Management of Tomato Late Blight Disease Using Reduced Fungicide Spray Regimes in Morogoro, Tanzania

A. I. Meya[1], D. P. Mamiro[1]*, P.M. Kusolwa[1], A. P. Maerere[1], K. P. Sibuga[1], M. Erbaugh[2], S. A. Miller[2], H. D. Mtui[1]

[1]Department of Crop Science and Production, Sokoine University of Agriculture, P. O. Box 3005, Morogoro, Tanzania
[2]The Ohio State University, Columbus, OH 43210-1086, USA

* Corresponding author: *delphimamiro@yahoo.com*

Abstract

Tomato (Solanum lycopersicum L.) production in Tanzania is affected by late blight disease caused by Phytophthora infestans (Mont.) de Bary. Currently, farmers spray more than 12 per crop per season to control diseases by weekly spraying. Field experiments were conducted at Morogoro to evaluate the performance of three tomato varieties subjected to different fungicide chemistries and reduced fungicide spray intervals. The treatment factors were tomato varieties Meru, Cal-J and Tanya as main plots; fungicides Ivory 72 WP, Volar MZ 690 WP and Topsin-M 70 WP as sub plots; and reduced number (4, 6, 8 and no-spray) of sprays per crop at a spray intervals of 14-, 10-, 7-days respectively as sub-sub plots. Variety Meru showed low tomato late blight incidence (1.4%) and severity (1.0) (P≤0.001) followed by Tanya (81.2%, 4.0) and Cal-J (82.6%, 4.0) respectively. Results show that plots sprayed with Topsin M-70 WP had significantly (P≤0.001) higher disease incidence and severity (66.2%, 3) compared to Ivory 72 WP (42.5%, 2) and Volar MZ 690 WP (44.5%, 2). The no-spraying regime (control) had highly significant (P≤0.001) disease incidence and severity than other spray regimes. Although there was no significant (P≤0.05) difference among the spray regimes plots sprayed 8 times had lowest disease incidence and severity (47.9%, 2) while, unsprayed plots had highest disease incidence and severity (66.3%, 4) followed by plots sprayed 6 times and 4 times (53.9%, 2) and (52.1%, 2) respectively. There were significant differences (P<0.001)) in yield among three commercial tomato varieties. Cal-J variety produced higher number of fruits per plant (27), marketable fruits (26.5 t/ha) and total yield (28.9 t/ha) followed by Tanya with 21 fruits per plant, 19.3 t/ha marketable fruits and total yield of 21.3 t/ha. Meru produced 13 fruits per plant, 13.6 t/h marketable yield and total yield of 17.6 t/ha. Tomato varieties, fungicides and spray regimes demonstrated significant influence on late blight disease incidence and severity. Results reveal that, variety Meru was resistant to tomato late blight disease while, Cal-J and Tanya varieties were highly susceptible. However, Meru had lowest yield due to production of few number of fruits per plants. Fungicides Ivory 72 WP and Volar MZ 690 WP verified higher field efficacy against P. infestans. These two fungicides significantly reduced disease intensity to lowest level than Topsin-M 70 WP. Similarly, spray regimes significantly gave appreciable reduction of tomato late blight disease intensity and consequently increased fruits yield in susceptible varieties Cal-J and Tanya when compared to no spraying regime. It was evident that the number of fungicide sprays was reduced from more than 12 (current farmers practice) to 8, 6 and 4 at intervals of 7-, 10- and 14- days respectively.

Key words: Tomato late blight disease, fungicides, reduced fungicides spray regime, tomato varieties.

Introduction

Tomato (*Solanum lycopersicum* L.) is among the most widely cultivated vegetable in the tropics (Fontem *et al.,* 1996; Van der Vossen *et al.,* 2004). It is the most important crop for cash and domestic use and is produced mostly by small and medium scale farmers in large areas of mainland Tanzania, with a total annual production of more than 235,000 tons (FAOSTAT, 2010). Tomato yield in the country ranges from 1.7 to 5.8 t/ha with an overall mean of 4.0 t/ha (Maerere *et al.,* 2010a). In Morogoro region, the yields vary greatly ranging from 2.2 to 16.5 t/ha (Maerere *et al.,* 2010a). The differences in yield levels could be attributed to insect pests, weeds, diseases, drought, excessive heat, declining soil fertility, use of susceptible varieties against insect pests and diseases, and use of poor agronomic practices (Minja *et al.,* 2011; AVRDC, 2009). Among the biotic problems, tomato late blight caused by *Phytophthora infestans* (Mont.) de Bary, is the major problem to most tomato growing areas (Ochwo *et al.,* 2002; AVRDC, 2009; Ojiewo and Kwazi, 2011) including Morogoro. In Tanzania and Morogoro, in particular, the yield loss from the disease infection is estimated to be up to 46% (AVRDC, 2009; Maerere *et al.,* 2010a).

