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EFFECT OF PRUNING AND TRELLISING OF TOMATOES ON RED SPIDER MITE INCIDENCE AND CROP YIELD IN ZIMBABWE

I.G.M. SAUNYAMA and M. KNAPP[1]
Plant Protection Research Institute (PPRI), P.O. Box CY 550, Causeway, Harare, Zimbabwe
[1]International Centre of Insect Physiology and Ecology (ICIPE), P.O. Box 30772, Nairobi, Kenya

ABSTRACT

Red spider mite, *Tetranychus evansi* Baker & Prichard, is a relatively new pest of tomato (*Lycopersicon esculentum*) in Africa, accidentally introduced into southern Africa around 1980. Since then, the species has spread and was recorded for the first time in Kenya in 2001. The International Centre of Insect Physiology and Ecology (ICIPE), together with National Research Institutions of eastern and southern Africa, are developing integrated control methods for this new pest. The effects of pruning and trellising on red spider mite incidence and control, as well as damage and yield of tomatoes were investigated in two important tomato production areas of Zimbabwe (Mutoko and Muzarabani). The practices, considered singly or combined, had no direct effect on initial infestation. Damage levels and population development became apparent in the later crop stages at Mutoko, while at Muzarabani, mite population levels remained low throughout the season, and showed no significant ($P<0.05$) differences between treatments. Unpruned and untrellised plots had 37.7 and 30.2 mites per leaf, respectively, in Mutoko, while the pruned and trellised plots had 4.6 and 17.3 mites per leaf. In Muzarabani, mite densities were 4.8 in the pruned and trellised plots, and 4.6 in the control. Chemical control was more effective on the pruned and trellised plots resulting in a yield increase of 60% in both trials at Mutoko, but not at Muzarabani. Pruning and trellising at Mutoko resulted in better mite management, less disease incidence, less fruit rots and a reduced damage in fruits. Pruning and trellising resulted in additional profit of US$ 18,780 per hectare at Mutoko.

Key Words: Arthropod pest, *Lycopersicon esculentum*, *Tetranychus evansi*

RÉSUMÉ

La petite araignée rouge, *Tetranychus evansi* Baker & Prichard accidentellement introduite en Afrique Australe vers 1980 est une peste relativement nouvelle pour la tomate *(Lycopersicon esculentum)* de l'Afrique. Depuis lors l'espèce s'est répandue. Elle a etait enregistrée pour la première fois au Kenya en 2001. L' International centre of Insect Physiology and Ecology (ICIPE) ensemble avec le National Research Institutions and southern Africa sont entrain de développer des méthodes de contrôle intégrées pour cette nouvelle peste. Les effets de la taille et du treillage sur l'incidence et le contrôle de la peste aussi bien que les dommages et les rendements de la tomate étaient évalués en des endroits du Zimbabwe ou la production de la tomate est importante: Mutoko et Muzarabani. Les pratiques considérées simples ou combinées n'avaient pas d'effets sur l'infestation initiale. Le niveau des dommages et le développement de la population sont devenus apparents dans les dernières tapes de la plante à Mutoko. A Muzarabani la population d'araignée est restée faible durant toute la saison et ne montra aucune différence significative due au traitement ($p<0.05$). Des parcelles non taillées et non treillissées avaient 37.7 et 30.2 araignées par feuilles; respectivement à Mutoko alors que les parcelles taillées et treillissées avaient 4.6 et 17.3 araignée par feuilles. Dans Muzarabani la densité d'araignée était de 4.8 dans les parcelles taillées et treillissées et 4.6 dans les contrôles. Le contrôle chimique était plus éfficace sur les parcelles taillées et treillissées résultant à une augmentation de 60% pour tous les essaies à Mutoko, mais pas à Muzarabani. La taille et treillisse ont permis une bonne gestion, une incidence faible, moins des fruits pourris et a réduit les dommages sur les fruits. Les deux méthodes ont permis un gain additionnel de 18,780 $ US par hectare à Mutoko.

Mots Clés: Peste anthropoïde, *Lycopersicon esculentum, Tetranychus evansi*

INTRODUCTION

Tomato is among the most important vegetables grown by smallholder farmers in Zimbabwe. It is a vital component of diets, providing essential nutrients in raw or relish recipes. Production and marketing of the crop provides occupation for many people. The crop also provides income for the smallholder farmers (Mariatou and Kwaramba, 1999; Zitsanza, 2000).

