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Effect of seedling quality on growth, yield and quality of tomato (*Solanum lycopersicum* L.)

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Summary: A two trial greenhouse experiment was carried out at Rwanda-Israel Horticulture Centre of Excellence located at Mulindi Station to evaluate seedling quality on growth, yield and quality of tomato. The seedlings were grown in different growing media and produced seedlings with varying quality indices. The growing media of peat moss 100% (T2) and sand + goat manure + carbonized rice husks 50%: 10%: 40% (T8) were revealed in seedlings with the highest mean quality indices of 31 and 28 respectively, while sand 100% (T2) presented the lowest quality indices during both trials. The transplants were planted in polybags filled with 2:1 of topsoil and kitchen manure arranged in a randomized complete block design (RCBD) with four replications. Collected data were subjected to analysis of variance and means were separated using HSD test at a 5% level of significance. The results revealed that the seedlings grown in T1 (S1) and T8 (S8) consistently presented tomatoes with better growth performance and yield. S1 and S8 produced mean yield of 93.59 and 92.35 t/ha respectively while S2 had the lowest yield with 53.86 t/ha. The fruit produced from seedlings grown in T4 (S4) had the highest mean sugar acid ratio of 5.88 but not significantly different from 5.61 and 5.44 of S1 and S8 respectively. Hence, there was a positive relationship among seedling quality and growth and yield performance of tomato but not in fruit quality.

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Key words: fruit firmness, number of flowers, titratable acidity, tomato, total soluble solids, seedling quality

Introduction

Vegetables are mostly annual horticultural crops, with certain sections such as roots, flowers, fruits, stalks of leaves that can be wholly or partially consumed either cooked or raw (Welbaum, 2015). They are nutritious because they provide dietary fiber, vitamins and minerals and reduce risk of chronic diseases such as cardiovascular diseases, diabetes, cancer, and obesity (Septembre-Malaterre et al., 2018). This vegetable is a source of minerals such as phosphorus and iron, lycopene, beta-carotene, vitamins such as A and C, and a high amount of water and low calories (Asgedom et al., 2011).

Tomato is the most popular and widely grown vegetable in the world (Singh, 2015). It is the most important fruit vegetable due to its commercial and dietary value (Nicola et al., 2009). It is eaten raw in salads or an ingredient in many dishes and drinks and provides diverse nutrients and health-related benefits to the body (Arah et al., 2016). The global production of tomatoes has tremendously increased in the past five decades. The production was 27.6, 116.5 and 171 million tons in 1960, 2002 and 2014 respectively (Heuvelink, 2018). In Rwanda, the production of tomatoes has increased by almost 300% since 2008 (Niek et al., 2017) and its total production was 97,426 tons in 2017 (FAOStat, 2019).

The seedling phase is the basic phase of tomato growth and development especially earliness of production and number of the fruits per plant (Markovic et al., 1996). Quality seedlings have healthy foliage and good carbohydrate reserves, produce new roots quickly and they should not have any nutrient deficiency or pest and disease problems (Baudoin et al., 2013). Seedling quality is influenced by the pre-transplant nutritional conditions which enable the seedlings to better tolerate transplant stresses and enhance earliness (Melton & Dufault, 1991). It is related to good root development and a balanced shoot to root ratio and it is considered as key element in successful vegetable production (Tuzel et al., 2014). Hence, earliness of yield and total number of fruits per tomato plant is directly dependent on seedling quality (Basoccu & Nicola, 1994).

A good growing medium should provide plenty of plant nutrients for plant growth and development and contains a mixture which favours a seed to simply germinate, drains excessive water, and holds moisture (Olaria et al., 2016). The growing medium is also a source and reservoir of plant nutrients and anchors the root system and therefore supports the plant (Mathowa et al., 2016). Soil is the most important and easily available growing medium for plants which provides nutrients and moisture to plants necessary for their growth and development (NCERT, 2018). Furthermore, the addition of fertilizers and manures maintains its nutrients values which thereafter ensures the availability of nutrients to plants and sustains productivity, as well as the fertility of the soil (NCERT, 2018). Kitchen manure is composted domestic solid waste materials used as soil amendment in crop production (Chen & Jiang, 2014). When it is amended to soil, it modifies soil properties such as physical, chemical, and biological conditions resulting in the slow release of nutrients and increases crop yield (Oguntade et al., 2019).

Soilless culture is a method from which the plants are grown without the use of soils as a rooting medium and absorb inorganic nutrients by roots through irrigation water (El-Kazzaz & El-Kazzaz, 2017). This modern cultivation technology applied mainly in greenhouses to eliminate problems associated with the greenhouse soil, such as soil-borne diseases, poor soil fertility and salinity (Savvas & Gruda, 2018). This technology concerns the development of suitable growing media with optimal physical, hydraulic, and chemical properties and the advances in plant nutrition and irrigation via modern fertigation equipment and automation technologies (Gruda et al., 2018). Polybag culture is a containerized soilless culture system under which the medium materials are put into a polybags for excellent retention qualities for nutrients and water, less expensive and time-consuming to install and facilitates easy fertigation (Gruda, 2009). Like other soilless culture types, this culture offers unique benefits such as capabilities to control water availability, pH, and nutrient concentrations in the root zone (Silber & Bar-Tal, 2008). The current study was conducted into two trials and evaluated growth, yield and fruit quality of tomato as influenced by different seedling quality indices grown from different growing media formulated from the mixture of different ratios of sand, goat manure and carbonized rice husks.