However, near complete yield losses are common under severe tomato late blight infection (Maerere *et al.,* 2010a). Currently farmers in Morogoro use high frequency, weekly fungicide applications or up to 12 sprays per tomato crop to control diseases (Maerere *et al.,* 2010a; SUA-IPM CRSP, 2006). In turn, these applications increase both production cost and the potential for human health and environmental risks associated with pesticides. The most common chemical products used to control diseases are dithiocarbamates, such as mancozeb, which break down into suspected carcinogens causing liver and thyroid tumours, and testicular effects (Novikova *et al.,* 2003; USA-EPA, 2004). This implies that, there are long-term risks for cancer development among tomato producers and consumers from exposure to such fungicides.

Tomato late blight diseases are mainly limited to tomato, black nightshades, pepper, eggplant, horse nettle and Irish potato (Widmark, 2010). Control of these diseases is accomplished by several strategies including; the use of seeds free of the pathogens, removal of volunteer plants from the fields, destruction of infected debris of any previous tomato crop, use of resistant varieties, crop rotation, fallowing and fungicides application (Mizubuti *et al.,* 2007; Maerere *et al.,* 2010a). Madden (1983) remarked that, in locations where disease pressure is high, a susceptible variety may require high frequency fungicide applications. In Indonesia, shorter spray intervals of 4 days were reported to be effective in controlling late blight disease of tomato although disease incidence was reported to be still high (Fontem *et al.,* 1996). In Cameroon, it was reported that, tomato growers usually apply 2-3 fungicidal sprays per week to limit early and late blight infections during the wet season, when plants were most susceptible to the diseases (Fontem *et al.,* 2004).

Therefore, it is in the best interest of the producer and consumer to develop late blight management strategies that reduce fungicide applications. The overall objective of the study was to evaluate field efficacy of reduced fungicides spray regimes for the control of tomato late blight disease in the Morogoro region.

Materials and Methods

Collection of Phytophthora infestans isolates and culturing: Tomato plants infected with *Phytophthora infestans* were collected from three different major tomato growing areas (Nyandira, Mlali and Sokoine University of Agriculture [SUA]) in Morogoro region. At each site, fresh leaves and stems containing lesions were randomly picked in the field and placed in plastic bags. In the laboratory the sample tissues were washed with 70% ethanol then rinsed with sterilized dH_2O for 5 to 10 minutes, followed by blotting of excess moisture with a sterile blotting paper. The clarified V-8 agar (to make 1 litre, V8 juice 200 ml, agar 20 g, and $CaCO_3$ 2 g in 800 ml of dH_2O) amended with Pimaricin and Rifampicin was used as isolation medium. The pH of the isolation medium was 5.76. The medium was autoclaved at 121°C and 15 psi for 15 minutes, allowed to cool to about 45°C thereafter it was amended with antibiotics (2.5% Pimaricin aqueous solution and 20 mg/L Rifampicin SV sodium salt). Rifampicin was dissolved in small volume of ethanol then mixed with distilled water. Antibiotics were filtered by using ultrafilters-microfilters (Sartorius, Minisart® steril 600 kPa max.) before being added to the growth medium. After amendments, 25 - 30 ml of the medium were poured to each of the Petri dishes and allowed to solidify in the laminar hood. Each sample was divided into 1 cm segments whereby 4 segments were placed equidistantly on each of five Petri dishes (9 mm diameter) containing V8 agar amended with antibiotics. The inoculated plates were incubated at 20ºC and observations were made on 3rd day whereby white colonies (cotton-like mycelia) characterized by water-like droplets were observed.

Identity of Phytophthora infestans and inoculum preparation: Inoculum was prepared as described by Trigiano *et al.,* (2004) whereby a pure culture was obtained by transferring small portion of mycelia from white colonies to fresh amended-V8 medium and incubated at 20ºC for 7 days in darkness. The presence of *P. infestans* was confirmed by taking a small portion of mycelia from the pure culture using a sterile inoculating needle, placed on microscope slide and observed using a compound microscope at 1000X magnification. Hyaline, non-septate hyphae with long sporangiophore swelling at the end with lemon-shaped sporangia were observed. Swelling sporangiophores and lemon shaped sporangia were the distinctive features of *P. infestans* (Trigiano *et al.,* 2004; Erwin and Ribeiro, 1996). Inocula were harvested from 10-day old cultures by adding 10 ml sterile distilled water and a drop of Tween 20 to each plate and scraping the surface lightly with the edge of a sterile glass rod to dislodge sporangia. Sporangial suspensions were filtered through a double layer of cheesecloth to remove mycelial fragments and were diluted to 3 x 103 sporangia per ml with the aid of a haemocytometer (Neubauer haemocytometer, Appleton Woods Laboratory Equipment and Consumables, Birmingham, UK). The sporangia were chilled at 8ºC for 3 h to induce zoospore liberation.

