Study on alternative technologies for the production of tomato during the rainy season in sub-humid climate of Bahir Dar, Ethiopia

Melkamu Alemayehu[1*] and Getachew Alemayehu[1]
[1] Bahir Dar University, College of Agriculture and Environmental Sciences

ABSTRACT

Tomato production is not common during main rainy season, especially in sub-humid climatic conditions like in Bahir Dar. Therefore, an experiment was conducted to study the production potential of tomato using rain-shelter and management practices during the 2013 rainy season (June-October) in Bahir Dar. The experimental treatments were laid down in split-plot-design at three replications, where with and without plastic rain-shelter were assigned as main plots and management practices (fungicide and stalking) as sub-plots. The results revealed that tomatoes grown in protected structure were significantly ($P<0.01$) longer (100.5 cm), had more branches (8.9) and flowered earlier (49.1 days) than those grown under open field condition with the mean values of 50.9 cm, 6.3 and 54 days, respectively. Incidence and severity of late blight and yield of tomatoes were also influenced significantly by growth conditions, management practices and their interactions. Tomatoes grown under rain-shelter structure produced significantly higher total fruit yield (31.3 t ha^{-1}) and exhibited low disease incidence (16.7%) and severity indexes (26.7%) on leaves and as well as on fruits with the mean values of 22.4% and 37.9%, respectively. Similarly, sprayed and staked tomatoes produced the highest marketable (35.2 t ha^{-1}) and total (41.8 t ha^{-1}) fruit yields and exhibited significantly lower late blight incidence and severity. In rain-shelter structure, the management practices had similar effects on both disease and yield parameters, where higher yield and lower late blight incidence and severity were generally observed. In open field condition, however, only sprayed and staked tomatoes exhibited lower late blight incidence (23.3%) and severity (24%) on leaves and fruits with the mean values of 39% and 40%, respectively. The highest marketable yield (36.4 t ha^{-1}) obtained from such tomatoes in open field condition was statistically similar with the yield obtained from the corresponding treatment in rain-shelter structure (34.1 t ha^{-1}). Generally, the present findings showed that rain-shelter technology reduced incidence of late blight and thus it can be used as alternative technology for the production of tomato during the rainy season in and around Bahir Dar. Moreover, tomato can also be produced in open field using improved management practices such as staking and spraying with appropriate fungicides against late blight and similar diseases. Further research is required to select tomato varieties suitable for rain-shelter technology as well as to optimize frequency of pesticide applications as their application may have residual effect on fresh vegetables like tomato.

Key words: Disease incidence, growth condition, late blight, rain-shelter, Ridomil, staking

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INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill) is one of the most economically important edible and nutritious vegetable crops in the world that belongs to the family *Solanaceae*. It supplies several nutrients of high nutritional values in human diet (Agarwal and Rao, 2000; Willcox *et al.*, 2003; Borguini *et al.*, 2009; Midas, 2013). Its production is steadily increasing in the last ten years worldwide. The current world tomato production reached to more than 163.4 million tons cultivated on more than 4.6 million hectares of land (FAO, 2016).

Tomato is widely cultivated in tropical, sub-tropical and temperate climates. The crop requires warm weather and abundant sunshine for its

*Corresponding author: melkalem65@gmail.com

best growth and development. Both vegetative and reproductive growths are affected by lower temperatures. Extended exposure of tomato to temperatures at 12^{o}C or lower can cause chilling injury. Furthermore, tomato requires uniform moisture supply and well-drained soil. Therefore, in temperate and sub-tropical climate where the environmental conditions are unsuitable especially during the winter season, tomatoes are produced under protected structure, whereas in tropical countries, they are mostly cultivated in open field (Kelley *et al.*, 2014).

The climatic and soil conditions of Ethiopia are suitable for the production of a wide range of tropical and subtropical fruits and vegetables including tomato. Tomato is mainly cultivated by smallholder farmers as cash crop in mid- to low-altitude areas of Ethiopia for both local consumption and regional export markets. Small-scale commercial production of tomato is also practiced especially in central Rift Valley region of the country (EIAR, 2007).

Although Ethiopia has huge potential, the production and productivity of tomato in the country is very low. According to CSA (2013), the annual average tomato production in Ethiopia is estimated to be about 55,514 tons which is harvested from about 7,237 hectares of land. Lack of improved varieties, poor and traditional agronomic practices and high disease and insect pest incidences are the major constraints of tomato production in Ethiopia. Moreover, especially in humid- and sub-humid areas of the country, tomato production is not common during the rainy season mainly due to high incidence of late blight (*Phytophthora infestans* (Mont) de Bary) due to high humidity. In these areas, tomato is cultivated mainly during the dry season using irrigation with resultant inadequate supply of tomato in the period of July to October that increases the price up to ten folds. The direct contact of plants with rain drops, coupled with other predisposing factors such as favorable temperatures and high relative humidity make the environment suitable for the development and spread of diseases including late blight (Agrios, 2005) which restrict the production of tomato in such areas (Palada *et al.*, 2003; Kratky, 2006; EIAR, 2007; Kelley *et al.*, 2014).