Materials and methods

Study Site

The research was conducted at Rwanda-Israel Horticulture Center of Excellence located at Rwanda Agriculture and Animal Resources Development Board, Mulindi Station/ Kigali city. It is located in Runyonza village, Nyagahinga Cell, Rusororo Sector, Gasabo District of Kigali city, on longitude of 30º16'876''E, latitude of 02º00'417''S and at altitude of 1340 m above sea level (GPS coordinates).

Experimental procedure

Preparation and description of carbonized rice husks (CRH)

Carbonization of the rice husks was done outdoor with the following materials: a holed tin of 10 litre volume and metal chimney of 25 cm diameter, firewood, shovel, water, watering can, candle and box of matches. The firewood was filled in the tin and a chimney was fixed on the top of the tin. Fire was set on the woods inside the tin, and the rice husks was piled around the tin until half of the chimney was covered. As the rice husks next to the tin were turning black, they were frequently turned over to prevent them from complete burning to ash until all were carbonized. After carbonization, water was immediately sprinkled over the entire pile to avoid continuous burning (Sarian, 2008). Thereafter, the CRH was broken into pieces to reduce their size while increasing the chance of water and nutrient-holding capacity.

Preparation of peat moss, topsoil, sand and goat manure

Peatmoss was purchased from Holland Greentech-Rwanda. Goat manure was prepared from goat droppings. They were collected from loafing shed located around the Rwanda-Israel Horticulture Centre of Excellence (HCoE). Thereafter, they were air-dried until a constant weight was reached and then ground using a mortar. Sand was collected from Rusine river and sieved using 2 mm sieve to get medium to coarse sand (0.2-2 mm diameter). Thereafter, the obtained sand was washed to flush out any salt content and then air-dried to remove remained water. The top layer of soil of about 5-20 cm (Ahmed et al., 2016) was collected from a field located around the experimental site using diagonal sampling method to obtain a composite sample. Thereafter, it was air-dried for one week and then subjected to sterilization.

Formulation and characterization of growing media

The substrates: carbonized rice husks, goat manure, topsoil, sand and peat moss were applied either singly or in combination at different ratios to formulate a growing medium with optimum level for better growth of tomato transplants. The formulated growing media were peat moss 100% (T1), sand 100% (T2), top soil + goat manure 70%: 30% (T3), sand + goat manure + carbonized rice husks 50%: 50%: 0% (T4), sand + goat manure + carbonized rice husk 50%: 40%: 10% (T5), sand + goat manure + carbonized rice husk 50%: 30%: 20% (T6), sand + goat manure + carbonized rice husk 50%: 20%: 30% (T7), sand + goat manure + carbonized rice husk 50%: 10%: 40% (T8) and sand + goat manure + carbonized rice husk 50%: 0%: 50% (T9). All the growing media were sterilized by drying them in an oven at 120 °C for 2 days. Their physical and chemical properties are presented in ***Table 1***.

Planting Material

Tomato Shanty + PM (Powdery Mildiew resistant) seeds were used as a test crop. It is a semi-determinate saladette fruit type and cultivated in open field cultivation and greenhouse for all planting seasons. The plants are vigorous and producing firm fruits with attractive red colour and oval shape weighing from 100-150 g (Hazeraafrica, 2018). The seeds were purchased from Hazera-Rwanda.

Preparation of tomato transplants

The study evaluated nine treatments in a randomized complete block design with four replications. Each treatment was assigned to four cells of a propagation tray representing a single plot. The treatments used in this study were; peat moss 100% (T1), sand 100% (T2), top soil + goat manure 70%: 30% (T3), sand + goat manure 50%: 50% (T4), sand + goat manure + carbonized rice husk 50%: 40%: 10% (T5), sand + goat manure + carbonized rice husk 50%: 30%: 20% (T6), sand + goat manure + carbonized rice husk 50%: 20%: 30% (T7), sand + goat manure + carbonized rice husk 50%: 10%: 40% (T8) and sand + goat manure + carbonized rice husk 50%: 0%: 50% (T9) to produce seedlings; S1, S2, S3, S4, S5, S6, S7, S8 and S9 respectively.

Sowing for trial one was done on 05th January, 2020 and transplanted on 04th February 2020 while sowing for the second was done on 15th March, 2020 and transplanted on 13th April, 2020. Sowing was performed by placing one seed in each cell of propagation tray (black plastic propagation tray of 50 cm^3 volume hole) with a volume of 50 cm^3. The seeds were sown at a depth of 0.5 cm and 16 seeds were applied per treatment translating to 576 seeds for each trial. After sowing, the trays were placed on tray stands of 0.3 m height in the nursery greenhouse. Irrigation was done twice per day, the first in the morning and another, afternoon. Thereafter, at fifteenth day after sowing, fertigation was done uniformly across all treatments using NPK 19-19-19 with the concentration of 3 g/l for fifteen days.

Table 1. Physical and chemical properties (Means ± SD) of different formulated growing media.