Establishment of tomato crop and inoculation: Field experiments were conducted at Sokoine University of Agriculture crop museum (06^{o}05'S; 37^{o}39'E) and Horticulture unit (06^{o}05'S; 35^{o}37'E) with an altitude of 524 m. a. s. l., during long rains from March to August 2011 and 2013. The area has warm tropical climate with mean annual rainfall, temperature and relative humidity of 800 mm, 30.4^{o}C and 83% respectively. In addition, the area receives rainfall two seasons per year: short rains *'vuli'* from October to December and long rains *'masika'* from March to June. Three tomato varieties: Meru (indeterminate), Cal-J and Tanya (determinate) were subjected to three fungicides: Ivory 72 WP (8% Metalaxyl + 64% Mancozeb manufactured by Arysta LifeScience, Route d''Artix-B.P.80, 64150 Nogueres, France), Volar MZ 690 WP (9% Dimethomorph + 60% Mancozeb manufactured by Rotam Agrichemical Co. Ltd., No. 18 Cheung Lee Street, Chai Wan, Hong kong) and Topsin-M 70 (70% Thiophanate-Methyl manufactured by Nippon Soda Co. Ltd., Tokyo, Japan) sprayed at 14, 10 and 7-day spray intervals at 4, 6 and 8 total sprays respectively. A non-sprayed treatment was included as a control. Treatments were arranged in a split-split plot with tomato varieties as main plots, fungicides as sub-plots and fungicides spray regimes as sub-sub-plots laid out in a randomized complete block design with three replications. The plot sizes were 4.2 m long ridges spaced 0.7 m apart.

Tomato seedlings were raised in a 4 m x 2 m flatbed shaded with transparent polythene sheet, which protected seedlings from too much sun and heavy rainfall. The main field was prepared by using a disc plough, while ridges were prepared by using hand hoe. Twenty-one day old seedlings were transplanted in the main field, one seedling per hole spaced at 70 cm x 70 cm which maintained a plant population of 20,408 plants/ha. Di-ammonium phosphate (DAP) was used as basal fertilizer at transplanting at the rate of 100 kg/ha. NPK (20:10:10) was used as top-dress at the rate of 200 kg/ha applied in two splits 5 g/plant four weeks after planting and 5 g/plant two weeks later. Selecron (Lambda-cyhalothrin 50 g/L; Uright Enterprise Company Ltd., RMB, 1/F., LAB BLDG, 66 corporation road, Grangetown, Cardiff, Wales, UK.) was used to control insect pests. The first spray was done on the 2nd week after transplanting to control grasshoppers, whiteflies, aphids and caterpillars at the dosage of 30 ml/15 L of water by using a 15 L capacity knapsack sprayer and there after followed by subsequent sprays as deemed necessary. The field was hand weeded. Plants in treated and non-treated control rows were inoculated with using a lever knapsack sprayer late in the evening four weeks after transplanting. Fungicide treatments were applied in the 5th week after transplanting when first foliar disease symptoms were observed. Fungicides were used according to the manufacturer's recommended rate.

Tomato late blight disease assessment: Disease incidence and severity were assessed after every seven days to the maturity of tomatoes. Disease incidence refers to the proportion of sick plants, while disease severity is the relative or absolute area of plant tissue affected by the disease. The disease scoring was made by visual assessment of symptomatic leaves, petioles, fruits and stems on scale rating of 1-4 where; 1 = 0% (no disease); 2 = < 10% blighted leaf area (low severity); 3 = 10-50% blighted leaf area and the disease extended to petioles, branches and stems (moderate severity) and 4 = > 50% blighted leaf area and the infection extended to petioles, branches, stems and fruits (high severity) (Maerere *et al.,* 2010a). Disease incidence values were calculated using the following formula:

$$Diseases\ incidence = \frac{Number\ of\ diseased\ plants}{Total\ plants\ per\ plot} x100$$

Tomato yield: Tomatoes were harvested on a weekly basis for five consecutive weeks when attain mature red. Harvested tomato fruits were graded into marketable and non-marketable quality based on quality accepted by the local market. Tomato weight per plant, per plot and other yield parameters such as number of fruits per plant and the weight of each individual fruit were recorded.

Data analysis: Data on tomato late blight incidence and severity were arc sine and square root transformed respectively before analysis (Arunakumara, 2006). All yield and yield component, tomato late blight incidence and severity transformed data were subjected to analysis of variance using the general linear model procedure of the SAS Statistical Package (SAS Institute Inc 1998; Cary, NC, USA.) and treatment means were separated by least significant difference at P≤0.05. Data on disease incidence and severity were subjected to an arc sine and square root transformation (Gomez and Gomez, 1984).

Results

Disease incidence and severity: The commercial variety Meru (8.6%, 1%) demonstrated significantly lower tomato late blight incidence (P≤0.001) and severity when compared to the other varieties (Fig. 1). There was no significant difference (P≤0.05) between Cal-J (67.5%, 6.5%) and Tanya (68.1%, 7%) varieties.

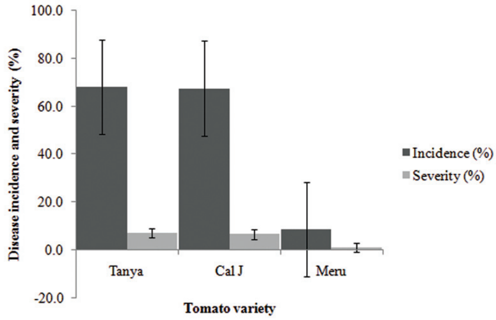

Figure 1: Late blight disease incidence and severity among three tomato varieties. Incidence was the percentage of diseased plants per plot. For disease severity scores 1= no disease; 2=<10% blighted leaf area; 3=10-50% blighted area and the disease extended to petioles, branches and stems; 4=>50% blighted area and the disease extended to petioles, branches, stems and fruits. Error bars are standard errors.

