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Effect of seed treatments and mulch on seedborne bacterial pathogens and yield of tomato (*Solanum lycopersicum* Mill.) in Tanzania

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Key words
Tomato, seedborne bacteria, bacterial spot, bacterial canker, bacterial speck, mulch

1 SUMMARY

The study was conducted to assess the presence of seedborne bacteria in four tomato seedlots, the efficacy of seed treatments in reducing bacterial contamination and to determine influence of seed treatment or mulch on crop development and yield. Tomato seedlots were treated using hot water, chlorine, and Ridomil® followed by seedborne bacteria pathogen detection. Seedlings from treated and non-treated seedlots were grown in the field in mulched and non-mulched plots. Results showed that all seedlots assessed were contaminated with *Clavibacter michiganensis* subsp. *michiganensis* (CMM), *Xanthomonas campestris* pv. *vesicatoria* (XCV) and *Pseudomonas syringae* pv. *tomato* (PST). 'Tanya G_1', 'Tanya G_2' (first and second generation farmer-saved seeds respectively) and commercial 'Cal J' seedlots were more highly contaminated with XCV than commercial 'Tanya' seedlot. 'Tanya G_2' had the highest PST contamination but did not differ from other seedlots for CMM. Chlorine and hot water significantly reduced bacterial populations on seeds. Ridomil seed treatment did not affect bacterial contamination compared to the untreated control. Marketable fruit yield differed statistically (P = 0.01) for commercial 'Tanya' and 'Cal J' seedlots. Commercial 'Tanya' and 'Tanya G_1' had higher yields compared to 'Cal J' and 'Tanya G_2'. There was no statistical difference (P = 0.05) among seed sources with respect to incidence of blossom end rot (BER) and sunscald disorders. Chlorine and hot water treatments led to higher number of fruits per plant and increased yield compared to Ridomil treatment and the control. Seed treatment had no significant influence on BER. Plants from hot water treatment produced statistically fewer sunscald fruits compared to control, because of more vigorous growth that provided protective shade. The effect of mulch on the yield components and in reduction of sun-scalded fruits was highly significant (P = 0.0001). Seed treatment and mulch therefore can reduce disease infestation and improve tomato yield.

2 INTRODUCTION

Tomato is one of the most important vegetable crops in Tanzania. Its production is widespread in the country with a total annual production of more than 145,000 tons (FAO, 2007). In the Morogoro region of Tanzania in East Africa, production is mainly undertaken by resource limited small-scale farmers who, as a common practice, use farmer-saved tomato seeds of unknown quality extracted from a previous crop to raise the next crop. The use of seeds of unknown quality is reported to contribute to reduced yields at harvest (Caseiro *et al.*, 2004) and constitute an important route for disease transmission (Miller *et al.*, 1996; Massomo *et al.*, 2003; Kaaya *et al.*, 2003). Poor quality seeds lead to poor crop establishment, increased susceptibility to diseases and subsequently low yields (Wien *et al.*, 1997).

In the Morogoro region, most small-scale farmers extract seeds from fruits that are not marketable (e.g. rotting fruits and those with other defects). According to Dias *et al.* (2006) the quality of such seeds is likely to be compromised. Seed maturity has been shown to have influence on both quality and sensitivity of seeds to physical sanitation treatments (Groot *et al.*, 2006). Even seeds obtained from the same plant, and harvested from different trusses have been found to differ in quality characteristics (Dias *et al.*, 2006).