Tr.	pH Water	EC (mS/cm)	K (meq/100g)	Tot. P (Ppm)	B. D. (g/cm^3)	Tot. N (%)	OM (%)	OC (%)	Porosity (%)
T1	5.8±0.21b	0.33±0.03fg	7.18±0.03a	600±4.54a	0.09±0.02c	0.18±0.02ab	89.70±0.42a	52.03±0.53a	90.00±2.16a
T2	6.8±0.28a	0.19±0.01g	0.26±0.02g	6.20±0.21g	1.53±0.02a	0.00±0.00e	0.48±0.05e	0.27±0.02e	42.42±0.66e
T3	6.9±0.21a	3.92±0.18b	2.82±0.24d	55.5±2.94f	1.08±0.05b	0.06±0.02cde	26.66±0.25b	15.46±0.57b	59.26±1.46bc
T4	6.7±0.21a	4.78±0.16a	4.36±0.34b	376.5±3.62b	1.16±0.04b	0.04±0.01de	27.2±1.31b	15.78±0.49b	56.28±2.81c
T5	6.7±0.43a	2.39±0.34d	3.85±0.36c	216±0.71d	1.08±0.08b	0.16±0.05ab	13.16±0.63c	7.63±0.94c	61.45±1.03b
T6	6.6±0.14a	3.34±0.24c	3.08±0.12d	302.5±3.19c	1.10±0.18b	0.06±0.03cde	7.74±0.30d	4.49±0.10d	48.49±1.08d
T7	6.8±0.18a	3.04±0.27c	2.31±0.20e	302.5±1.18c	1.09±0.02b	0.13±0.04bc	7.88±0.19d	4.57±0.37d	58.85±1.05bc
T8	6.5±0.18a	1.86±0.13e	2.05±0.06e	302.5±1.15c	1.17±0.05b	0.11±0.03c	7.57±0.42d	4.39±0.26d	55.96±0.87c
T9	6.8±0.21a	0.71±0.11f	1.28±0.04f	166.7±1.24e	1.16±0.06b	0.19±0.04a	6.77±0.16e	3.93±0.18d	56.32±0.48c
p	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

Treatment means followed by the same letter within a column are not significantly different according to Tukey's honestly significant difference test (HSD) at ($p \leq 0.05$). T1: Peat moss 100%, T2: Sand 100%, T3: Top soil + Goat manure 70%: 30%, T4: Sand + Goat manure 50%: 50%, T5: Sand + Goat manure + Carbonized rice husk 50%: 40%: 10%, T6: Sand + Goat manure + Carbonized rice husk 50%: 30%: 20%, T7: Sand + Goat manure + Carbonized rice husk 50%: 20%: 30%, T8: Sand + Goat manure + Carbonized rice husk 50%: 10%: 40% and T9: Sand + Goat manure + Carbonized rice husk 50%: 0%: 50%.

Determination of seedling quality

At 30 days after sowing, seedlings from each treatment were determined for their quality indices and recorded. Thereafter, healthy seedlings lot from each treatment was transplanted into the inside a greenhouse.

In calculation of the development quality index (IQD), the method of Dickson et al. (1960) was used considering the dry mass of shoots, roots and total dry mass, height and diameter of the lap of the seedlings using the formula:

$$\mathbf{IQD} = \frac{\mathbf{PMST}}{\frac{\boldsymbol{AP}}{\boldsymbol{DC}} + \frac{\boldsymbol{PMSPA}}{\boldsymbol{PMSR}}}$$

Where **IQD** = Dickson development index, **PMST** = total dry mass (g), **AP** = plant height (cm), **DC** = lap diameter (mm), **PMSPA** = dry weight of aerial part (g), and **PMSRA** = root dry mass weight (g).

Fresh shoot mass **(MFPA)** and roots **(MFR)** were obtained by separating the seedlings in aerial part and roots. Afterwards, the roots were washed in water; the parts were placed together and identified according to the treatment and taken for air drying until the constant weight is reached. Analytical balance with a precision of 0.001g was used to weigh dry mass of the aerial (**MSPA**) and roots (**MSR**) parts.

Formulation and preparation of growing media for transplanting

Growing media for tomato production was formulated from a mixture of soil and kitchen manure at a ratio of 2:1. The composite sample was sterilized by steam sterilization method which involves heating the sample by fire in enclosed system. Sterilization was done for eight hours counted after the temperature out of the chimney reaches at least 92 ^{o}C. Thereafter, the sample was left to cool for two days.

Experimental design, trial establishment and treatment application

The study evaluated nine treatments (seedlings grown from different formulated growing media) in a randomized complete block design with four replications. The individual experimental plots were 3.2 m long and 1 m wide, with 1m wide paths between them. There were a total of 4 beds considered as blocks each measuring 1 m x 28.8 m separated by 1.2 m path. Thirty days old, healthy and uniform tomato seedlings from each growing medium were transplanted into polybags of the height of 30cm and width of 40cm filled with growing media. Transplanting for trial one and two was carried out on 5th February 2020 and 12th April 2020 respectively. The treatments included: seedlings grown in peat moss 100% (S1), sand 100% (S2), top soil + goat manure 70%: 30% (S3), sand + goat manure 50%: 50% (S4), sand + goat manure + carbonized rice husk 50%: 40%: 10% (S5), sand + goat manure + carbonized rice husk 50%: 30%: 20% (S6), sand + goat manure + carbonized rice husk 50%: 20%: 30% (S7), sand + goat manure + carbonized rice husk 50%: 10%: 40% (S8) and sand + goat manure + carbonized rice husk 50%: 0%: 50% (S9).