The most common varieties grown by smallholder farmers are open pollinated and determinate such as Rodade, Floradade, Roma, Rossol, Heinz and Red Khaki and the indeterminate variety, Money Maker (Dobson *et al.*, 2001). While indeterminate varieties are usually trellised and pruned to 2-3 shoots per plant to achieve better plant health and fruit quality, determinate varieties are mostly left untrellised. Pruning to 2-3 shoots is optional. Trellising or staking refers to support of plants with sturdy material to keep the fruits and foliage off the ground. Pruning is the selective removal of side shoots to limit plant growth and to divert nutrients to flower clusters on the main stem (Chen and Lal, 1999). Tomato production in the smallholder sector is mainly seasonal, but some farmers grow the crop all year round (Mariatou and Kwaramba, 1999). Highest returns from tomato production are achieved with the summer crop grown from October to March (Zitsanza, 2000). However, the summer crop is also prone to higher pest and disease pressure.

Production trends of smallholder farmers growing determinate varieties indicate distinct yield differences between trellised and untrellised crops (Nyamuda, G. pers. comm.). The bulk of smallholder tomato growers in Zimbabwe are in Mutoko, 140 Km north east of Harare and in Chinamhora, 30 Km north of Harare. The Mutoko farmers do not trellis, while most of their counterparts in Chinamhora do (Dobson *et al.*, 2001).

The produce is marketed at the Central Mbare Market in Harare. For the summer crop, it is fairly easy to distinguish the source of tomatoes by visual assessment. Tomatoes from Chinamhora have superior quality over the Mutoko produce (Nyamuda, G. pers comm.). Generally, farmers are reluctant to prune tomato because they believe that pruning significantly reduces fruiting points, resulting in lower yields. In addition, farmers in Mutoko have cited reasons such as shortage of poles, especially for larger plots and no observed economic benefits in carrying out this practice.

Reports on the influence of pruning and trellising on tomato yields from other tomato production areas are conflicting (Davis and Estes, 1993; Lédo *et al.*, 1998; Rughoo and Govinden, 1999). Staked plants usually produce higher yields and better quality fruits than unstaked plants. However, the influence of pruning is variable. Rughoo and Govinden (1999) reported from Mauritius that yield of pruned and staked tomatoes was significantly lower than in unpruned and unstaked plots, in a determinate variety, but significantly higher in indeterminate and semi-determinate varieties. In Brazil, pruning and staking as well as staking without pruning resulted in significantly higher yields than the unpruned and unstaked control. Differences between staked and pruned, and staked and unpruned were not significant (Lédo *et al.*, 1998). Davis and Estes (1993) reported that staked but unpruned plants produced low yield of large fruits, though total yields were greater than those of staked and pruned plants.

The red spider mite (*Tetranychus evansi* Baker & Pritchard) is the most damaging and most difficult to control arthropod pest of tomatoes in Zimbabwe (Mariatou and Kwaramba, 1999). Chemical control of red spider mite is difficult in untrellised tomatoes due to poor spray penetration. The mites prefer the lower surfaces of the leaves and spray deposit in these areas is far from optimal with the spraying techniques currently used by most small-scale farmers (Sibanda *et al.*, 2000). Pruning and trellising should improve this situation to make it easier for the farmer to cover the plant properly with acaricides.

The International Centre of Insect Physiology and Ecology (ICIPE), together with National Research Institutions of eastern and southern Africa, are developing integrated control methods for this new pest. This study was conducted to establish the effect of pruning and trellising on red spider mite incidence and yield of tomatoes in Zimbabwe.

MATERIALS AND METHODS

Zimbabwe is demarcated in natural regions according to the degree of adequacy of rainfall (Gore *et al.*, 1992; Nyakanda, 1997). The studies reported here were carried out on farmers' fields at Mutoko in the dry season in 1999 and 2001, and at the Agricultural Research and Development Authority (ARDA) farm at Muzarabani in 2001. The trial sites are situated in Natural Region IV with an annual rainfall of 450-650 mm (Vincent and Thomas, 1961). The mean annual maximum temperature is 26.6 °C in Mutoko and 28.2 °C in Muzarabani, while the mean annual minimum is 14.2 and 14.7 °C, respectively (Corbett *et al.*, 2000).