Recently rain-shelter technology is developed and promoted in various countries of the world including Africa as alternative production system for tomatoes and similar vegetables in humid and sub-humid climates. The technology reduces the predisposition of tomato plants against late blight and other similar diseases as indicated by various researches (Palada *et al.*, 2003; Kratky, 2006; Srinivasan, 2011; Wani *et al.*, 2011). Hence, such technology is being promoted in the last few years in some African countries for the production of tomatoes during rainy season in humid-,and sub-humid climates (KHDP, 2007; RESCAP, 2011). Conversely, vegetable production under protected structure is not a common practice in Ethiopia. Only floricultural plants like roses are produced recently in greenhouses (Van der Maden *et al.*, 2011). The use of this technology for the production of vegetables is a new initiative in Ethiopia which may help to improve the supply of fresh vegetables throughout the year and thus contributes to the improvement of livelihood of smallholder farmers in humid and semi-humid areas. The objective of this study was thus mainly to assess the potentials of producing tomato during the rainy season in Bahir Dar using transparent plastic rain-shelter and management practices such as staking and spraying of appropriate fungicides against late blight disease.

MATERIALS AND METHODS

Description of the Study Area

The experiment was conducted during the main rainy season of 2013 at Kiflemariam`s Fruit and Vegetable Farm in Bahir Dar, Northwestern of Ethiopia. The experimental site is located at $11^0$6`N latitude and $37^0$38`E longitude and at an altitude of 1980 m.a.s.l. The mean monthly temperature of the study area during the experimental period (June-October) was about 19.3^{O}C with the mean maximum and minimum temperatures of 25.5^{O}C and 13^{O}C, respectively, whereas that of rainfall was about 248.8 mm (Personal communication with Ethiopian Meteorology Agency, Bahir Dar Branch).

Experimental Materials, Treatments and Design

"Roma VF" variety of tomato was used for the experiment. The variety is produced commonly for fresh as well as processing industries in Ethiopia (EIAR, 2007). The effect of four management practices (spraying and stalking, non-spraying and stalking, spraying and non-stalking, and non-spraying and non-stalking) on growth and yield performances of tomato were compared under rain-sheltered and open field conditions. A broad spectrum fungicide, Ridomil-gold, was applied against late blight disease with the concentration of 4 kg ha^{-1} at 7-10 days interval after transplanting until 10 days before the first harvest as recommended by Lemma Dessalegn *et al.* (2003). Rain-shelter structure with the size of 12 m x 14 m was made using locally available construction materials and covered with white plastic sheets (10 micrometer thickness) to protect experimental plants from rainfall. The height of the structure was 4 m at the center. Side walls were kept open during the day time for the purpose of aeration and humidity control. The experimental treatments were laid out in split-plot design at three replications. Growing conditions (rain-shelter structure and open field) were assigned in main plots and management practices were assigned in sub-plots. The size of each experimental plot was 5.76 m^2.

Management of Experimental Plants

Seeds of "Roma VF" variety were sown in rows of 15 cm on 1m x 5m well prepared seedbed and covered with light soil. The seedbed was mulched with grasses and regularly watered using watering can to keep the soil moist. After emergence, mulch was removed and nursery over-shade was constructed to protect tomato seedlings from strong sunlight.

At first true leaf stage, seedlings were thinned at 3 cm within rows. Finally, well hardened healthy and strong tomato seedlings at 2-3 true leaves stage were carefully transplanted to the experimental plots using the recommended spacing of 40 cm within rows and 60 cm between rows (EIAR, 2007). Transplanted seedlings were provided with inorganic fertilizers of Diammonium Phosphate (DAP) and Urea at the rate of 69 kg ha^{-1} P_2O_5 and 64 kg ha^{-1} N, respectively. The whole phosphorous fertilizer was applied at transplanting whereas nitrogen was applied in two equal splits. The first half was applied after the establishment of the seedlings (ten days after transplanting) and second half was applied forty days after transplanting as side dressing as described by Lemma Dessalegn *et al.* (2003). Experimental plants were sprayed with broad-spectrum insecticide, namely Sevin ® 80WSP Carbaryl at the concentration of 2 kg ha^{-1} uniformly to control insect pests as recommended by Lemma Dessalegn *et al.* (2003). Tomato plants grown in open field were cultivated with natural rainfall whereas plants in rain-shelter structure were irrigated with watering can uniformly as required. All other management practices in the nursery as well as in the experimental field such as weeding and soil cultivation were done according to the recommendation of EIAR (2007) and kept uniform for all experimental plots.