The fungicide Topsin-M 70 WP had significantly low field efficacy (P≤0.001) in reducing disease incidence (Fig. 2) and suppressing disease severity (P≤0.001) when compared to the other Volar MZ 690 WP and Ivory 72 WP (Fig. 2). Though the latter fungicides demonstrated higher performance in suppressing the disease, there was no significant difference (P≤0.05) between the two. Results show that plots sprayed with Topsin M-70 WP had higher disease incidence and severity (57.2%, 6%) whereby; Ivory 72 WP and Volar MZ 690 WP maintained low levels of disease incidences and severity (42.5%, 4.5%) and (44.5%, 5.5%) respectively.

When spray regimes were compared in terms of effectiveness in suppression of tomato late blight, the no-spraying regime (control) had significantly higher (P≤0.001) disease incidence and severity than other spray regimes (Fig. 3). Although 8, 6 and 4 total sprays at an interval of 7-, 10- and 14-days respectively maintained

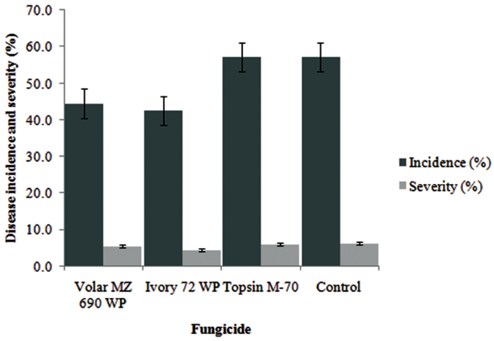

Figure 2: Late blight disease incidence and severity on tomato varieties treated with three different fungicides. Incidence was the percentage of diseased plants per plot. For disease severity scores 1= no disease; 2=<10% blighted leaf area; 3=10-50% blighted area and the disease extended to petioles, branches and stems; 4=>50% blighted area and the disease extended to petioles, branches, stems and fruits. Error bars are standard errors.

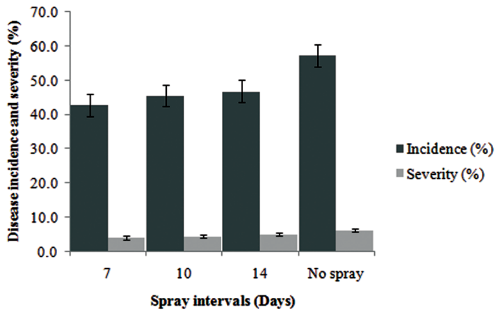

Figure 3: Late blight disease incidence and severity on tomato plants at different fungicide spray intervals. Incidence was the percentage of diseased plants per plot. For disease severity scores 1= no disease; 2=<10% blighted leaf area; 3=10-50% blighted area and the disease extended to petioles, branches and stems; 4=>50% blighted area and the disease extended to petioles, branches, stems and fruits. Error bars are standard errors.

low levels of disease incidence and severity, there was no significant (P≤0.05) difference among these three spray regimes (Fig. 3). Plots sprayed at 8 times had lowest disease incidence and severity (42.7%, 4%) while, unsprayed plots had highest disease incidence and severity (57.2%, 6.2%) followed by plots sprayed 6 times and 4 times (45.6%, 4.5%) and (46.8%, 5%) respectively.

Yield of tomato varieties under different fungicides spray regimes: There were highly significant (P<0.001) differences in yield among tomato varieties. Cal-J variety produced higher number of fruits per plant, more marketable fruits and a higher total yield. Meru variety had also significantly higher fruit weight (Table 1). Meru variety produced the least with 13 fruits per plant, 13.7 t/ha marketable yield and 17.6 t/ha total yield compared to Cal J and Tanya. On the contrary, variety Meru differed highly significantly with varieties Cal-J and Tanya in

Table 1: Fruit yield harvested by tomato varieties under different fungicides spray regimes

Varieties	Fruits per Plant (Number)	Fruit weight (g)	Yield (t/ha)	Marketable yield (t/ha)	Non-marketable yield (t/ha)
Meru	13.150 c	73.105 a	17.583 c	13.652 c	4.3458 a
Tanya	21.866 b	51.678 c	21.304 b	19.329 b	1.9764 b
Cal-J	27.051 a	55.388 b	28.941 a	26.538 a	2.396 b
CV%	25.096	10.069	23.230	26.209	36.891
SE±	26.958	36.565	27.586	27.036	1.149
$LSD_{0.05}$	2.443	2.846	2.472	2.447	0.505
F-test	***	***	***	***	***

Means followed by the same letter within the column are not significantly different (P<0.05) based on LSD.
SE = standard error, CV = coefficient of variation, *** = very highly significant different at (P<0.001).