Bacterial canker, bacterial spot and bacterial speck of tomato caused by *Clavibacter michiganensis* subsp. *michiganensis* (CMM), *Xanthomonas campestris* pv. *vesicatoria* (XCV) and *Pseudomonas syringae* pv. *tomato* (PST) are common diseases affecting tomato in most producing areas in Tanzania (Shenge *et al.*, 2007). These pathogens are effectively transmitted through contaminated seeds (Jardine *et al.*, 1988; Miller *et al.*, 1996;; Shenge *et al.*, 2007). Bacterial leaf spot of tomato has been reported to be a major problem in tomato growing areas where high temperature and moist conditions prevail (Ward and O'Garro, 1992; Jones *et al.*, 1995). CMM, PST and XCV are seedborne and can overwinter on plant debris, in soil and on the roots of many perennial plants (Jardine *et al.*, 1988; Fatmi and Schaad, 2002). There is no official set of regulations in Tanzania to test tomato seeds for seedborne pathogens, which often results in severe crop losses and the spread of potentially diseased seeds to new production regions (Mortensen and Mabagala, 1996; Umesha, 2006). Very low levels of seedborne inoculum may lead to extremely high field incidence when the weather is favorable for disease development (Umesha, 2006). The earlier a pathogen comes in contact with the crop, the greater the potential for a serious disease problem to develop which makes it crucial to start with clean seeds (Lewis Ivey and Miller, 2005). Bacterial diseases are difficult to control but various measures have been suggested to manage them. These include use of (1) certified disease-free seeds; (2) resistant cultivars; (3) healthy transplants (4) biocontrol agents and seed treatment (Hausbeck *et al.*, 2000; Lewis Ivey and Miller, 2005; Umesha, 2006)

Seed treatment is considered an essential tool in integrated pest management. An effective seed treatment can eliminate or reduce the need to use fungicides or bactericides later in the season (Babadoost, 1992). Both hot water and sodium hypochlorite (2%) seed treatments have been shown to be effective in reducing bacterial pathogen contamination of vegetable seeds, but occasional reductions in seed germination rate with hot water treatment have also been observed (Miller and Lewis Ivey, 2005; Lewis Ivey and Miller, 2005). Treating seeds with 1% sodium hypochlorite for between 5 and 20 minutes has been shown effective in reducing the incidence of bacterial diseases without affecting the germination percentage of lettuce seeds (Sahin and Miller, 1997; Carisse *et al.*, 2000; Pernezny *et al.*, 2002).

This study was conducted to assess the presence of seedborne bacteria in four different tomato seedlots, evaluate the efficacy of seed treatments in reducing bacterial contamination and determine any influences of seed treatment or mulch on crop development and yield

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3 MATERIALS AND METHODS

3.1 Seed procurement: Seed extraction was done from tomato fruits obtained from farmers who stipulated how many times seeds had been saved from consecutive tomato crops beginning with the crop produced from commercial seeds. A crop established from commercial seeds was designated "G_1" and gave "G_1" seeds. A tomato crop established from 'G_1' seeds was designated 'G_2', and gave 'G_2' seeds (Fig. 1).

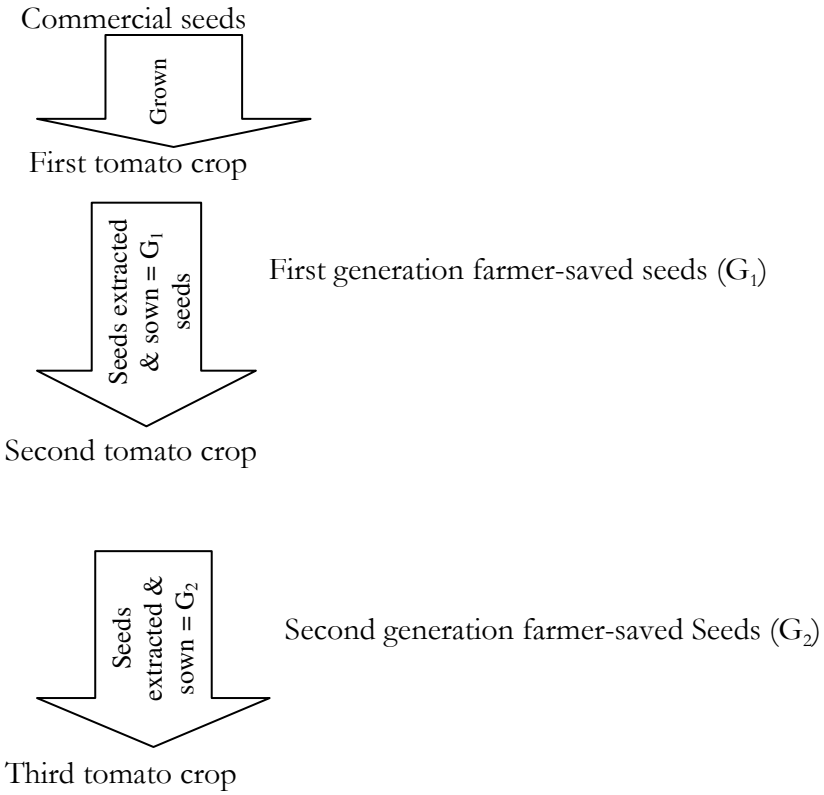

Figure 1: Illustration showing how small-scale farmers in the Morogoro region, Tanzania save seeds from previous tomato crop