Tomato plants of variety Rodade, were raised in seedling trays and transplanted into the field four weeks after sowing. The spacing was 0.45 m by 1 m. Basal application of Compound S fertiliser (NPK =7:21:7) was done at 1,500 kg ha^{-1} in two split applications; 3 weeks after transplanting and between the onset of flowering and fruit formation. Top-dressing was done with ammonium nitrate (34.5% N) and potassium sulphate (50% K_2O) at a rate of 100 kg ha^{-1} each.

Treatments included (1) trellising and pruning, (2) trellising only, (3) pruning only and (4) control (no pruning, no trellising). These were laid out in a randomised complete block design (RCBD). Each plot consisted of 5 rows, each measuring 10 m in length. The tomato plants were trellised and pruned four weeks after transplanting. Along each row, two poles were planted and three wire strands stretched one above the other between these poles. The plants were secured to the horizontal wire using soft pliable tying wire.

Prophylactic control of early blight (*Alternaria solani* (Ell. & Martin) Sor.) and late blight (*Phytophtora infestans* (Mont.) de Bary) diseases was achieved with weekly sprays of mancozeb (Dithane M45) at a rate of 200 g 100 l^{-1}, alternated with copper oxychloride at 500 g 100 l^{-1}. Metalaxyl (Ridomil) was also included in the routine at 300 g 100 l^{-1} whenever it rained mainly because of its systemic activity. Sucking pests (aphids and whiteflies) were controlled by drenching seedlings with imidacloprid (Confidor) prior to planting and at 3 weeks after transplanting, at the rate of 12.5 ml 100 l^{-1}. Mite control started as soon as initial infestation was sighted, using 150 g 100 l^{-1} propargite (Omite) at weekly intervals until three weeks prior to harvest. After this, amitraz (Mitac) was used at 300 ml 100 l^{-1} until end of crop cycle because it has a shorter pre-harvest interval. Plants were irrigated by flood irrigation as required.

All cultural practices as well as spraying, plus harvesting were executed by the farmers according to common practices in the area except the pruning and trellising.

Plants were inspected for infestation at weekly intervals after transplanting. Sampling started when the first mites were observed and was done weekly prior to spraying. Data were only collected from the three middle rows of each plot. Leaf samples taken were placed in a cool box and brought to the laboratory for examination under stereomicroscopes.

In the first trial at Mutoko (1999), one leaf was taken from the central part of 2 randomly selected plants in each plot. All motile stages of red spider mites on these leaves were counted in the laboratory. Sampling was intensified in the later trials and 5 plants were sampled per plot weekly. From each plant, 3 leaves were collected, one each from the bottom, the middle and the top third of the plant. Motile stages of spider mites were counted only on the three terminal leaflets. Sampling was executed for 6 weeks in the first trial at Mutoko because mite infestation started very late. It was, however, done for 11 weeks in the other two trials. Marketable yield was recorded weekly over 8 weeks in all trials. The fruits were graded by the farmers according to common practices in Zimbabwe. Marketable fruits of Grade A were those without blemishes from disease attack or insect feeding. Bronzing of fruits due to mite attack led to downgrade to Grade B.

Mite counts and yields were subjected to analysis of variance (ANOVA) using SAS (SAS Institute, 2001). Mite numbers were transformed into logarithms for the ANOVA to achieve normality and independence of the variance from the mean. Means for the different treatments were separated by Student-Newman-Keuls (SNK) test at $P \leq 0.05$.

Costs and benefits of pruning and trellising were estimated by calculating the additional cost incurred for material and labour needed to prune and trellis the tomatoes, and the additional gain in profits due to higher yield and quality of tomatoes from the pruned and trellised plots. Farmers in Mutoko immediately started to prune and trellis their tomatoes using sticks cut from the communal woodlands when they realised the yield benefits resulting from this technique. The cost of this local practice was also estimated using information provided by the farmers and from experiences from other trials where sticks from woodlands were used.

RESULTS

Overall mite density and tomato yield. The number of mites was lower in the pruned and trellised plots than in the other treatments, in both trials in Mutoko (Table 1). However, the influence of pruning or trellising alone was less clear. In Muzarabani, mite numbers were very low throughout the season and no differences between treatments were observed.

Mite numbers were generally higher ($P<0.05$) in Mutoko than in Muzarabani. There were no significant ($P>0.05$) differences between the treatments at most sampling dates (Fig. 1). However, in Mutoko, there was a clear trend that mite numbers were lowest in the pruned and trellised plots. In Muzarabani, mite numbers remained very low throughout the season and no difference in mite number between treatments occurred.