Data Collection and Analysis

Data on growth parameters, disease incidence and severity caused by late blight on leaves and fruits, and yield of tomato were collected. All parameters were collected from net plot area of 1.92 m^2 by excluding the border effects. Data of important parameters were collected using standard methods and procedures as given below.

Plant height (cm): Plant height at first harvesting was measured from five randomly selected plants in each net plot using meter from the ground level to the main apex of each plant and the average height was taken for further analysis.

Number of primary branches per plant: Number of primary branches per plant was recorded from five randomly selected plants per plot by counting during first harvest growth stage and means were used for analysis.

Days to 50% flowering: Number of days was counted from date of transplanting to date of 50% of plants in each net plot flowered.

Days to first harvest: It was assessed by counting the number of days from date of transplanting to date of 50% of plants in each net plot reached harvest maturity. Fruits were ready for harvesting when they attained pink stage (30-60% yellow or red) as indicated by Rai and Yadav (2005).

Marketable and unmarketable yields (t ha^{-1}): At each harvest, fruits were categorized as marketable or unmarketable fruits. Bruised, damaged, small-sized (2.5-3.5 cm in diameter) and sun burnt fruits were considered as unmarketable as indicated by Lemma Dessalegn *et al.* (2003). Fruits free from visible damages and having diameter greater than about 3.5 cm were considered as marketable and the average yield was then taken for further analysis.

Total yield (t ha^{-1}): The average total yield was obtained by adding marketable and unmarketable fruit yields.

Disease incidence (%): It was assessed by counting diseased plants in net plot area and expressed as percentage. In case of fruits, diseased fruits from randomly selected ten fruits during each harvest were counted and expressed as percentage of the total fruits inspected.

Disease severity index (%): Five plants per plot were selected randomly from each replicate per treatment, and then five leaves of each plant were used to determine the disease severity. In case of fruit severity, ten fruits were selected randomly and their disease severities were determined. Disease severity was recorded on the base of 1-5 rating scales, where scale 1= trace to 25%, 2= 26-50%, 3= 51-75%, 4= 76-99%, 5= 100% and then the rating scales were converted into percentage severity index for the analysis using the formula indicated by Mohammed Amin *et al.* (2013).

DSI = (Sum (n)/ (a x b)) x100

Where

DSI = Disease severity index (%)

n = individual numerical ratings; a = total number assessed; b = maximum score in scale

The collected data were tested for their normal distribution and homogeneity and subjected to analysis of variance (ANOVA) using Statistical Analysis System (SAS) software version 9.1. Based on ANOVA results, treatment means were further separated using least significant difference (LSD) at 1% or 5% probability level.

RESULTS AND DISCUSSION

Growth Parameters

Plant height

Protection of tomato plants with rain-shelter as the main effect increased the plant height of tomatoes significantly (P<0.01) compared to open field with the mean values of 100.5 cm and 50.9 cm, respectively (Table 1). However, management practices as the main effect didn't have significant effect on the plant height of tomatoes. Similarly, the interaction of growth conditions and management practices didn't show significant influence on the height of tomato (Data not shown).

The increase of tomato plant height in rain-shelter condition would probably be associated with the improved growth conditions including temperature during rainy season that in turn promote the growth and development of the plants. This argument is in line with the observations of Palada *et al.* (2003), Kratky (2006) and Wani *et al.* (2011) who found an increment of air temperature up to 2-5^{O}C in rain-shelter structure than in open field condition. Moreover, the variety "Roma VF" is an open field variety required high sunlight and short in height (EIAR, 2007). Therefore the increase in height of tomatoes may also be associated with lack of sunlight in rain-shelter condition.

Number of primary branches

As indicated in Table 1 tomato plants grown under rain-shelter produced significantly (P<0.01) more primary branches per plant (8.9) than those grown in open field (6.3). This difference can be associated with the increase of plant height of tomatoes grown in plastic rain shelter as mentioned above.

Regardless of the growing conditions, the management practice of spraying and staking resulted an increase in the number of tomato branches (8.7) significantly (P<0.05) compared to non-sprayed/non-staked tomatoes (6.9). The number of branches in non-sprayed but staked tomatoes was lower (7.4), but not statistically different, than sprayed and staked tomatoes. This result demonstrates in some extent the positive role of staking in the reduction of disease predisposing conditions in tomato production. The increased number of primary branches in sprayed and staked tomatoes could be related with the fungicidal effect of Ridomil spray which would be preventing tomato plants from fungal disease infestations like late blight as observed by Mohammed Amin *et al.* (2013). The interaction of growing conditions and management practices didn't show significant influence on the branch number of tomato plants (data not shown), where each level in management practices had similar effect on each level of growing conditions.