Fully ripened 'G_1' and 'G_2' tomato fruits were collected from selected farmers' fields and transported to the Sokoine University of Agriculture laboratories for seed extraction. Both healthy looking fruits and those with symptoms of disease were included. The fruits were punctured and most of the pulp and seeds removed by hand. The mixture was fermented in a plastic bin at room temperature (28°-30°C) for 48h. Seeds were separated from the pulp, washed by hand and surface dried at room temperature (28°-30°C) for 4days (Opeña *et al.*, 2001). After drying, seeds were placed in labelled paper envelopes and stored at 20°C and 20% Relative Humidity until they were used for evaluation. Commercial seeds coated with Thiram® (1-(dimethylthiocarbamoyldisulfanyl)-N, N-dimethyl-methanethioamide) were obtained from open market seed vendors in the Morogoro municipality. Commercial cultivars, 'Tanya VF' and 'Cal J VF', which are the two most commonly grown cultivars in the Morogoro region and reported to be susceptible to bacterial leaf spot, bacterial speck and bacterial canker diseases were used (Shenge *et al.*, 2007). The 'Tanya' seedlot was packed on July, 2006 and had a labelled germination percentage of 94% and 99.9% purity. The 'Cal J' seedlot was packed on January, 2006 with labelled germination percentage of 89% and 99.9% purity. All seeds were stored in an incubator (FIRLABO.sa, 69330 Meyzieu France) at 20°C and approximately 20% relative humidity until evaluation.

3.2 Experiment I

3.2.1 Seed treatments: Two sanitizing seed treatments, namely hot water and sodium

hypochlorite were performed. For hot water treatment, 20g seed samples were wrapped in a cotton cloth and pre-warmed in water at 37°C for ten minutes then placed in a water bath at 50°C for 25 minutes. After treatment, the seeds were cooled under cold tap water (10°C) for 5 minutes to stop the heating action and then dried for 48h at room temperature of 25°C (Babadoost, 1992; Boucher *et al.*, 1997; Lewis Ivey and Miller, 2005). Locally available chlorine, (Jik®- 3.5% sodium hypochlorite by Reckitt Benckiser, East Africa Limited, was used to treat the seeds. The Jik® was diluted with distilled water to 2% sodium hypochlorite (100mls Jik®:175mls distilled water). Seed samples (20g each) were soaked in the solution at room temperature and agitated for 5 minutes, rinsed thoroughly in running tap water (10°C) for 5 minutes and then dried at room temperature as described above. Seedlots were also treated with Ridomil 68WP® (Zinc ion and manganese-ethylene-bis-dithio carbamate), a fungicide effective against oomycetes. Twenty grams of seeds were mixed with 0.2g of the fungicide in a flask with 150 ml water. The mixture was shaken by hand until the walls of the flask were free of fungicide followed by seed drying as described above.

3.2.2 Pathogen detection: Seed samples weighing 12g were placed into plastic bags containing 100 ml peptone buffered saline (PBS) and 0.02 ml of Tween 20 (Kaaya et al., 2003). The mixture was incubated for 15 minutes at 4oC and then shaken vigorously in a stomacher (Bag Mixer™, Interscience; 78860 St Nom, France). Three times 1:10 serial dilutions were prepared with sterile PBS buffer as diluent. Using a glass rod, 0.05 ml of undiluted and diluted seed extract suspensions were spread onto each of three petri plates of tryptic soy agar (TSA), pseudomonas F (PF) and yeast dextrose carbonate (YDC) media. Standard pathogen cultures were obtained from the African Seed Health Center (ASHC), Sokoine University of Agriculture, for comparison. The standard cultures were IPO 542, NCPPB 170 DGISP and NCPPB 422 for CMM, PST and XCV respectively. The inoculated plates were incubated at 27+ 1oC for 4days. Petri plates were divided into four quadrants using a marker pen and colony counts were performed with an aid of a counter clock based on morphological characteristics compared to the pathogen standard cultures.