Cultural practices, crop establishment and maintenance

Apart from the difference in applied treatments, all other cultural operations were uniformly done in all the experimental plots. Prior to transplanting, the experimental greenhouse was prepared mechanically by ploughing and creating beds. The greenhouse mean temperature was between 15 ^{o}C and 26.1 ^{o}C from 6AM to 9AM and 34.3 ^{o}C to 37.2 ^{o}C between 12PM and 14PM. Thereafter, the soil was covered by plastic sheets to suppress weeds, soil pests and diseases. Then, the polybags filled with soil mixed with compost as a growing media were placed on the plastic sheet. Tomato seedlings were transplanted in two rows in each block at spacing of 40 cm between rows and 40 cm within row giving a total of eight plants per treatment replicated four times translating to a total of 288 plants per trial. Irrigation was done immediately after

transplanting. Fertigation with 0.2 m^3 of water mixed with 224 g of NPK 19-19-19 was done from 3 days after transplanting until twenty first day. Thereafter, 0.3 m^3 of water mixed with 112 g of NPK 19-19-19 + 112 g of KNO_3 and 56g of urea was applied until harvesting stage. The fertigation was done at one-day interval while irrigation was done twice a day; one in the morning, another in the evening for 30 minutes for each single application. Foliar application of fungicide was done every week by alternating Copper oxychloride 50% WP and Ridomil® (mancozeb + metalaxyl) both with concentration of 50 g/l and insecticides such as Nimbecidine, Lambda Cyhalothrin, Imidacloprid and Abamectin with concentration of 2 g/l. Other cultural practices like weeding, and pruning were carried out conventionally across all treatments.

Data collection and analysis

Growth parameters

Plant growth parameters such as plant height and number of branches, number of internodes and stem collar diameter per plant were recorded every two weeks. The plant height was measured in meters (m) using a tape measure from the ground to the apex of top leaf from the second week after transplanting until the first harvest and number of branches was also counted. Stem collar diameter was measured at the base of the plant using vernier caliper and recorded in centimetres (cm).

Yield

Yield variables such as number of days taken to 50% flowering, number of trusses and number of flowers per truss, number of fruits and marketable and non-marketable fruits weight were recorded. The number of days taken to flower was counted when 50% of the plants in each treatment had at least one flower. The days obtained were used to compute the mean number of days to 50% flowering for different treatments. Number of trusses and flowers per truss was counted from the appearance of the first truss until the first harvest and individual flowers on each truss were also counted and recorded as number of flowers per truss. The fruits were harvested at breaker stage, physically counted and recorded as number of fruits per treatment. At the end of the experiment, fruits obtained from each treatment during various harvest days were summed up to obtain the total number of fruits for every treatment. For marketable and non-marketable fruit weight; at each harvest, the fruits from different treatments were separately weighed in g using an electronic balance which would be later converted in kg. The marketable fruits were obtained by removing the damaged fruits by insects, diseased, cracked, rotten, and undersized from the entire fruits per treatment. These fruits were then weighed and recorded in kg. Thereafter, the total weight for marketable fruits obtained from different harvest days for the same treatment were summed up after the last harvest then converted into kg per treatment. The non-marketable fruits weight was determined per treatment and then converted into kg. Thereafter, the yield was converted into tons per hectare (ha).

Fruit quality

The fruits of middle harvest were used to determine quality variables such as fruit firmness (kgF/cm^2), total soluble solids (TSS) (%Brix), titratable acidity (TA) and sugar acid ratio (SAR). To determine fruit firmness, eight tomatoes were harvested at the pink stage from each treatment and stored at room temperature until the uniform red ripe stage. Then, four fruits were randomly selected from each lot and fruit firmness was measured in the equatorial zone of each tomato using a hand- held penetrometer (Ritenour et al., 2002). Total soluble solids were determined on the same fruits used for the determination of fruit firmness using a hand- held refractometer (Majidi et al., 2011). Titrable acidity was determined as described by Majidi et al. (2011) using the same fruits and results were recorded in g/100 ml. SAR was determined by calculating the ratio of TSS and TA (TSS/TA).

Data analysis

The results of tomato growth yield and fruit quality parameters were subjected to analysis of variance (ANOVA). The general linear model (GLM) was used to determine whether the studied parameters from different formulated growing media were significantly different among them. Tukey's honestly significant difference test (HSD) was used to separate treatment means. These analyses were performed using the Statistical Analysis Software package, SAS software version 9.2 at 5% level of significance (SAS Institute, 2010). The fitted model for this experiment was:

$$y_{ijk} = \mu + T_i + \beta_j + \varepsilon_{ijk}$$

where; Y_{ijk} = Overall observations, μ = Overall mean, T_i = Effect due to *i*th treatment, β_k = Effect due to ***k*th** block, and ε_{ijk} = Random error term, ***i***: 1, 2, 3, 4, 5, 6, 7, 8 and 9 ***j***: 1, 2, 3 and 4.

Results

Plant height

The treatments significantly ($p \leq 0.05$) influenced tomato plant height from 30 days after transplanting (DAT) (***Table 2***). In trial one, the plant height was significantly different among treatments from 15 DAT to 60 DAT while in both trials. Plant height highly increased with time until 45DAT and reduced from 45 DAT to 60 DAT. In both trials, there was no significant difference among plots treated with S1, S8 and S9 on all days of observations. The lowest plant height was recorded in plots treated with sand alone in both trials.