Yields followed the same trend as for the overall mite density in both trials at Mutoko, with highest yields in the pruned and trellised tomatoes, followed by trellising only, pruning only and the control (Table 2). In the pruned and trellised plots, yield was significantly ($P<0.05$) higher than in the pruned only tomatoes and control in both trials. There were no significant ($P>0.05$) differences between trellised only and pruned and trellised as well as between pruned only and the control. In Muzarabani no significant differences between the treatments occurred.

Cost-benefit analysis. The additional cost of pruning and trellising one hectare of tomato using the experimental system was US$ 3,320 (Table 3) and the additional revenue was calculated at US$ 22,100 (Table 4) resulting in a net profit of US$ 18,780 per hectare. The farmers' system is much cheaper at a cost of US$ 1,104 per hectare (Table 3). Under the assumption that the yields would be the same as in our experimental plots with this pruning and trellising system, the net profit would amount to US$ 20,996.

DISCUSSION

Chemical control of red spider mites by contact acaricides, are more effective in pruned and trellised tomatoes since better coverage is achieved. This is clearly indicated by lower mite numbers in the pruned and trellised plots compared to the control in the trials at Mutoko (Table 1). In addition, this practice very likely results in reduced environmental contamination as the bulk of the chemical applied lands on the target. However, mite numbers were not significantly different among most sampling dates (Fig. 1). The sampling was intensified after the first trial in order to compensate for high fluctuation of mite numbers within the field.

Picanço *et al.* (1995) reported that the chemical control of *Scrobipalpuloides absoluta* (Meyrick) was more efficient in pruned tomatoes trellised to a vertical stake compared to the traditional system

TABLE 1. Overall mite number in pruned & trellised, trellised only, pruned only and unpruned & untrellised tomatoes in 3 trials at Mutoko and Muzarabani

Trial site/season	Mite number[1] ± standard error			
	Pruned & Trellised	Trellised	Pruned	Control[2]
Mutoko 1999	4.6 ± 0.9	25.5 ± 7.4	19.3 ± 3.6	37.7 ± 9.0
Mutoko 2001	17.3 ± 1.5	23.4 ± 2.2	32.0 ± 2.1	30.2 ± 3.5
Muzarabani	4.8 ± 0.7	4.3 ± 0.6	4.9 ± 0.6	4.6 ± 0.5

[1] Mite number per leaf in trial Mutoko 1999 mite number per 3 terminal leaflets in trial Mutoko 2001 and Muzarabani; [2] Not pruned and not trellised