To confirm pathogen identification, one distinct representative colony of each suspected bacterial genus was picked from each plate and streaked on different petri plates containing YDC medium for XCV and CMM, and PF medium for PST. Purified cultures of CMM and XCV were inoculated onto nutrient agar and PST on Kings B media for biochemical tests. Four biochemical tests were conducted, which included Arginine dehydrolase, Kovac's oxidase test, gram reaction (KOH solubility test) and nitrate reduction according to the procedures described by Mortensen (2000).

3.3 Experiment II

3.3.1 Nursery establishment: Seedlings were raised at the Horticultural Unit at Sokoine University of Agriculture, Morogoro (6°05'S, 35°37'E and 525m above sea level). Seeds were subjected to one of four treatments; hot water, chlorine, Ridomil 68WP or untreated as control and sown on light sterile soil media. Seedlings were pricked 5 days after emergence then grown further on soil blocks in a greenhouse with sunscreen netting which allowed 60% of the sunlight to pass through. Seedlings were transplanted to the field 3 weeks after pricking.

3.3.2 Field establishment: The field study was conducted in Mlali village in Mvomero District, at 600 m.a.s.l. The field was slashed, disc ploughed and hand harrowed to remove plant debris and break large soil clods before seedbed preparation. Sunken beds of 500cm×360cm were prepared using hand hoes. Seedlings were transplanted into the beds at a spacing of 90cm between rows and 60cm between plants with four rows per bed and 32 plants per plot. Dry grass (Panicum sp.) was applied as mulch one day after transplanting. The grasses were 25cm long, laid down by hand at a thickness of 15cm, making sure the soil was completely covered.

Nitrogen fertilizer in the form of urea was applied at a rate of 55.2kgN ha-1 two weeks after transplanting. Plants were irrigated individually with water pumped from a nearby river once a week using a hose pipe with a shower nozzle attached at the end. Ivory 80WP® (mancozeb) and Karate® (lambda cyhalothrin) were sprayed at the dosage rates of 3 g/l two times and 2 ml/l three times respectively during the growing season to control fungal diseases and insect pests respectively. The treatment factors comprised; Mulching (two levels), seed treatments (four levels) and seed sources (four levels) combined in a 2×4×4 factorial arrangement in a randomized complete block design with three replications each with 32 plots. Yield estimates were

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made based on harvests from eight plants from the middle two rows of each bed. Fruits were harvested in the morning and sorting was done by the same person for the four harvests. Blossom end rot (BER) and sunscald-affected fruits were recorded and discarded. Marketable yield was calculated based on fruit quality accepted by the local vegetable vendors.

3.3.3 Data analysis: Data analysis was carried out using SAS Statistical Package (SAS Institute Inc; Cary, NC, USA.). Analysis of variance (ANOVA) was performed and when significant differences existed ($P<0.05$), the Least Significant Difference (LSD; $\alpha=0.05$) test was used as a means separation procedure.

4 RESULTS AND DISCUSSION

The four biochemical tests conducted to assess the presence of seedborne bacteria on tomato seedlots used in our study revealed the presence of the detected pathogens XCV, CMM and PST but gave negative results for oxidase, arginine dehydrolase and nitrate reduction tests. With exception to CMM, which was gram positive, XCV and PST were gram negative. The commercial 'Tanya' tomato seedlot had the least XCV contamination while 'Tanya G_2' was more highly contaminated with PST than the other seedlots (Table 1).

Table 1: Populations of *Clavibacter michiganensis* subsp. *michiganensis* (CMM), *Xanthomonas campestris* pv. *vesicatoria* (XCV) and *Pseudomonas syringae pv. tomato* (PST) from four tomato seed sources.