Days to 50% flowering and first harvest date

Days to 50% flowering was highly significantly influenced by growing conditions (P<0.01). Tomato plants protected from rainfall flowered about six days earlier than those grown in open field (Table 1). However, early flowering in rainfall protected structure didn't bring significant change on the first harvest date of fruits in this study. This result disagrees first flowering first maturity principle in greenhouse tomato production where the environmental conditions such as temperature, relative humidity and light intensity are controlled (Kelley *et al.*, 2014). This could be due to uncontrolled growth environment except rainfall existed in rain-shelter that depends on the outside environmental conditions during the experiment.

Moreover shortening of tomato flowering for about six days in plastic rain shelter in this study due to comparatively high temperature may not enough to express itself on first harvest date like probably the case in controlled greenhouse production (Kelley *et al.*, 2014).

Table 1. Effects of growth conditions and management practices on growth parameters of tomatoes grown during the main rainy season of 2013 in Bahir Dar

Main factor	Treatment	PH (cm)	NoB	FD (days)	FHD (days)
Growing condition	Rain-shelter	100.52a	8.90a	49.08b	95.0
	Open field	50.88b	6.25b	54.00a	96.0
LSD (1%)		16.31	0.69	2.42	6.10
CV (%)		17.3	7.28	3.78	5.13
SE±		5.35	0.23	0.79	2.00
Management practice	Sprayed and stalked	78.87	8.73a	51.83	95.00
	Non-sprayed and staked	77.50	7.43ab	50.67	95.00
	Sprayed and non-stalked	78.03	7.22ab	52.67	97.30
	Non-sprayed and non-stalked	68.40	6.92b	51.00	94.00
LSD (5%)		10.39	1.47	2.51	2.81
CV (%)		10.91	15.40	3.87	2.34
SE ±		4.77	0.67	1.15	1.29

Means within a column followed by the same letter(s) are not significantly different at P = 0.01; PH = plant height; NoB = number of branches; FD = days to 50% flowering; FHD =first harvest date

On the other hand days to 50% flowering and first harvest date were not significantly affected by all management treatments (Table 1). Similarly, both days to 50% flowering and first harvest date were not significantly influenced by the interaction of rain shelter and management treatments (data not shown). This implied that the effects of the management treatments on days to 50% tomato flowering and first harvest date were similar in both rainfall-protected and open field conditions.

Marketable, Unmarketable, and Total Yields

The results of analysis of variance revealed that growing conditions, management treatments and their interaction affected significantly the yield of tomatoes grown during the rainy season of Bahir

Dar. Regardless of the management practices, growing tomatoes under plastic covered growth structure produced significantly (P<0.01) higher marketable and total yields as well as lower unmarketable yield than those grown in open field condition (Figure 1). Growing plants in plastic rain-shelter structure increased the marketable and total fruit yield by 40.9 and 30.6%, respectively, and reduced the unmarketable fruit yield by 18.1% compared to the corresponding plants grown in open field.

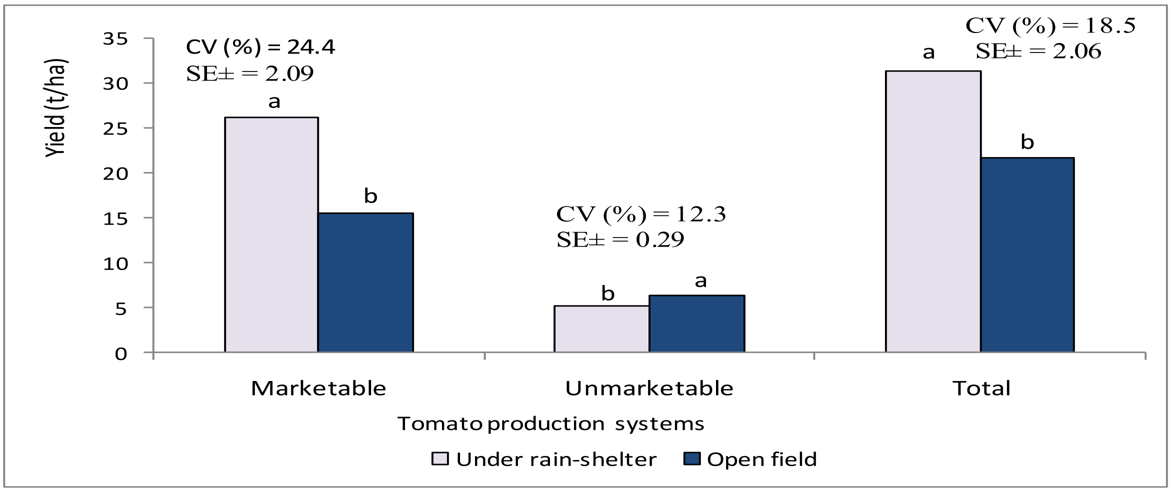

Figure 1. Marketable, unmarketable and total yields of tomato as influenced by growth conditions during the rainy season of 2013 in Bahir Dar
Means within a group followed by the same letter(s) are not significantly different at P = 0.01