Table 2. Seedling quality indices of different formulated growing media (Means ± SD) of tomato var. Shanty + PM.

Treatment	Trial 1	Trial 2
S1	0.32±0.03a	0.30±0.03a
S2	0.14±0.03c	0.14±0.03c
S3	0.19±0.07bc	0.20±0.06bc
S4	0.22±0.04abc	0.20±0.02bc
S5	0.22±0.02abc	0.23±0.04abc
S6	0.22±0.06abc	0.22±0.07abc
S7	0.23±0.06abc	0.22±0.04abc
S8	0.28±0.02ab	0.28±0.01ab
S9	0.22±0.01abc	0.24±0.01ab
***P*-value**	<.0047	<.0001

Number of branches

The treatments significantly ($p \leq 0.05$) influenced tomato number of branches from 30 days after transplanting (DAT) (***Table 2***). In both trials, the number of branches was significantly different among treatments from 15 DAT to 60 DAT. The number of branches increased with time and became almost constant between 45 to 60 DAT. In most cases, there was no significant difference among plots treated with seedlings grown in peat moss 100% (S1), sand + goat manure + carbonized rice husk 50%: 10%: 40% (S8) and sand + goat manure + carbonized rice husk 50%: 0%: 50% (S9) at 60DAT during all days of observations. In addition, there was the highest number of branches and no significant difference in plots treated with S1 and S8 in most cases in both trials. The lowest number was recorded in plots treated with sand alone in both trials during all days of observations.

Stem collar diameter

Collar diameter was increasing with time after transplanting and the speed in collar growth was highly reduced from 45DAT. The highest values in diameter with no significant difference were observed in plots treated with S1 (Seedlings grown in T1), S8 (Seedlings grown in T8) and S9 (Seedlings grown in T9) at 60 DAT while the lowest number was recorded in plots treated with sand alone in both trials during all days of observations. All studied treatments influenced ($p \leq 0.05$) number of internodes of tomato plant from 30 days after transplanting (DAT) (***Table 3***).

Mean values followed by different letters in the same column are significantly different according to Tukey's test ($p \leq 0.05$). Tr. Treatment, DAT: Days after transplanting. Seedlings raised in peat moss 100% (S1), sand 100% (S2), top soil + goat manure 70%: 30% (S3), sand + goat manure 50%: 50% (S4), sand + goat manure + carbonized rice husk 50%: 40%: 10% (S5), sand + goat manure + carbonized rice husk 50%: 30%: 20% (S6), sand + goat manure + carbonized rice husk 50%: 20%: 30% (S7), sand + goat manure + carbonized rice husk 50%: 10%: 40% (S8) and sand + goat manure + carbonized rice husk 50%: 0%: 50% (S9).

Number of flower trusses

The studied treatments did not differ ($p \leq 0.05$) in number of flower trusses at 15, 45 and 60 DAT in trial one and at 15 DAT in trial two. The highest values with no significant difference were observed in plots treated with S1, S8 and S9 while the lowest number was recorded in plots treated with S2 in both trials during all days of observations. The flower trusses increased with time after 30 days of transplanting (***Table 4***).

Number of flowers per truss

The evaluated treatments significantly influenced ($p \leq 0.05$) number of flowers per truss at all days of observations in both trials. In both trials, the treatments were significantly different in number of flowers per truss at 15DAT but indicated no significant difference for 30 to 60DAT. The plot treated with S1, S8 and S9 continued to reveal the highest values of all studied parameters while the lowest number was recorded in plots treated with sand alone in both trials during all days of observations (***Table 5***).

Total number of fruits, marketable and non marketable yield

The study showed that the treatments significantly ($p \leq 0.05$) influenced the number of fruits at all days of observations. The treatments revealed significant difference in number of fruits in both trials. Growing media formulated with S1, S8 and S9 continued to reveal the highest number of fruits while the lowest number was recorded in plots treated with sand alone in both trials during all days of observations. The treatments under study revealed a significant difference ($p \leq 0.05$) among them at all harvests of both trials. The plots treated with sand alone showed the lowest number of fruits and yield compared to other treatments while the ones treated with S1, S8 and S9 indicated the highest number of fruits and the highest yield in both trials during all days of observations. On another hand S3 indicted the highest number of non-marketable fruits which resulted in the highest non-marketable yield of 0.76 tonnes/ha which was not significantly different from 0.73 tonnes/ha produced from S3 (***Table 6***).

Fruit quality

There was a significant difference in all quality parameters studied as influenced by the treatments under study. In general, the plots treated with S8 and S9 and S1 showed the highest quality values of fruit firmness penetration (FFP), total soluble solids (TSS) and sugar acid ratio (SAR) compared to other treatments. On another hand, the plots treated with these above treatments indicated low value of titratable acidity (TA) as they followed the plots treated with S2, S3 and S4 in trial one. Their TA value increased in trial two but was not very high compared to other treatments. Generally, it was observed that seedling quality has not shown a correlated relationship with studied quality parameters of tomato fruits.