Table 2: Tomato fruit yield harvested in three varieties under different types of fungicides spray to manage late blight disease

Fungicides	Fruits per Plant (Number)	Fruit weight (g)	Yield (t/ha)	Marketable yield (t/ha)	Non marketable yield (t/ha)
Volar MZ 690 WP (9% Dimethomorph + 60% Mancozeb)	21.895 a	60.921 a	23.578 a	20.564 a	3.013 a
Ivory 72 WP (8% Metalaxyl + 64% Mancozed)	20.743 a	62.208 a	22.702 a	19.820 a	2.875 a
Topsin-M-70 WP (Thiophanate-Methyl)	19.430 a	57.042 b	21.549 a	19.134 a	2.830 a
No spray	8.024c	50.793d	9.749d	8.306c	1.986c
CV%	25.096	10.069	23.230	26.209	36.891
SE±	26.958	36.565	27.586	27.036	1.149
$LSD_{0.05}$	2.443	2.846	2.472	2.447	0.505
F-test	ns	**	ns	ns	ns

Means followed by the same letter within the column are not significantly different (P<0.05) based on LSD. SE = standard error, CV = coefficient of variation, ns = not significant, * = significantly different at (P<0.05), ** = highly significantly different at (P<0.01), *** = very highly significantly different at (P<0.001).

their non-marketable yield but the latter two varieties did not differ significantly. Variety Meru produced significantly higher non-marketable yield compares to Cal-J and Tanya which were not significantly different.

Fungicides had no significant influence on number of tomato fruits per plant or fruit quality. Plots treated with Topsin-M produced fruits, which had significantly lower (P<0.001) fruit weight compared to those treated with Ivory M72 and Volar MZ, which did not differ (Table 2).

The spray regimes used had significant influence (P<0.001) on tomato fruit number per plant, yield per plant, marketable fruit yield as well as non-marketable yield. However, when comparing 6

Table 3: Fruit yield by three tomato varieties as influenced by number of fungicides sprayed per crop

Number of fungicides sprays	Fruits per Plant (Number)	Fruit weight (g)	Yield (t/ha)	Marketable yield (t/ha)	Non marketable yield (t/ha)	Non marketable yield (%)
8	28.190 a	67.060 a	30.604 a	27.350 a	3.254a b	10.636b
6	24.333 b	62.626 b	26.612 b	23.090 b	3.523 a	13.238a
4	22.210 b	59.750 b	23.473 c	20.611 b	2.861 b	12.188b
No spraying	8.024 c	50.793 c	9.749 d	8.306 c	1.986 c	20.371c
CV%	25.096	10.069	23.230	26.209	36.891	36.891
SE±	26.958	36.565	27.586	27.036	2.906	2.906
$LSD_{0.05}$	2.821	3.286	2.854	2.826	0.583	0.583
F-test	***	***	***	***	***	***

Means followed by the same letter within the column are not significantly different (P<0.05) based on LSD. SE = standard error, CV = coefficient of variation, ns = not significant, * = significantly different at (P<0.05), ** = highly significantly different at (P<0.01), *** = very highly significantly different at (P<0.001).

and 4 number of fungicides spray for the whole tomato crop, there was no significant difference ($P<0.05$) on fruit number per plant, fruit weight or marketable yield (Table 3).

Discussion

The field experiment results indicated that variety Meru was not significantly affected by tomato late blight compared to Cal-J and Tanya. Therefore, the findings of this study confirm that, the commercial variety Meru was resistant to *P. infestans* while varieties Cal-J and Tanya were highly susceptible to tomato late blight disease. According to William (1998), tomato late blight disease development is favoured by moderate temperature and wet conditions. Thus, variety Meru could be used in highland agro-ecological zones of Morogoro Region especially at Mgeta, Matombo, Mahenge and Sali where the temperatures are low and have wet conditions most of the time. According to an AVRDC (2009) report, one of the key technological components in tomato production package that has contributed to increased yield in Arusha, Kilimanjaro, Tanga and Manyara regions is the use of new improved varieties Meru and Kiboko with resistance to *P. infestans*. Moreover, the higher susceptibility of varieties Cal-J and Tanya to *P. infestans* in our study validates the findings of Cooper and Odour (1999), Shaba *et al.* (2006) and Masinde *et al.* (2011) which reported that varieties Cal-J and Tanya were highly susceptible to the disease compared to the other tested varieties.

Fungicides performed differently against *P. infestans* whereby, Ivory 72 WP and Volar MZ 690 WP showed good control over tomato late blight while, Topsin-M 70 WP had low field efficacy against *P. infestans*. The observation implied that, Ivory 72 WP and Volar MZ had higher field efficacy in suppressing the disease. Higher field efficacy demonstrated by Ivory 72 WP and Volar MZ 690 WP against *P. infestans* could be attributed to the presence of Metalaxyl and Dimethomorph active ingredients which works by inhibiting glucan synthetase and β-hydroxy sterols and thiamine synthesis from exogenous sources respectively and thus stops cell wall production in Oomycetes (Erwin and Ribeiro, 1996; Matheron, 2001; Kamoun, 2003). Thus, these fungicides can be used in rotation to avoid *P. infestans* resistance development against the fungicides. Findings of this study are consistent with the results reported by Fontem (2003), Lung'aho *et al.* (2003) and Muchiri *et al.* (2009) in that the application of Ridomil® MZ 72 WP (8% Metalaxyl + 64% Mancozeb) significantly reduced late blight disease severity in tomato and potato by 86%. In other tomato late blight study, fungicide application schemes that included Dimethomorph provided better control of this disease as well (Inglis *et al.,* 1998).