Similarly, in the main effect of management practices, the treatment spraying and staking increased marketable and total yields of tomato significantly (Table 2). The maximum marketable and total yields of tomato were obtained from sprayed and staked treatment followed by sprayed and non-staked treatment. Staking alone without fungicide spray had non-significant effect on marketable, unmarketable, and total yields of tomato plants. The lowest marketable yield of tomato was obtained from non-sprayed and non-staked treatment.

Table 2. Effects of management activities on yield performances of tomatoes grown during the rainy season of 2013 in Bahir Dar

Main factor	Treatment	Yield (t ha^{-1})		
		marketable	unmarketable	total
Management practice	Sprayed and staked	35.21a	6.45a	41.76a
	Non-spraying and staked	13.99c	3.61b	17.60c
	Sprayed and non-staked	22.41b	8.44a	30.85b
	Non-sprayed and non-staked	11.45c	4.39b	15.84c
LSD (1%)		2.55	2.49	3.51
CV (%)		9.77	24.64	10.34
SE ±		0.83	0.82	1.15

Means within a column followed by the same letter(s) are not significantly different at P = 0.01

In the present study, there was a clear interaction effect between growing conditions and management practices on the yields of tomatoes (Table 3). Under rain-shelter condition, there was no significant difference between the management practices for marketable, non-marketable and total yields of tomatoes. However, the highest marketable (34.1 t ha^{-1}) and total (39.3 t ha^{-1}) fruit yields were obtained from sprayed and staked tomato plants.

Under open field condition, however, significant differences between management practices were clearly observed for all the tomato yield parameters (Table 3). The treatment spraying and staking in open field condition gave the highest marketable (36.4 t ha^{-1}) and total (44.2 t ha^{-1}) yields. These highest marketable and total yields of tomato obtained from open field condition were statistically similar with those yields obtained from all treatments except from non-sprayed and non-staked in rain-shelter condition.

Although the treatment spraying and non-staking had no significant effect on yields of tomato in rainfall-protected structure, it reduced the marketable yield of tomato significantly ($P<0.01$) in open field condition. Similarly, staking without spraying reduced the marketable and total yields of tomato in open field condition. Generally, the lowest marketable and total yields were obtained from non-sprayed treatments in open field growing condition.

In open field growth condition, the unmarketable fruit yields obtained from treatments sprayed/staked and sprayed/non-staked tomatoes were significantly ($P<0.01$) high with the mean values of 7.8 t ha^{-1} and 11.6 t ha^{-1}, respectively. However, their proportions to the total yields obtained from the same treatments were relatively lower (about 17.7% and 37.2%, respectively, in the same order) compared to non-sprayed/staked and non-sprayed/non-staked with the mean values of 48.7% and 52.3%, respectively. Generally, growing tomato in open field condition without fungicide spray during the main rainy season resulted low yield and high proportion of unmarketable yield.

The results of the present study clearly showed that it would be possible to produce tomato successfully in Bahir Bar during the rainy season using plastic rain shelter. Protecting tomato plants from rainfall using simple growing structure covered by transparent plastic materials increased the fruit yield of tomato. This was the mere fact that in plastic rain shelter grown tomato plants were protected from direct rain droplets which will otherwise create suitable micro-climates for the growth and development of diseases like late blight. Hence, protecting tomato plants from direct rainfall reduce the predisposition of tomatoes against late blight. Moreover growing tomato under plastic rain-shelter during rainy season may improve the growing conditions like temperature and relative humidity that in turn increase the growth, development and yield of the plant.

The present findings are in agreement with the findings of many previous studies which showed increased quantity and quality of economic yields of tomato and other similar vegetables grown under rain-shelters during rainy season in different humid and semi-humid areas of the world (Palada *et al.*, 2003; Kratky, 2006; KHDP, 2007; RESCAP, 2011; Wani *et al.*, 2011).

