, and adjuvant activity of trihydroxy fatty acids. Tetrahedron. 2006; 62:9483-9496.
13. Nagai T, Shimizu Y, Shirahata T, Sunazuka T, Kiyohara H, Omura S. *et al.* Oral adjuvant activity for nasal influenza vaccines caused by combination of two trihydroxy fatty acids stereoisomers from tuber of *Pinellia ternata*. International Immunopharmacology. 2010; 10:655-661.

14. Baur C, Grosch W, Wiesser W, Hugel H. Enzymatic oxidation of linoleic acid: formation of bittertasting fatty acids. Zeitschrift für Lebensmittel-Untersuchung und Forschung. 1977; 164(3):171-173.
15. Baur C, Grosch W. Investigation about taste of dihydroxy, trihydroxy and tetrahydroxy fatty acids. Zeitschrift für Lebensmittel-Untersuchung und Forschung. 1977; 165:82-84.
16. Esterbauer H, Schauenstein E. Isomeric trihydroxyoctadecenoic acids in beer – evidence for their presence and quantitative determination. Zeitschrift für Lebensmittel-Untersuchung und Forschung. 1977; 164:255-259.
17. Kuroda H, Kobayashi N, Kaneda H, Watari J, Takashio M. Characterization of factors that transform into di- and trihydroxyoctadecenoic acids in mash. Journal of Biosciences and Bioengineering. 2002; 93:73-77.
18. Andrew K. Farming Systems of the African Savana: A Continent in Crisis. International Development Research Centre, Canada. 1995, 125.
19. FAOSTAT. Cameroon FAOT STAT – Land Use and Agricultural Inputs. 2015.
20. Adayo F, Mukalama JB, Enyola M. Using *Tithonia* concoctions for termite control. Institute for Low external Input Agriculture Newsletter. 1997; 13(4):24.
21. Goffin E, Ziemons E, Mol P, Madureira MC, Martins AP, Cunha A. *et al. In vitro* antiplasmodial activity of *Tithonia diversifolia* and identification of its main active constituent: tagitinin C. Planta Medica. 2002; 68(6):543-545.
22. Shyur L-F, Tsung J-H, Chen J-H, Chiu C-Y, Lo C-P. Antioxidant properties of extracts from medicinal plants populary used in Taiwan. International Journal of Applied Science and Engineering. 2005; 3(3):195-202.
23. Olabode OS, Sola O, Akanbi WB, Adesina GO, Babajide PA. Evaluation of *Tithonia diversifolia* (Hemsl.) as gray for soil improvement. World Journal of Agricultural Sciences. 2007; 3(4):503-507.
24. Hutchings A, Scott AH, Lewis G, Cunningham AB. Zulu Medicinal Plants, an Inventory. University of Natal Press, Pietermarizburg.
25. Koduru S, Grierson DS, Afolayan AJ. Antimicrobial activity of *Solanum aculaestrum*. Pharmaceutical Biology. 2006; 44:283-286.
26. Koduru S, Grierson DS, Aderogba MA, Eloff JN, Afolayan AJ. Antioxidant activity of *Solanum aculeastrum* (Solanaceae) berries. International Journal of Pharmacology. 2006; 2:262-264.
27. Koduru S, Jimoh FO, Grierson DS, Afolayan AJ. Antioxidant activity of two steroid alkaloids extracted from *Solanum aculeastrum*. Journal of Pharmacology and Toxicology. 2007; 2:160-167.
28. Taiz L, Zeiger E. Plant Physiology. Sinauer Associates, Inc., Publishers, Sunderland, Massachusetts, USA. 2006, 764.
29. Saidana D, Ben Halima-Kamel M, Majoub MA, Hedal AN. Insecticidal activities of Tunisian halophytic plant extracts on larvae and adults of *Tribolium confusum*. Tropicultura. 2007; 25(1):193-199.
30. Fontem DA. Quantitative effects of early and late blights in tomato yields in Cameroon. Tropicultura. 2003; 2(1):36-41.
31. Aghofack-Nguemezi J, Christmann A, Frosch S, Trémolières A, Wagner E. Contrasting photo- and thermoperiods induced changes in abscissic acid and lipid contents in leaves of mungbean seedlings. Physiologia Plantarum. 1991; 83:346-352.
32. Walkley A, Black IA. An examination of Degtjareff method for determining soil organic matter, and proposed modification on the chromic acid titration method. Soil Science. 1934; 37:29-38.
33. Taiwo LB, Makinde JO. Influence of water extract of Mexican sunflower (*Tithonia diversifolia*) on growth of cowpea (Vigna unguiculata). African Journal of Biotechnology. 2005; 4(4):355-360.
34. Oyerunde RO, Otsunya OO, Akpor OB. Allelopathic effects of *Tithonia diversifolia* on the germination, growth and chlorophyll contents of maize (*Zea mays*). Scientific Research and Essay. 2009; 4(2):1553-1558.
35. Ojniyi So, Odedina SA, Agbede TM. Soil productivity improvement attributes of Mexican sunflower (*Tithonia diversifolia*) and siam weed (*Chromoleana odorata*). Emirat Journal of Food and Agriculture. 2012; 24(3):243-247.
36. García A, Delgad G. Constituents from *Tithonia diversifolia*. Stereochemical revision of 2α-hydroxytirotundin. Journal of Mexican Chemistry Society. 2006; 50(4):180-183.
37. Zhai H, Zhao G, Yang G, Sun H, Yi B, Sun L. *et al.* A new chromene glycoside from *Tithonia diversifolia*. Chemistry of Natural Products. 2010; 46(2):198-200.
38. Otusanya O, Olasupo I. Phytochemical screening and phytotoxic effects of *Tithonia diversifolia* (Hemsl.) A. Gray. International Journal of Biology. 2012; 4(3):97-101.
39. Zhao G, Li X, Chen W, Xi Z, Sun L. Three new sesquiterpenes from *Tithonia diversifolia*. and their anti-hyperglycemic activity. Fitoterapia. 2012; 3(8):1590-1597.
40. Ademiluyi BO, Omotoso SO. Comparative evaluation of *Tithonia diversifolia* and NPK fertilizer for soil improvement in maize (*Zea mays*) production in Ado Ekiti, Southwestern Nigeria. American Eurasian Journal of Sustainable Agriculture. 2007; 1(1):32-36.
41. Coe DG. The effects of various methods of applying fertilizers on crop and certain soil conditions. Retrospective Theses and Dissertations. 1924, Paper 14231, Iowa State University.
42. Yap CA. Impact of different fertilization methods on the soils, yield and growth performance of black pepper (*Piper nigrum* L.). Malaysian Journal of Soil Science. 2012; 16:71-87.
43. Boorboori MR, Eradatmand AS, Therant MM. Effects of micronutrient application by different methods on yield, morphological traits and grain protein percentage of barley (*Hordeum vulgare* L.) Revista Scientifíca UDO Agrícola. 2012; 12(1):127-134.