Discussion and conclusions

The longest plants with the highest number of branches and stem diameter obtained from seedlings with high quality indices; S1 with the mean values of 1.67 m, 5.90 and 1.48 cm followed by the plant produced from S8 with 1.67 m, 5.65 and 1.47 cm respectively which were not significantly different from the plants produced from S9 with 1.62 m, 5.75 and 1.43 cm while the shortest plants were observed from S2 with mean height of 1.35 m, number of branches of 4.37 and stem diameter of 1.04 cm. The significant differences observed among the growth parameters could be attributed to differences in quality of the seedlings. The performance observed from seedlings with poor quality might be due to nutrients applied and other crop maintenance practices done across all treatments during the study. These results are supported by Markovic et al. (1996) who stated that seedling phase is the basic in re-establishment in the field, growth and development because the seedlings with the highest and the lowest produced tomatoes with the height of 97.9 cm and 87.4 cm respectively. However, the growth performance observed in this study could be also attributed to the fertilizers used and greenhouse conditions such as temperature, light and CO_2 concentration. Nitrogen has an important effect on vegetative growth and development of tomato (Rao et al., 2014) which forms the base for flowering and fruiting (Aminifard et al., 2012). Phosphorus plays an important role in cell division, photosynthesis and tissue formation which thereafter improve plant growth (Singh, 2000)

Table 1. Stem collar diameter (cm) (Means ± SD) of tomato var. Shanty + PM grown in polybags inside the greenhouse.

		Collar diameter per plant			
Trial	**Treatment**	**15DAT**	**30DAT**	**45DAT**	**60DAT**
1	S1	0.55±0.02a*	1.17±0.02a	1.39±0.02a	1.50±0.02a
1	S2	0.33±0.01b	0.70±0.04e	1.00±0.08e	1.08±0.10e
1	S3	0.49±0.02a	0.83±0.02de	1.11±0.05d	1.24±0.04d
1	S4	0.46±0.02ab	0.83±0.04de	1.14±0.03cd	1.29±0.04cd
1	S5	0.55±0.17a	0.89±0.08cd	1.23±0.03bc	1.37±0.03bc
1	S6	0.49±0.02a	0.87±0.05cd	1.35±0.02a	1.39±0.01abc
1	S7	0.52±0.05a	1.02±0.12ab	1.32±0.02ab	1.42±0.03ab
1	S8	0.53±0.02a	1.15±0.12ab	1.37±0.06a	1.46±0.04ab
1	S9	0.52±0.02a	1.00±0.00bc	1.35±0.02a	1.45±0.04ab
	p	<.0022	<.0001	<.0001	<.0001
2	S1	0.56±0.16ab	1.22±0.02a	1.32±0.12a	1.46±0.10a
2	S2	0.35±0.02c	0.69±0.08c	0.86±0.09b	1.00±0.07c
2	S3	0.37±0.08bc	0.80±0.08c	0.99±0.05b	1.14±0.07bc
2	S4	0.42±0.05bc	0.85±0.08c	0.98±0.08b	1.16±0.29bc
2	S5	0.51±0.09abc	0.89±0.08bc	1.23±0.08a	1.37±0.05ab
2	S6	0.48±0.04abc	0.90±0.05bc	1.29±0.07a	1.38±0.04ab
2	S7	0.57±0.15ab	1.10±0.21ab	1.31±0.10a	1.43±0.04ab
2	S8	0.54±0.05abc	1.20±0.21a	1.38±0.02a	1.48±0.06a
2	S9	0.65±0.13a	1.15±0.05a	1.37±0.08a	1.42±0.05ab
	p	<.0165	<.0001	<.0001	<.0021

Mean values followed by different letters in the same column are significantly different according to Tukey's test ($p \leq 0.05$). Tr. Treatment, DAT: Days after transplanting. Seedlings raised in peat moss 100% (S1), sand 100% (S2), top soil + goat manure 70%: 30% (S3), sand + goat manure 50%: 50% (S4), sand + goat manure + carbonized rice husk 50%: 40%: 10% (S5), sand + goat manure + carbonized rice husk 50%: 30%: 20% (S6), sand + goat manure + carbonized rice husk 50%: 20%: 30% (S7), sand + goat manure + carbonized rice husk 50%: 10%: 40% (S8) and sand + goat manure + carbonized rice husk 50%: 0%: 50% (S9).

Table 4. Number of flower trusses (Means ± SD) of tomato var. Shanty + PM.

Trial	**Tr.**	**15DAT**	**30DAT**	**45DAT**	**60DAT**
1	S1	1.75±0.50a	4.43±0.12a	7.50±0.00a	9.56±1.66a
1	S2	1.00±0.00b	3.25±0.20bc	4.50±0.20c	5.06±0.12d
1	S3	1.00±0.00b	2.75±0.50c	4.75±0.35c	5.93±0.23cd
1	S4	1.17±0.11b	2.93±0.59c	4.75±0.35c	5.75±0.54cd
1	S5	1.31±0.12ab	2.75±0.20c	5.75±1.13b	6.56±0.62cd
1	S6	1.31±0.12ab	4.06±0.31a	5.87±0.25b	7.00±0.20bc
1	S7	1.18±0.12b	3.12±0.32c	5.87±0.14b	7.31±0.31bc
1	S8	1.37±0.14ab	4.50±0.00a	7.18±0.23a	8.50±0.00ab
1	S9	1.25±0.00b	4.00±0.00ab	7.31±0.23a	8.00±0.25ab
	p	<.0020	<.0001	<.0001	<.0001
2	S1	2.00±0.40a	4.87±0.25ab	7.56±0.12 a	9.56±1.63a
2	S2	1.25±0.23ab	3.43±0.12c	4.68±0.23 c	5.81±0.12d
2	S3	1.18±0.00b	3.25±0.20c	4.68±0.23 c	6.87±0.25bcd
2	S4	2.00±0.40a	4.25±0.28b	5.43±0.23 b	6.62±0.14cd
2	S5	1.50±0.20ab	3.56±0.12c	5.68±0.23 b	6.87±0.25bcd
2	S6	2.00±0.40a	5.37±0.32a	5.75±0.20 b	7.00±0.28bcd
2	S7	2.00±0.40a	4.75±0.20ab	5.81±0.12 b	7.50±0.20bc
2	S8	1.68±0.23ab	5.00±0.20a	7.18±0.23 a	8.31±0.12ab
2	S9	1.50±0.20ab	5.12±0.43a	7.25±0.20 a	8.31±0.12ab
	p	<.0046	<.0001	<.0001	<.0001