Management practices like application of fungicides and staking also attributed to the increase of tomato yields grown in open field during the rainy season of the study area. Management practices other than the joint use

Table 3. Interaction effects of growth conditions and management practices on yield performances of tomatoes during the rainy season of 2013 in Bahir Dar

Growing condition	Management practice	Yield (t ha^{-1})		
		marketable	unmarketable	total
Rain-shelter	Sprayed and staked	34.05ab	5.24bcd	39.29ab
	Non-sprayed and staked	24.75ab	4.16bcd	28.81ab
	Sprayed and non-staked	25.25ab	5.27bcd	30.52ab
	Non-sprayed and non-staked	20.39b	6.02bcd	26.41b
Open field	Sprayed and staked	36.38a	7.84ab	44.23a
	Non-sprayed and staked	3.22c	3.06cd	6.28c
	Sprayed and non-staked	19.57b	11.60a	31.17ab
	Non-sprayed and non-staked	2.51c	2.75d	5.26c
LSD (1%)		19.54	3.73	18.87
CV (%)		9.77	24.64	10.34
SE ±		2.07	1.02	2.47

Means within a column followed by the same letter(s) are not significantly different at P = 0.01

of spraying and staking indeed will result the reduction of yields both in quantity and quality as observed in open field condition in this study (Table 3). Compared to fungicide spraying and stalking, other management practices reduced the total and marketable yields of tomato by 46.2-93.1% and 29.5-88.1%, respectively. The yield reductions especially in non-sprayed tomatoes were relatively high attributed by the occurrence of high late blight disease infestation.

These results of the present study are in agreement with the reports made by several researchers who revealed that non-sprayed tomatoes and other *Solanaceous* plants gave the lowest yields (Dowley and Neville, 2001; Shamiyeh *et al.*, 2001; Zende, 2008; Mohammed Amin *et al.*, 2013). Similar to the present results EIAR (2007) and Mohammed Amin *et al.* (2013) reported that spraying of tomato with appropriate fungicides against late/early blight diseases and staking gave the highest fruit yield both in rain-shelter and open field using the same variety (Roma VF). Indeed, using appropriate tomato varieties for protected cultivation like indeterminate types may enhance the productivity and profitability of this technology in Ethiopia which of course requires further research in the future.

Incidence and Severity of Late Blight

Tomato is susceptible to various diseases and insect pests. Among these, late blight (*Phytophthora infestans* (Mont) de Bary) is one

Figure 2. Late blight affected tomato plants: Left: - infested stem; Right: - dead plants (Photos taken from open field grown tomato plants)

of the most distractive diseases of tomatoes, potatoes and other *Solanaceae* species (Kratky, 2006). In this study late blight was also observed on different parts of plants with various degrees of severity (Figure 2).

The assessment of disease incidence and severity was conducted on tomato plant leaves after fifty days of transplanting, as well as, on fruits at each harvest. The late blight disease incidence and severity on tomato leaves and fruits were highly significant between growth methods as shown in Figure 3. Tomatoes grown in open field showed significantly (P<0.01) higher late blight incidence and severity on leaves and fruits compared to those grown under rain-shelter. Growing tomatoes in open field increased disease incidence and severity by 200% and 91% on leaves, and by 148% and 69% on fruits, respectively.

The present results are in agreement with the reports of various researches who found that growing tomatoes under protected structure during the rainy season reduced the incidence and severity of late blight by creating unfavorable environmental conditions for the infection, growth and development of the disease (Bowen and Kratky, 1982; Palada *et al.*, 2003; Kratky, 2006; Pandey *et al.*, 2006; Srinivasan, 2011; Wani *et al.*, 2011; Kelley *et al.*, 2014). In this regard, some African countries are started to promote rain-shelter technology for the production of tomatoes and other similar vegetables during the main rainy season in humid/semi humid climates (KHDP, 2007; RESCAP, 2011).

The management practices tested also influenced the occurrence and severity of late blight on tomato leaves and fruits (Table 4). Fungicide spraying with or without staking as a management practice reduced significantly (P<0.01) the incidence and severity index of late blight on leaves of tomato plants. However, on fruits fungicide spraying reduced the incidence of the disease only on staked tomatoes. Ridomil application alone also reduced significantly (P<0.01) disease incidence and severity on leaves compared to non-sprayed and non-staked tomatoes. But, Ridomil spraying alone couldn't able to reduce disease incidence on fruits although it reduced the disease incidence significantly. Similarly, staking without Ridomil spraying could not able to reduce disease incidence and severity