Seed source	Colony counts (CFU/g of seed)		
	XCV (spot)	PST (speck)	CMM (canker)
Commercial 'Tanya'	1.8×10^{2} b	5.5×10^{5} b	1.9×10^{4} ns
'Tanya G_1'	2.9×10^{3} a	4.8×10^{5} c	1.1×10^{4} ns
'Tanya G_2'	3.9×10^{3} a	6.7×10^{5} a	5.3×10^{4} ns
Commercial 'Cal J'	3.6×10^{3} a	4.6×10^{5} c	4.3×10^{4} ns
Mean	2.6×10^{3}	5.5×10^{5}	3.2×10^{4}
C.V (%)	61.5	11.5	168.9

Means followed by the same superscript are not statistically significant different ($p\leq 0.05$) column by LSD
CFU = Colony forming units; Log transformation was done prior data analysis; ns= Not significantly different

CMM contamination was high but not significantly different among the seed sources ($p=0.2172$) and the Coefficient of Variation value was high compared to that of other pathogens, indicating a high degree of variation among seedlots. The high PST contamination rate of 'Tanya G_2' seedlot can be one of the reasons why the seedlots led to seedlings with low vigor, poor survival in the field (data not shown) and low marketable yields (Table 3).

Table 2: Effect of tomato seed treatments on *Clavibacter michiganensis* subsp. *michiganensis* (CMM), *Xanthomonas campestris* pv. *vesicatoria* (XCV) and *Pseudomonas syringae* pv. *tomato* (PST) contamination.

Seed treatment	Colony counts (CFU/g of seed)		
	XCV (spot)	PST (speck)	CMM (canker)
Hot water	2.5×10^{1} b	1.0×10^{4} b	4.8×10^{2} b
Chlorine	4.2×10^{1} b	9.0×10^{3} b	1.4×10^{3} b
Control	5.0×10^{3} a	1.1×10^{6} a	7.1×10^{4} a
Ridomil	5.5×10^{3} a	1.1×10^{6} a	5.4×10^{4} a
Mean	2.6×10^{3}	5.5×10^{5}	3.2×10^{4}
CV (%)	61.5	11.5	168.9

Means followed by the same superscript are not statistically significant different ($p\leq 0.05$) column by LSD
CFU = Colony forming units; Log transformation was done prior data analysis. The bacterial populations were averaged over four seedlots

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Table 3: Effects of seed source on tomato fruit yield parameters and fruit disorders

Seed lots	Marketable fruit number plant^{-1}	Average fruit wt (g)	Marketable yield (t/ha)	Marketable yield (%)	BER (t/ha)	SS (t/ha)
Commercial Tanya	15^{ab}	54.1^{ab}	18.2^{a}	53.4	10.1^{ns}	5.8^{ns}
Tanya G_1	17^{a}	52.5^{ab}	20.3^{a}	56.4	10.6^{ns}	5.1^{ns}
Tanya G_2	13^{b}	56.2^{a}	15.7^{b}	49.2	9.8^{ns}	6.5^{ns}
Commercial Cal J	13^{b}	49.0^{b}	14.5^{b}	48.6	9.0^{ns}	6.4^{ns}
Mean	15	52.9	17.2	51.9	9.9	6.0
CV (%)	38.70	21.36	38.60	-	48.76	50.38

Means followed by the same superscript are not statistically significant different ($p \leq 0.05$) column by LSD, t/ha = Tones per hectare; LSD = Least significant difference; BER = Blossom end rot; SS = sunscald

The results suggest the frequency of seed extraction does have a significant effect on PST bacterial contamination and consequently yield.

In this study, the effectiveness of hot water and chlorine in reducing XCV, PST and CMM was similar (Table 2). Hot water and chlorine seed treatments significantly reduced contamination on the seeds by bacteria XCV (p=<.0001), PST (p=<.0001) and CMM (p=0.0074) (Table 2). These results are in agreement with findings by Lewis Ivey and Miller (2005) who reported that seedlings from tomato seedlots that were hot water treated did not become diseased in the greenhouse or field, and bacterial pathogens were not detected. Nega *et al.* (2003) and Carisse *et al.* (2000) found similar effect of hot water seed treatment in eliminating *Xanthomonas campestris* in contaminated vegetable seeds.

Sahin and Miller (1997; Carisse *et al.* (2000) and Pernezny *et al.* (2002)) reported that chlorine effectively reduced *Xanthomonas campestris* pv. *vitians* contamination of lettuce seeds. These findings agree with our results in which tomato seed treatment with 2% sodium hypochlorite significantly reduced bacterial contamination. The populations of plant pathogenic bacteria on Ridomil-treated seeds were not significantly different (P = 0.05) from those of the control samples (Table 2). Previous experiments showed that hot water and chlorine seed treatments resulted in seedlings with higher vigor, reduced bacterial leaf spot and bacterial speck incidence compared to Ridomil treated seedlots, which were the same as the untreated control (data not shown). There were highly significant interactions between tomato seedlots and seed treatments for reduction of PST (p=0.0001) and XCV bacterial contamination (p=0.004) suggesting that the seed treatments played a significant role on reducing PST and XCV contamination.