Mean values followed by different letters in the same column are significantly different according to Tukey's test ($p \leq 0.05$). Tr.: Treatment, DAT: Days after transplanting.

Seedlings raised in peat moss 100% (S1), sand 100% (S2), top soil + goat manure 70%: 30% (S3), sand + goat manure 50%: 50% (S4), sand + goat manure + carbonized rice husk 50%: 40%: 10% (S5), sand + goat manure + carbonized rice husk 50%: 30%: 20% (S6), sand + goat manure + carbonized rice husk 50%: 20%: 30% (S7), sand + goat manure + carbonized rice husk 50%: 10%: 40% (S8) and sand + goat manure + carbonized rice husk 50%: 0%: 50% (S9).

Table 5. Number of flowers per truss (Means ± SD) of tomato var. Shanty + PM.

Trial	Tr.	15DAT	30DAT	45DAT	60DAT
1	S1	1.75±0.20a	3.87±0.14a	4.87±0.85a	5.87±0.59a
1	S2	0.62±0.25d	2.43±0.23c	3.18±0.23c	4.18±0.23c
1	S3	0.75±0.20cd	2.56±0.12bc	3.50±0.35bc	4.50±0.00c
1	S4	0.93±0.23cd	2.62±0.25bc	3.25±0.50c	4.25±0.00c
1	S5	1.00±0.20cd	3.25±0.50ab	4.37±0.12ab	4.57±0.11c
1	S6	1.00±0.00cd	3.12±0.14abc	4.43±0.23ab	4.93±0.12bc
1	S7	1.50±0.20ab	2.62±0.75bc	4.50±0.20a	4.93±0.31bc
1	S8	1.18±0.23bc	3.00±0.00bc	4.75±0.20a	5.75±0.35a
1	S9	1.06±0.12bcd	3.18±0.23abc	4.81±0.31a	5.43±0.42ab
	p	<.0001	<.0001	<.0004	<.0001
2	S1	1.56±0.12a	4.12±0.14a	5.00±0.00a	6.18±0.23a
2	S2	0.56±0.12d	2.87±0.25d	4.00±0.20d	4.43±0.12e
2	S3	0.81±0.23cd	2.93±0.31cd	4.25±0.20cd	4.56±0.31e
2	S4	0.81±0.23cd	2.93±0.65cd	4.37±0.43bcd	4.75±0.28de
2	S5	1.00±0.00bcd	3.50±0.20abcd	4.50±0.00abcd	4.81±0.12cde
2	S6	1.25±0.20abc	3.00±0.20bcd	4.50±0.00abcd	4.87±0.14cde
2	S7	1.37±0.14ab	3.50±0.45abcd	4.56±0.12abc	5.25±0.54bcd
2	S8	1.31±0.31ab	3.81±0.23abc	4.93±0.12a	5.87±0.25ab
2	S9	1.12±0.14abc	3.87±0.43ab	4.87±0.25ab	5.43±0.42b
	p	<.0001	<.0024	<.0002	<.0001

Mean values followed by different letters in the same column are significantly different according to Tukey's test ($p \leq 0.05$). Tr.: Treatment, DAT: Days after transplanting.
Seedlings raised in peat moss 100% (S1), sand 100% (S2), top soil + goat manure 70%: 30% (S3), sand + goat manure 50%: 50% (S4), sand + goat manure + carbonized rice husk 50%: 40%: 10% (S5), sand + goat manure + carbonized rice husk 50%: 30%: 20% (S6), sand + goat manure + carbonized rice husk 50%: 20%: 30% (S7), sand + goat manure + carbonized rice husk 50%: 10%: 40% (S8) and sand + goat manure + carbonized rice husk 50%: 0%: 50% (S9).

Table 6. Total number of fruits, marketable and non-marketable yield (t/ha) of tomato var. Shanty + PM (Means ± SD) grown in polybags inside the greenhouse.