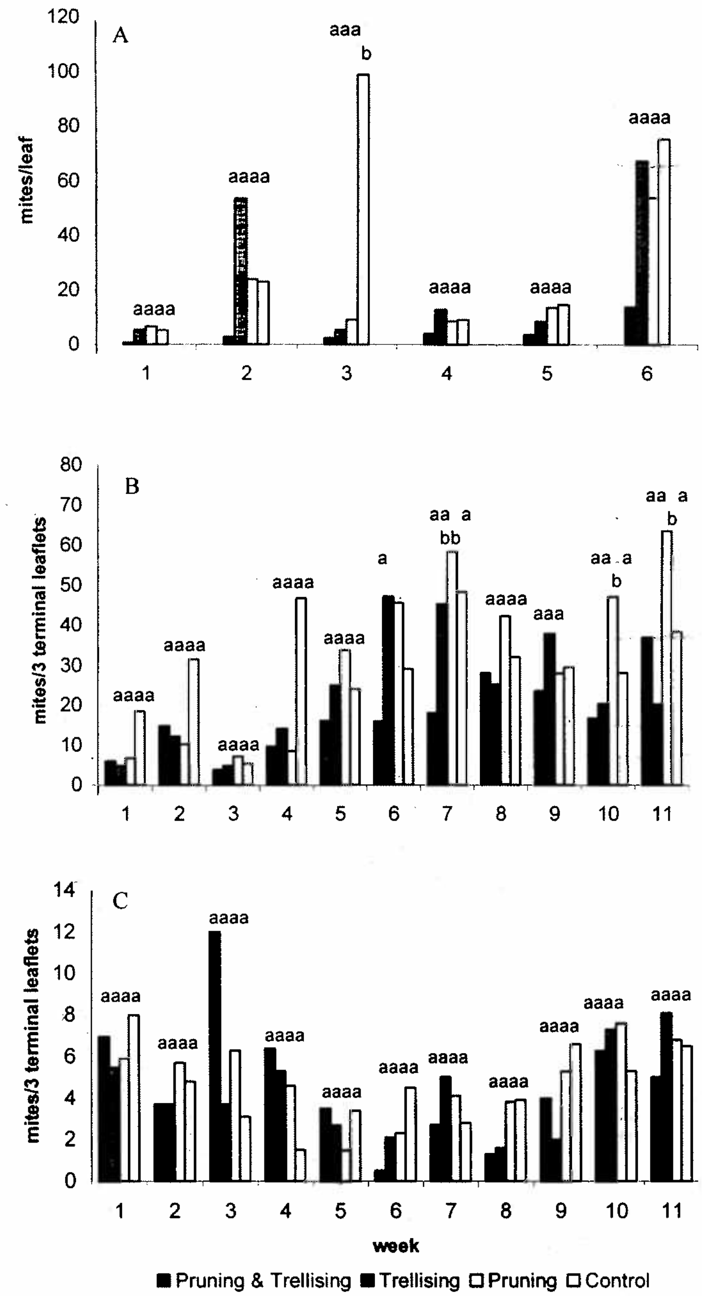

Figure 1. Mite numbers at each sampling date under different pruning and trellising regimes in (A) Trial Mutoko 1999, (B) Trial Mutoko 2001 and (C) Trial Muzarabani. Means marked with the same letter within each sampling date are not significantly different (SNK, $P \leq 0.05$).

TABLE 2. Yield of marketable fruits in pruned & trellised, trellised only, pruned only and unpruned & untrellised tomatoes in 3 trials at Mutoko and Muzarabani

Trial site/season	Average yield (kg plot^{-1}) ± standard error			
	Pruned & Trellised	Trellised	Pruned	Control[2]
Mutoko 1999	179.0 ± 9.8 a[1]	163.0 ± 12.8 a	126.0 ± 9.0 b	112.0 ± 9.8 b
Mutoko 2001	174.4 ±10.0 a	158.6 ± 4.3 ab	134.6 ± 13.5 b	132.3 ± 8.6 b
Muzarabani	98.2 ± 8.3 a	113.2 ± 17.3 a	84.6 ± 14.9 a	117.4 ± 5.7 a

[1]Means within one row followed by the same letter are not significantly different (SNK-test, $P \leq 0.05$);
[2]Not pruned and not trellised

TABLE 3. Additional cost for pruning and trellising of tomatoes with the pruning and trellising system used in the experiments and estimated cost of the farmers' system of pruning and trellising

Item	Amount/10 m row	US$/unit	US$/10 m row	US$ ha^{-1}
Experimental system				
Poles	2 pieces	0.52	1.04	1,040.00
Tying wire	33 m	0.04	1.32	1,320.00
Vertical wire	20 m	0.006	0.12	120.00
Twine	0.075 kg	9.68	0.73	730.00
Labour	0.8 hours	0.14	0.11	110.00
Total			3.32	3,320.00
Farmers' system				
Stake cutting	1,800 hours	0.14		252.00
Pruning & trellising	900 hours	0.14		126.00
Twine	75 kg	9.68		726.00
Total				1,104.00

US$ = United States of America Dollar

TABLE 4. Revenue from pruned and trellised tomatoes compared to unpruned and untrellised tomatoes (average values of the two trials in Mutoko)

	Pruned/trellised			Unpruned/untrellised		
	kg	US$	US$ ha^{-1}	kg	US$	US$ ha^{-1}
Yield/row (total)	58.9			40.7		
Grade A (0.97 US$/kg)	53.0	51.40	51,400.00	20.4	19.80	19,800.00
Grade B (0.65 US$/kg)	5.9	3.80	3,800.00	20.4	13.30	13,300
Total			55,200.00			33,100
Additional revenue			22,100			

US$ = United States of America Dollar

in which two tomato rows are trellised together on two oblique crossed bamboo stakes and not pruned. They attributed the better control of the pest to the fact that in vertically staked tomatoes spraying was possible from both sides of the row and, therefore, insecticide deposit on the leaves was better.