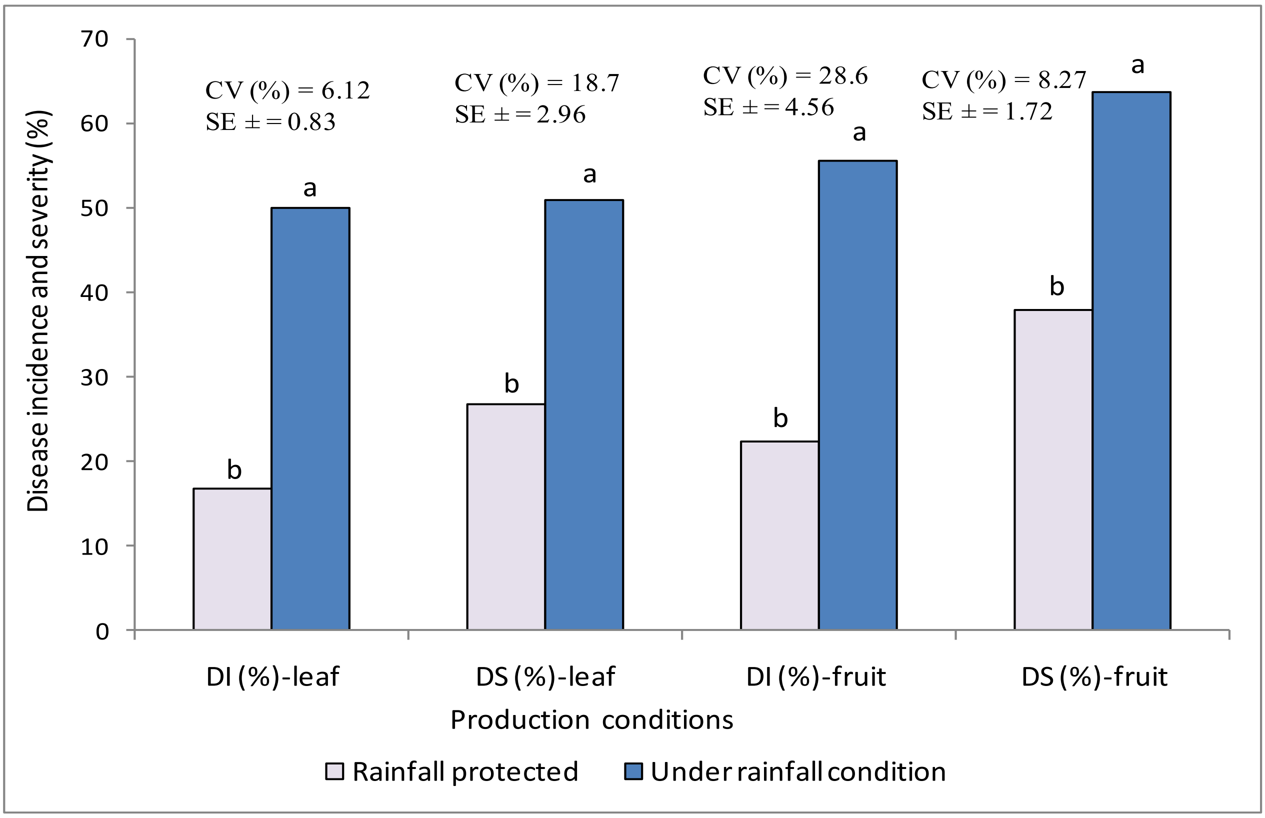

Figure 3. Effects of growth conditions on late blight incidence and severity of tomatoes grown during the rainy season of 2013 in Bahir Dar

Means within a group followed by the same letter(s) are not significantly different at P = 0.01.

DI = Disease incidence; DS = Disease severity index

on leaves as well as disease incidence on fruits of tomatoes. Generally, leaves and fruits of non-sprayed and non-staked tomato plants exhibited significantly (P<0.01) higher disease incidences and severity indexes than leaves and fruits of sprayed and staked plants.

The present study is in agreement with reports of various researchers who found that late blight was effectively controlled by application of broad spectrum fungicide like Ridomil-gold on various vegetables including tomatoes (Dowley and Neville, 2001; Shamiyeh *et al.*, 2001). According to Agrios (2005), high late blight incidence and severity in open field grown tomatoes is due to the fact that rainfall creates suitable micro climates especially in humid and semi-humid environments that favor the occurrence and development of this and other similar diseases. Spraying alone also reduced the incidence of late blight on leaves and fruits as well as its severity on leaves. As indicated in Table 4, indeed, the absence of staking increased late blight severity on fruits and this might be associated with multiple pathogen infection sourced probably from the ground soil where fruits were in contact. In agreement with these findings Lemma Dessalegn *et al.* (2003), EIAR (2007) and Mohammed Amin *et al.* (2013) recommended that tomatoes should be staked to avoid the contact of fruits with the soil and thus to reduce infection of fruits with soil born diseases that in turn reduces the quality of fruits.