All fungicidal spray regimes significantly gave appreciable reduction of disease severity when compared to no spraying regime (control). Susceptible tomato varieties in no spraying regime were severely infected by late blight disease compared to the treated plots. While 8, 6 and 4 number of fungicides sprays sprayed at 7-, 10- and 14-days intervals for the whole tomato crop suppressed tomato late blight disease severity to low levels, these regimes did not differ significantly on their efficacy. These observations agreed with the findings by Olanya *et al.* (2000) and Kakuhenzire *et al.* (2007) who reported lowest late blight disease severity on plots sprayed at 7-day interval followed closely by those sprayed at 14- and 21-day intervals with Ridomil® MZ 72 WP (8% Metalaxyl + 64% Mancozeb). The integration of fungicides, resistant tomato varieties Meru, Kiboko, Duluti and Tengeru 2010 and the use of forecasting systems has been adopted as the best strategy for tomato late blight control in Northern Regions of Tanzania (Ojiewo and Kwazi, 2011). Late blight resistant tomato varieties can be grown with fewer fungicide applications while maintaining higher production in aspects of both quality and quantity (AVRDC, 2009). In this research, fungicidal sprays were initiated after the first disease symptoms were observed in the field. This, in turn, reduced the number of sprays, amount of fungicide used, and labour requirement for application. It was evident that the number of fungicidal sprays was reduced from more than 12 (current farmers practice) to 8, 6 and 4 at an intervals of 7-, 10- and 14-days respectively. In the same way, Bakele and Hailu (2001), Fontem (2001) and Hakiza *et al.* (2005) significantly reduced late blight disease with 3 applications of

8% Metalaxyl + 64% Mancozeb in susceptible potato varieties. The current tomato blight management strategy under farmers practice in Morogoro is more than 12 sprays (based on routine weekly fungicide sprays) per growing season (Maerere *et al.,* 2010a) but from this study 3-6 number of fungicide sprays per whole tomato crop sufficiently controlled the disease.

Tomato varieties differed highly significantly on their total tonnage of fruits yield per ha. Varieties Cal-J and Tanya produced higher yields when compared to variety Meru. The difference in yield could be attributed to variation in yield in number of fruits per plant, which had direct impact on total fruit yield per ha. Variety Cal-J and Tanya produced total fruits yield of 28.9 t/ha and 21.3 t/ha which is above the average African tomato yield which is estimated to be 19.0 and 33.5 t/ha (Fontem, 2003; FAOSTAT, 2010). However, Meru produced 17.6 t/ha, which is far below the African and world average yield. This is because Meru produced few fruits which in turn affected the yield. Tanya and Cal-J are varieties mostly used by Morogoro tomato producers. Meru performed very well in Morogoro low land agro-ecology by growing vigorously. Therefore, Morogoro tomato producers should be advised to use this variety to avoid total crop loss in areas where late blight disease is very severe.

Fungicides treatment demonstrated no significant effect on yield per hectare. However, plots treated with Volar MZ 690 WP produced slightly higher yield, followed by Ivory 72 WP and Topsin-M 70 WP. A slightly higher performance recorded on tomato plants sprayed with Volar MZ 690 WP and Ivory 72 WP could be attributed to curative effect against late blight disease offered by Dimethomorph and Metalaxyl (Bartlett *et al.,* 2002; Kamoun, 2003), which provided excellent control of the disease from within the plant. Furthermore, the protective effect offered by Mancozeb (Hassall, 1990; Bartlett *et al.,* 2002) provided *P. infestans* control on the foliage. Fontem (2003) likewise reported high tomato yield in plots sprayed with Volar MZ 690 WP (Dimethomorph + Mancozeb).

Spray regimes verified highly significant influence on total fruits yield per ha. No spraying regime (control) produced lowest yield while, the highest fruits yield was harvested on fungicidal spray regime of 7-days interval followed by 10- and 14-day intervals respectively. Fungicides treatment at respective spray regimes significantly increased tomato yield when compared to no spraying regime (control) implying that total fruit yield was greatly influenced by spray intervals (Kakuhenzire *et al.,* 2007). Seven, 10 and 14-days spray regime yielded far above the African average tomato yield. Therefore, tomato growers could use 14-days spray regime in combination with tomato varieties with resistance against late blight disease in integrated disease management to improve production while minimizing costs, health risks for applicator and consumer as well as environmental risks.