The results clearly indicate that hot water and chlorine seed treatments led to a reduction in bacterial contamination on tomato seeds. These two seed treatments can be effectively applied by small-scale tomato growers in the Morogoro region of Tanzania and elsewhere since they involve locally available materials. Further studies are needed to investigate other locally available materials for their potential use in seed treatment. Botanicals such as Neem, (*Azadirachta indica*) have shown beneficial effects on control of insects and nematodes (Rahman *et al.*, 2003; Ahmad *et al.*, 2004) and may have potential for use as seed treatment.

Effective seed treatment will reduce bacterial contamination on seeds, disease severity in the crop (Table 2) and lead to gains in yield. In addition, it may be possible to reduce pesticide sprays, which will be economically beneficial to the farmers as well as protect the environment from pesticide abuse. Effective seed treatments can reduce the introduction of these pathogens into relatively disease pathogen-free areas through the movement of contaminated seeds.

Fruit yield differed significantly among different seed sources (Table 3). 'Tanya G_1' produced the highest number of marketable fruits per plant but non significantly different (P = 0.05) from commercial Tanya. However, plants from the commercial 'Tanya' seedlots did not produce significantly different (P = 0.05) results compared to those from 'Tanya G_2' and commercial 'Cal J' seedlots for fruit number per plant. These results indicate that fruit productivity of plants from different 'Tanya' sources (commercial 'Tanya' vs. farmer-saved seeds 'G_1') was not different although fruit number declined for seed source 'G_2'. The results suggest that there was no added advantage of using commercial seeds compared to using 1st generation farmer-saved seeds with respect to fruit

number per plant or yield (Table 3). There was no significant difference in average fruit weights for 'Tanya' cultivar seedlots. Similarly, 'commercial Tanya' and 'Tanya G_1' produced significantly (P = 0.05) the same average fruit weight as 'commercial Cal J'. seedlots. However, plants from 'Tanya G_2' seeds had relatively higher average fruit weights compared to plants from commercial 'Cal J' seeds (Table 3). The average fruit number per plant as well as average fruit weight for plants from the two commercial cultivars ('Tanya VF' and 'Cal J VF') were similar (p=0.0190 and p=0.1687 respectively)

Overall, the variety Tanya produced higher marketable fruit number, average fruit weight and marketable yield per acre than 'Cal J'. There was no significant difference (P = 0.05) in marketable yields between commercial 'Tanya' seedlot and 'Tanya G_1' seeds. Similarly, there was no significant difference between 'Tanya G_2' and 'commercial Cal J'. Due to the relatively higher number of fruits and average fruit weight, plants from the commercial 'Tanya' seedlots led to greater yields compared to those of 'Tanya G_2' and commercial 'Cal J' which were similar (Table 3). This may be among the reasons for farmers' preference of 'Tanya' over 'Cal J' cultivar.

Rwezaula *et al.* (2005) reported blossom end rot (BER) and fruit sunscald (SS) as common fruit disorders affecting tomato production in the Morogoro region. BER is a physiological disorder caused by a localized calcium deficiency with symptoms observed at the distal end of the fruit (Abdel-Mawgoud *et al.*, 2005). There were no significant differences in these physiological disorders among the seed sources. An average of 48% of the total harvested yield was of poor quality and or unfit for market due to these two disorders combined.

There was significantly higher average fruit number from plants grown from chlorine treated seeds, which did not differ from that of hot water treated seeds (Table 4). Ridomil treated seeds had the lowest number of marketable fruits per plant but which did not statistically differ with the control. Seed treatments did not influence average fruit weight (p=0.7009). All the seed treatments did not results in significant increases in fruit weight (Table 4).