It is believed that removal of axillary shoots normally enhances the quality of fruits and leads to earlier fruiting, but may result in a reduction in total yield compared to unstaked and unpruned plants (Tindall, 1983). However, there seem to be considerable difference between varieties (Davis and Estes, 1993; Lédo *et al.*, 1998; Rughoo and Govinden, 1999). Rughoo and Govinden (1999) reported significantly higher total yield and yield of Grade 1 fruits in the unpruned/unstaked, and unpruned/staked treatments than in pruned/staked and pruned/unstaked for determinate varieties in Mauritius. Davis and Estes (1993) reported higher yields of large fruits in staked tomatoes that were pruned, but higher total yields in unpruned staked tomatoes. Lédo *et al.* (1998) reported significantly higher yields in staked/pruned and staked only tomatoes compared to the unstaked/unpruned control for all six varieties investigated. They, however, did not state if the varieties were determinate.

In our trials, the determinate variety Rodade was used because it is the most common variety in Zimbabwe. The highest yields of marketable fruits were recorded from pruned and trellised tomato (Table 2). Yield of non marketable fruits was not recorded. The farmers only recorded the number of boxes of Grade A and Grade B tomatoes harvested. It was, however, obvious that the untrellised tomato plants produced a high proportion of unmarketable fruits due to small fruit size and had higher pest and disease incidence. These results are in agreement with Davis & Estes (1993) and Lédo *et al.* (1998) who also reported higher proportions of large fruits from pruned and trellised tomatoes.

There were generally higher yields in Mutoko than in Muzarabani and non significant yield differences in Muzarabani could be explained by the fact that Mutoko (mean annual maximum temperature 26.6 °C) is better suited for tomato growing than Muzarabani (mean annual maximum temperature 28.2 °C). Temperatures of 21-24 °C are usually considered optimal for tomato production (Geisenberg and Stewart, 1986) and moderately higher temperatures lead to a reduction of fruit numbers (Willits and Peet, 1998; Sato *et al.*, 2001).

The crop in Muzarabani was preceded by a rainy season with exceptionally high rainfall. Therefore, the mite reservoir for infestation of the crop was presumably low. High relative humidity in Muzarabani also likely favoured the development of fungal diseases. Therefore, early and late blight were more severe in Muzarabani than in Mutoko. Despite the regular fungicide treatments administered, extensive leaf damage strongly hampered the development of the mite population.

In Mutoko, we observed lower incidence of early and late blight in the pruned and trellised plots. This might have been caused by better spray deposit of the fungicides and/or less favourable microclimatic conditions for fungal diseases in the less dense plant canopy. No differences in disease incidence occurred in Muzarabani. Positive effects of pruning and staking on disease incidence were also recorded by Lyimo *et al.* (1998) and Kumar and Sugha (2000).

Pruning and trellising of tomatoes has a significant effect on the revenue in high potential tomato growing areas like Mutoko (Tables 3 and 4). An additional net benefit of up to US$ 21,000 per hectare was observed. This was realised by the farmers in Mutoko, who started to prune and trellis tomatoes with local means when they saw the yield and quality differences even before we finished the first trial. The farmers used stakes from the communal woodlands instead of the large poles and wires used in our experiments. Costs and benefits presented here for this practice have to be treated as an estimate based on statements of the farmers and experiences from other areas. However, the figures clearly show that pruning and trellising has a tremendous effect on the profitability of the tomato crop.

In Mauritius, profitability of indeterminate and semi-determinate varieties was highest when the plants were staked but not pruned, whereas with the determinate variety, the highest profit was obtained when plants were neither staked nor pruned (Rughoo and Govinden, 1999). In contrast staking of determinate varieties increased economic return of fresh market tomatoes in the USA (Rimal *et al.*, 1996).

The economic benefit analysis performed in this study is a comparatively rough estimate and we did not take records on the time required for trellising or pruning only as well as for harvesting in the different plots. More detailed economic investigations are planned for the second phase of the project.

CONCLUSIONS AND RECOMMENDATIONS

Pruning and trellising has a strong positive effect on yield and quality of tomatoes as well as the profitability of tomato production in high potential tomato growing areas of Zimbabwe. A yield increase of 60% compared to unpruned and untrellised tomatoes is achievable with a determinate variety. In addition, the proportion of Grade A fruits is higher in the pruned and trellised plots. This is caused by a combination of several factors including better red spider mite and disease control, better handling of the crop and physiological effects of pruning and trellising on the tomato plant. The results of our trials do not allow the separation these effects from each other. This will be subject for further investigations.

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