Conclusion

Tomato varieties, fungicides and spray regimes demonstrated significant influence on late blight disease incidence and severity. Results reveal that, variety Meru was resistant to tomato late blight disease while, Cal-J and Tanya varieties were highly susceptible. However, Meru had lowest yield due to production of few number of fruits per plants. In view of total fruits yield in tonnage per ha, variety Cal-J produced significantly higher yield followed closely by variety Tanya while, variety Meru yielded the lowest. In addition, fungicides Ivory 72 WP and Volar MZ 690 WP verified higher field efficacy against *P. infestans*. These two fungicides significantly reduced disease intensity to lowest level than Topsin-M 70 WP. Thus, in areas with inadequate supply of late blight resistant varieties tomato growers could use varieties Cal-J and Tanya while protecting them with fungicides Ivory 72 WP and Volar MZ 690 WP in season wise rotation to avoid P. infestans from developing resistance. Similarly, spray regimes significantly gave appreciable reduction of tomato late blight disease intensity and consequently increased fruits yield in susceptible varieties Cal-J and Tanya when compared to no spraying regime. It was evident that the number of fungicide sprays was reduced from more than 12 (current farmers practice) to 8, 6 and 4 at intervals of 7-, 10- and 14- days respectively.

Acknowledgement

Appreciation is expressed to Mrs. Hellen Mbije and Mr. Charles Henry for technical assistance in carrying out various laboratory and field activities. The authors also wish to thank both the Alliance for Green Revolution in Africa (AGRA) project/SUA and U.S. Agency for International Development through the Integrated Pest Management - Collaborative Research Support Program (IPM – CRSP East Africa) [Award No. EPP-A-00-04-00016-00] for financial support.

References

Arunakumara, K. T. (2006). Studies on Alternaria solani (Ellis and Martin) Jones and Grout Causing Early Blight of Tomato. Thesis for Award of MSc Degree at Dharwad University of Agricultural Sciences, India. 64pp.

AVRDC-The World Vegetable Center Newsletter (2009). Develop a robust and comprehensive strategy for defence against late blight. AVRDC Publication 04-610.

Bartlett, D. W., Clough, J. M., Godwin, J. R., Hall, A. A., Hamer, M and Parr-Dobrzanski, B. (2002). The strobilurin fungicides. Pest Management Science 58: 649-662.

Blay, E. T., Danquash, E. Y., Offei, S. K. and Kudadjie, C. (1999). Morphological and agronomic characterization of some tomato (*Lycopersicon esculentum*) germplasm in Ghana. Ghana Jnl agric. Sci Vol. 32: 169-175.

Cooper, J. and Oduor, G. (1999). Pest management in horticultural crops; integrating sustainable pesticide use into biocontrol-based peri-urban production systems in Kenya. Final technical report-Crop protection programme (1996-1999). 26 pp. [http://www.researchintouse.com/nrk/RIUinfo/outputs/R6616_FTR.pdf] site visited 03/12/2011.

Erwin, D. C. and Ribeiro, O. K. (1996). Phytophthora Diseases Worldwide. American Phytopathological Society, St. Paul; MN. 562pp.

Fontem, D. A., Younyi, P. C. and Suh, M. N. (2004). Effects of Crop Sanitation and Ridomil MZ Applications on Late Blight Severity and Tomato Yields in Cameroon. Tropicultura 22(3): 122 - 126.

Fontem, D. A. (2003). Quantitative Effects of Early and Late Blights on Tomato Yields in Cameroon. Tropicultura 21(1): 36-41.

Fontem, D. A. (2001). Influence of rate and frequency of Ridomil® Plus application on Late blight severity and potato yields in Cameroon. Journal of African Crop Science. 9(1): 235-243.

Fontem, D. A., Nono-womdim, R., Opena, R. T and Gumedzoe, Y. D. (1996). Impact to Blight Infections to Tomato Yield. TVIS Newsletter: 1 (2): 7-8.

Food and Agriculture Organization of United Nations - Statistics (FAOSTAT) (2010). Regional Trade in vegetables and fruits. 15pp.

Gomez, K. A. and Gomez, A. A. (1984). Statistical Procedures for Agricultural Research. 2nd Ed. A Wiley-Interscience Publications, Canada. 680 pp.

Hakiza, J. J., Kakuhenzire, R. M., Namanda, S., Adipala, E., Ragama, P., Lemaga, B., Olanya, M. O., El Bedewy, R., Warren, H., and Bhagsari, A. S. (2005). Evaluation of the efficacy of contact and systemic fungicides for management of potato late blight in Uganda. African Crop Science Conference Proceedings. 7: 1407-1410.

Hassall, K. A. (1990). The biochemistry and uses of pesticides: Structure, metabolism, mode of action and uses in crop protection. (2nd Ed.). Macmillan Press Ltd, London. 536pp.

Inglis, D., Gundersen, B. and Vestoy, E. (1998). Evaluation of fungicides for control of potato late blight. In: Fungicide and Nernaticide Tests (Edited by Raid, R. N). American Phytopathological Society, St. Paul, MN. 158 pp.

Kakuhenzire, R., Kimoone., G., Wagoire, W. W., Gildemacher, P., Lemaga, B., Ekwemu, A. and Mateeka, B. (2007). Adapting fungicide spray regimes to potato late blight host resistance in Uganda. African Crop Science Conference proceedings 8: 801-807.