Table 4. Effects of management practices on late blight incidence and severity of tomatoes grown during the rainy season of 2013 in Bahir Dar

Main factor	Treatment	Leaf		Fruit	
		Incidence (%)	Severity (%)	Incidence (%)	Severity (%)
Management practice	Sprayed and staked	16.67b	22.67b	27.92b	33.33c
	Non-sprayed and staked	46.67a	48.00a	41.74a	53.81b
	Sprayed and non-staked	26.67b	32.67b	39.36ab	52.38b
	Non-sprayed and non-staked	43.33a	52.00a	46.94a	63.81a
LSD (1%)		17.61	10.37	11.44	8.39
CV (%)		30.00	15.16	16.66	9.37
SE ±		5.77	3.40	3.75	2.75

Means within a column followed by the same letter(s) are not significantly different at P = 0.01

The interaction effect of growing conditions and management practices on disease incidence and severity index of leaves and fruits of tomatoes is presented in Table 5. In rain-shelter condition, significant differences were not observed among management practices for late blight incidence and severity on leaves and fruits of tomatoes. The mean values of late blight incidence and severity at all management practices were relatively lower in this growing condition compared to the values due to the corresponding treatments in open field. On the contrary, significant differences among management practices in open field were observed for both late bight incidence and severity. In open field condition, fungicide spraying and staking resulted in the lowest significant mean values of late blight incidence and severity index on both tomato leaves and fruits. The mean values of late blight incidence and severity on tomato plant leaves due to fungicide spraying and staking in open field were similar to the results of the corresponding plants grown in rain-shelter, while their mean values on fruits were much higher than the corresponding plants grown under rain-shelter growing condition.

Generally, the management practices such as a joint application of fungicide spraying (Ridomil Gold) and staking reduced significantly the incidence and severity of late blight compared to the other management practices tested in the study that verified the effectiveness of Ridomil-gold against late blight in the production of tomatoes.

Table 5. Interaction effects of growth conditions and management practices on incidence and severity of late blight on tomatoes grown during the rainy season of 2013 in Bahir Dar

Growing condition	Management practice	Leaf		Fruit	
		Incidence (%)	Severity (%)	Incidence (%)	Severity (%)
Rain-shelter	Sprayed and stalked	10.00c	21.33c	16.90c	26.67e
	Staked and non-sprayed	23.33c	25.33c	25.07bc	40.00cd
	Sprayed and non-stalked	13.33c	28.00bc	18.06c	38.10d
	Non-sprayed and non-stalked	20.00c	32.00bc	29.68bc	46.67c
Open field	Sprayed and stalked	23.33c	24.00c	39.00b	40.00cd
	Staked and non-sprayed	70.00a	70.67a	58.4a	67.62b
	Sprayed and non-stalked	40.00b	37.33b	60.66a	66.67b
	Non-sprayed and non-stalked	66.67a	72.00a	64.20a	80.95a
LSD (5%)		15.53	11.35	14.49	8.33
CV (%)		30.00	15.16	16.66	9.37
SE ±		7.1	4.66	5.61	3.58

Means within a column followed by the same letter(s) are not significantly different at P = 0.05

This result was also supported by correlation analysis made between disease assessment parameters and marketable yield of tomatoes. There was a strong negative and significant ($P<0.01$) correlation between late blight disease incidence ($r = -0.836$) and marketable fruit yield and late blight severity ($r = -0.902$) of leaves and marketable fruit yield. Similarly, negative significant correlation was also observed between disease incidence ($r= -0.718$) and severity index ($r= -0.839$) of fruits and marketable yield of tomatoes.

CONCLUSIONANDRECOMMENDATIONS

Late blight is the limiting biological factor for the production of tomatoes in warm humid areas during the rainy season. Therefore, farmers in such areas of Ethiopia are not producing tomatoes during the main rainy season. Consequently, the prices of tomatoes steeply rise during the summer. The results of the present study revealed that protecting tomato plants from rainfall using plastic rain-shelter helped to significantly reduce the incidence and severity of late blight and other similar diseases. Besides, growing tomatoes in protected structure may improve the environmental conditions for the growth and development of tomato and similar crops during the rainy season and thus increases the marketable yield of the crop plant. Moreover, a joint use of Ridomil application and staking reduced the incidence and severity of late blight on leaves and fruits of tomatoes grown in open field. The results of the present study clearly showed that successful tomato production during the main rainy season would be possible in transparent rain-shelter structures as well as with appropriate fungicide application against late blight disease and staking of tomato plants in Bahir Dar. If tomato plants are protected from rainfall, regular fungicide spraying may not be necessary for the management of this disease. Nevertheless, further study should be done to optimize the frequency of pesticide application and to select tomato varieties suitable for plastic rain-shelter technology. Furthermore, cost-benefit analysis for these technologies should also be well studied before recommending them for wider application.

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