Table 4: Results on effect of seed treatment on tomato yield parameters and fruit disorders

Seed treatment	Marketable fruit number plant^{-1}	Average fruit wt (g)	Marketable yield (t/ha)	Marketable yield (%)	BER (t/ha)	SS (t/ha)
Chlorine	17^{a}	55.2	21.0^{a}	57.2	9.6	5.9^{ab}
Hot water	16^{ab}	52.3	19.5^{a}	55.6	10.6	4.9^{b}
Control	13^{bc}	52.6	15.6^{b}	47.6	10.4	6.9^{a}
Ridomil	11^{c}	51.6	12.8^{b}	46.3	8.6	6.2^{ab}
Mean	15	52.9	17.2	51.7	9.9	6.0
C.V (%)	38.70	21.36	38.60	-	48.76	50.38

Means followed by the same superscript are not statistically significant different (p≤ 0.05) column by LSD, t/ha = Tones per hectare; LSD = Least significant difference; BER = Blossom end rot; SS = sunscald

Marketable yields were higher for plants from chlorine and hot water-treated seeds compared to control and ridomil-treated seeds. Seed treatment had no influence on average fruit weight and BER disorder. The severity of SS was lower for the hot water-treated seeds compared to plants from control seeds (Table 4). This may be due to the higher vigor of plants from hot water treated seeds observed in the field, which led to a denser canopy thereby providing better fruit protection from the sun. Fruit yield components were consistently improved for plants grown in mulched plots compared to tomato crops grown on bare soil (Table 5). Plants in mulched plots produced a higher number of fruits per plant, higher marketable yield, larger fruits, and less sunscald fruits (p<0.0001, p<0.0001, 0.0016, and p<0.0001 respectively) compared to the non-mulched check. The yield increase when mulch was used was 26% higher than that of the control (Table 5). These findings are consistent with the results by other workers studying the effect of mulches on tomato growth and yield (Agele *et al.*, 1999; Ramalan and Nwokeocha, 2000; Vos *et al.*, 1995; Ramakrishna *et al.*, 2005).

Table 5: The effect of mulch on tomato yield parameters and fruit disorders

Treatment	Marketable fruit number plant^{-1}	Average fruit wt (g)	Marketable yield (t/ha)	Marketable yield (%)	BER (t/ha)	SS (t/ha)
Mulched	18^{a}	56.8^{a}	21.9^{a}	60.4	9.9^{ns}	4.5^{b}
Non-mulched	11^{b}	49.1^{b}	12.5^{b}	42.0	9.8^{ns}	7.4^{a}
Mean	15	52.9	17.2	51.2	9.9	6.0
C.V (%)	38.70	21.36	38.60	-	48.76	50.38

Means followed by the same superscript are not statistically significant different ($p \leq 0.05$) column by LSD; LSD = Least significant difference; t/ha = Tones per hectare; BER = Blossom end rot; SS = sunscald

The incidence of blossom end rot for the mulched plots was not significantly different compared to non-mulched control. It is usually assumed that mulching regulates the soil moisture regime, enhances calcium availability and reduces evaporative heat thereby reducing the BER problem. Thus, our current results are contrary to these assumptions but correlate well with the report by Abdel-Mawgoud *et al.* (2005) who reported that BER incidence has a relationship with fruit load through competition for assimilates including calcium nutrition. In our current study, plants in the mulched plots had more fruits per plant which resulted to higher competition for assimilates and therefore more BER effect on fruits than those in non-mulched plots (Table 5). Ho *et al.* (1993) also found that BER incidence in tomato was markedly affected by light and temperature independent of calcium supply to the plant. Tomato productivity was shown to depend on seed source, seed treatments and mulch ($p=0.0164$, $p=0.0002$, $p<0.0001$) respectively. Plants from commercial 'Tanya' seeds were found to be more productive than those from commercial 'Cal J'. Moreover, plants from 'Tanya G_1' had higher fruit yield than plants from 'Tanya G_2' seedlots suggesting that higher frequency of seed extraction from previous crops has negative impacts on fruit yield.

Plants from chlorine and hot water treated seeds gave higher fruit yields than plants from Ridomil treated seeds which were similar to control. Mulching led to higher fruit numbers per plant, greater average fruit weight and higher marketable yields per acre compared to plants from the non-mulched control. In addition, mulching significantly reduced the sunscald fruit disorder which should have resulted from vigorous plant growth in mulched plots due to improved moisture regime and nutrient uptake.

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