Kamoun, S. (2003). Minireviews: Molecular Genetics of Pathogenic Oomycetes. American Society for Microbiology 2(2): 191-199.

Lung'aho, C., Nyongesa, M. and Wakahiu, M. (2003). Evaluation of Globe (6% Cymoxanil/ 70% Mancozeb) for Potato late blight management. 6pp. [http://www.kari.org/fileadmin/publications/10thproceedings/

Volone/EvaluationGlobe.pdf] site visited 16/09/2011.

Madden, L. V. (1983). Measuring and modelling crop losses at the field level. Journal of Pathology 73: 1591 - 1596.

Maerere, A. P., Sibuga, K. P., Bulali, J. E. M., Mwatawala, M. W., Kovach, J., Kamanywa, S., Mtui, H. D. and Erbaugh, M. (2010a). Deriving appropriate pest management technologies for smallholder tomato (Solanum lycoperscum Mill.) growers: A case study of Morogoro, Tanzania. Journal of Animal and Plant Sciences 6 (3): 663-676.

Masinde, A. O. A., Kwambai, K. T. and Wambani, N. H. (2011). Evaluation of tomato (*Lycopersicon esculentum* L.) variety tolerance to foliar diseases at Kenya Agricultural Research Institute Centre-Kitale in North west Kenya. African Journal of Plant Science 5(11): 676-681.

Matheron, M. (2001). Modes of Action for Plant Disease Management Chemistries. [http://ag.arizona.edu/crop/diseases/papers/dischemistry.html] site visited 22/11/2011.

Minja, R. R., Ambrose, J., Ndee A., Swai, I. S., and Ojiewo, C. O. (2011). Promising improved tomato varieties for eastern Tanzania. African Journal of Horticultural Science 4: 24-30.

Mizubuti, E. S. G., Junior, V. L. and Forbes, G. A. (2007). Management of Late Blight with Alternative Products. Pest Technology. 1(2): 106-116.

Muchiri, F. N., Nada, R. D., O1anya, O. M., Nyankanga, R. O. and Ariga, E. S. (2009). Efficacy of fungicide mixtures for the management of Phytophthora infestans (US-1) on Potato. Phytoprotection 90: 19-29.

Novikova, I. I., Litvinenko, A. I., Boikova, I. V., Yaroshenko, V. A. and Kalko, G. V. (2003). Biological activity of new microbiological preparations alirins B and S designed for plant protection against diseases. In: Biological activity of alirins against diseases of vegetable crops and potato. Mikologiya i Fitopatologiya 37(1): 92-98.

Ojiewo, C. O. and Kwazi, N. (2011). New variety releases expand market options for Tanzania's farmers. East African Fresh Produce Journal. Horticultural News. February 2011.

Olanya, O. M., El-Bedewy, R., Ojiambo, P. S., Ewell, P. T. and Hakiza, J. J. (2000). Relationships of Fungicide Application to Late Blight Development and Potato Growth Parameters in the Tropical Highlands of Uganda and Kenya. CIP Program Report: 77-86.

Shaba, E. R., Khonje, P. T., Butao, E. A., Kameta, S., Banda, B. E. and Silue, S. (2006). Integrated control of late blight (Phytophthora infestans) disease of tomato (*Lycopersicum esculentum* L.) in Thyolo and Ntcheu districts, Malawi. Malawi Journal of Agricultural Sciences 3(1): 6-11.

Shoba, N. and Arumugam, R. (1991). Association of leaf curl virus resistance in tomato. South-Indian Hort 35(5): 281-283.

Singh, K. P., Sharma, U. N., Prasad, B., Sinha, R. P., Maury, K. R. and Saha, B. C. (1990). Correlation and path analysis in tomato. Res. Develop. Rep 7(1-2): 164-168.

Sokoine University of Agriculture – Integrated Pest Management - Collaborative Research Support Program - East Africa. (SUA-IPM CRSP). (2006). Morogoro Tomato Baseline Survey Report. 30 pp.

Trigiano, R. N., Windham, M. T. and Windham, A. S. (2004). Plant Pathology: Concepts and Laboratory Exercise. CRC Press. New York. 413pg.

United State of America Environmental Protection Agency (USDA-EPA). (2004). Thiophanate-methy: Pesticide Fact Sheet. 17pp.

Van der Vossen, H. A. M., Nono-Womdim, R and Messiaen, C. M. (2004). Lycopersicon esculentum Mill. In: PROTA 2: Vegetables/Légumes. (Edited by Grubben, G. J. H. and Denton, O. A.). [CD-Rom]. PROTA, Wageningen, Netherlands. [http://database.prota.org/PROTAhtml/Lycopersicon%20esculentum_En.htm] site visited 29/03/2010.

William, E. F. (1998). Vegetable crops. Late Blight of Potatoes and Tomatoes. Department of Plant pathology, NYS College of Agriculture and Life Sciences Cornel University, Ithaca. [http://vegetablemdonline.ppath.cornell.edu/factsheets/Potato_LateBlt.htm] site visited on 12/07/2011.