Trial	Treatment	Total number of fruits	Marketable yield	Non marketable yield
1	S1	155.75±9.21a	92.62± 6.20a	0.03±0.02c
1	S2	89.25±9.18c	53.86±4.77d	0.75±0.17a
1	S3	113.25±10.34bc	70.95±7.18bcd	0.76±0.12a
1	S4	98.50±8.70bc	61.85±3.51cd	0.69±0.14a
1	S5	108.50±12.77bc	72.04±7.69bcd	0.46±0.24ab
1	S6	111.75±11.73bc	68.89±5.68cd	0.46±0.22ab
1	S7	118.25±4.35b	81.20±9.05abc	0.29±0.16b
1	S8	150.25±6.07a	92.16±4.67a	0.05±0.03c
1	S9	148.75±12.92a	85.75±8.77ab	0.09±0.08bc
	p	**<.0001**	**<.0001**	**<.0001**
2	S1	173.00±27.87a	94.57±5.57a	0.09±0.05bc
2	S2	90.00±6.68c	53.86±4.86d	0.77±0.20a
2	S3	111.75±7.23bc	72.14±8.43bcd	0.71±0.12a
2	S4	102.75±9.57c	67.64±13.64cd	0.66±0.09a
2	S5	110.25±8.18bc	68.51±9.78bcd	0.64±0.32a
2	S6	115.00±17.66bc	68.83±6.18bcd	0.44±0.20ab
2	S7	125.00±16.79bc	76.30±4.26abc	0.16±0.10b
2	S8	147.00±20.41ab	92.55±7.03a	0.06±0.02c
2	S9	144.50±17.00ab	82.51±5.05ab	0.10±0.04bc
	p	**<.0001**	**<.0001**	**<.0001**

Mean values followed by different letters in the same column are significantly different according to Tukey's test ($p \leq 0.05$).
Tr.: Treatment, DAT: Days after transplanting. Seedlings raised in peat moss 100% (S1), sand 100% (S2), top soil + goat manure 70%: 30% (S3), sand + goat manure 50%: 50% (S4), sand + goat manure + carbonized rice husk 50%: 40%: 10% (S5), sand + goat manure + carbonized rice husk 50%: 30%: 20% (S6), sand + goat manure + carbonized rice husk 50%: 20%: 30% (S7), sand + goat manure + carbonized rice husk 50%: 10%: 40% (S8) and sand + goat manure + carbonized rice husk 50%: 0%: 50% (S9).

while potassium helps in vigorous tomato growth and stimulates early flowering and fruit setting (Fandi et al., 2010).

The seedlings with the highest quality indices produced the highest mean yield of 93.59 tonnes/ha (S1) which was not significantly different from 92.35 tonnes/ha of S8 which showed also better quality index value at transplanting time while S2 produced 53.86 tonnes/ha. This is supported by Markovic et al. (1996) whose study revealed that the highest tomato yield has been achieved with seedlings with the highest quality and vice-versa where the seedling with the highest quality produced the mean yield of 47.6 tonnes/ha while the seedlings with the lowest quality revealed in 32.3 tonnes/ha. These results are supported Basoccou et al. (1995) who stated that seedling quality is a fundamental parameter in production of tomato plant as it positively influences tomato yield especially early yield and number of fruits per plant and enhance total production of tomato plant (Markovic et al., 1996). On another hand, the yield performance observed in this study could be influence by the fertilizers containing major elements such as nitrogen, phosphorus and potassium because the availability, acquisition, mobilization and influx of essential nutrients into the plant tissues improve numbers of flowers and fruits per truss of tomato plant (Shukla et al., 2009). Nitrogen accelerates protein synthesis, photosynthesis and carbohydrate production which thereafter promotes floral primordia development (Kumar et al., 2013). Phosphorous stimulates healthy root growth which helps in better utilization of water and nutrients which, thereafter, promote a strong stem and foliage growth, producing large number of flower and early fruit setting (Sainju et al., 2003) while potassium helps in vigorous tomato growth and stimulates early flowering and fruit setting (Fandi et al., 2010).

Seedling quality did not relatively influence fruit quality characteristics because there was no correlation between these parameters during this study. This is explained by no significant difference observed in fruits firmness among seedlings with low and high quality indices because they all produced fruits with acceptable firmness range of between 1.31-1.78 kg/cm^2 as stated by Batu (2004) while marketable tomato fruits should have at least a firmness value of not below 1.22 kg/cm^2 though it mainly depends on variety (Markovic et al., 1996). In addition, all seedlings with different quality indices produced sweet fruits with acceptable range of consumers' preference at European market of TSS and TA with values of between 3.5-5.5 and <10% respectively (Yara, 2021). This is supported by Basoccou & Nicolas (1995) who proved that seedling quality influenced fruit size but not quality parameters. The fruit quality parameters observed in this study may be influenced by a grown tomato variety rather than seedling quality. This is supported by Markovic et al. (1996) who proved that quality of tomato is mainly influenced by variety. Fruit quality could be also influenced by applied fertilizers through fertigation. The nitrogen contributes to fruiting and productivity but it can decrease fruit firmness (Almeida et al., 2019). Furthermore, the performance in firmness may be due to EC or Ca presence in the growing medium. Calcium maintains cell wall, particularly the middle lamella structure because it binds to pectic substances resulting in maintaining tissue integrity (Papadopoulos, 2003). Potassium has an influence in TSS content in tomato fruits because K plays an important role in the configuration of tomato fruit quality (Truong et al., 2018).

The studied seedling quality significantly influenced growth, yield and quality of tomato var. Shanty + PM grown during this study. The best growth and yield of tomato were obtained from S1 with no significant difference with S8. This study revealed seedling quality has a positive relationship with growth and yield of tomato but not with fruit quality of tomato.

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