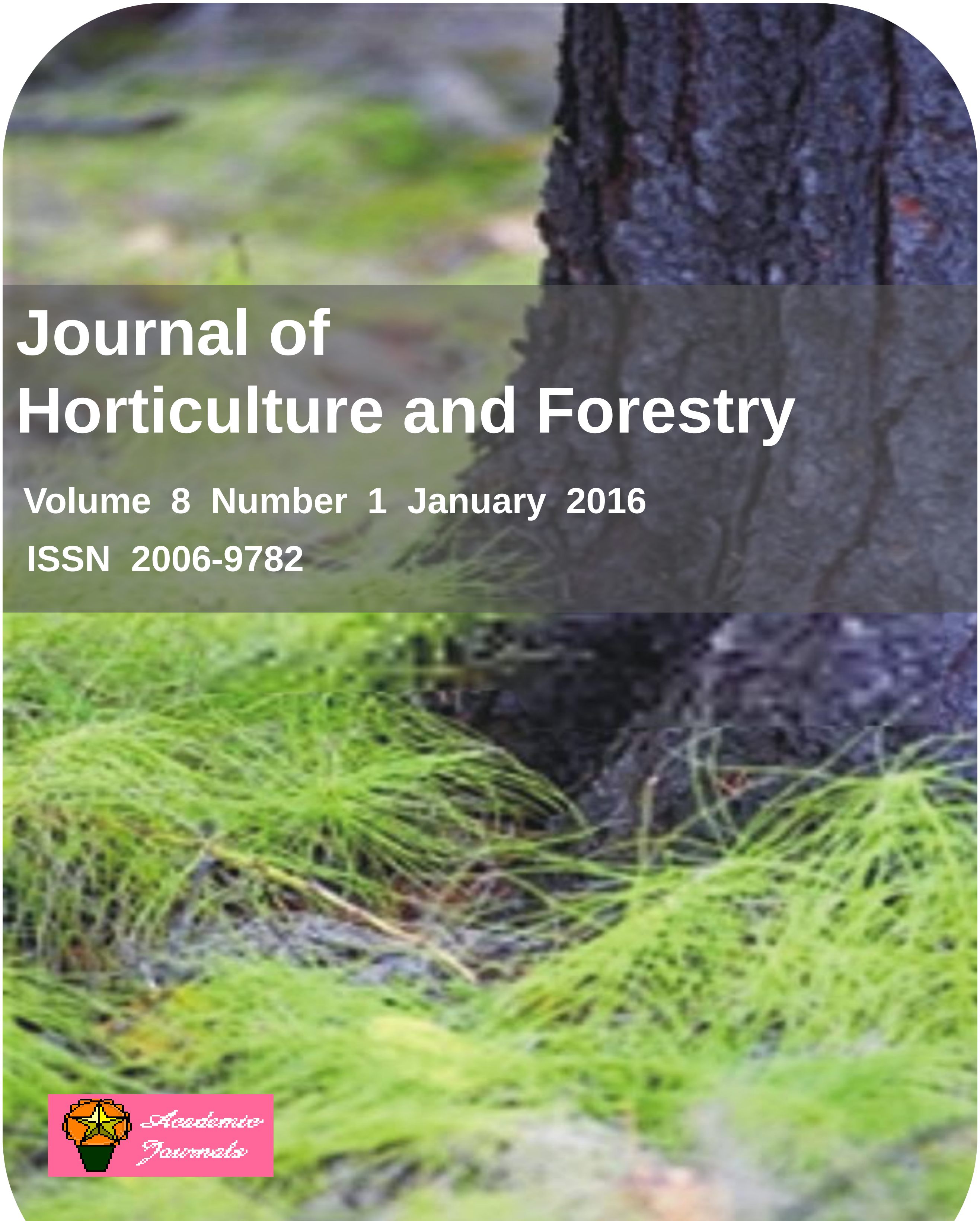

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Full Length Research Paper

Influence of mulching and varieties on growth and yield of tomato under polyhouse

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The experiment was conducted to study the effect of mulch on growth and yield of tomato varieties under polyhouse condition at Bahir Dar, Ethiopia in 2012 and 2013. The treatments were 4 × 2 factorial combinations of mulching material (Black plastic mulch (BPM), White plastic mulch (WPM), Grass mulch (GM) and no mulch with two varieties (Cochoro and Miya). White plastic mulch recorded significantly tallest plant height followed by black plastic mulch. Significantly highest number of primary and secondary branches per plant were recorded for un-mulched Cochoro variety and mulched with grass, respectively in 2013. Cochoro variety mulched with grass produced significantly highest number of flowers per cluster in 2013. Significantly highest number of fruits per cluster and percent fruit set was registered when Miya variety was grown on grass and black plastic mulch, respectively. Earlier flower, fruit set and maturity of fruits were recorded from plants mulched with white plastic. Significantly early flowering, fruit setting and fruit maturity were recorded inthe Miya variety. The highest marketable fruit yield was obtained with grass mulch treatment (60.90 t ha^{-1}) and the lowest was obtained with no mulch treatment (43.76 t ha^{-1}). The increase in fruit yield gained by the application of grass mulch in polyhouse was attributed to its favorable effect on soil temperature and soil moisture which subsequently created conducive condition for root growth and development. Significantly higher marketable yield was obtained in Miya variety (57.83 t ha^{-1}) as compared to Cochoro variety (44.32 t ha^{-1}). The mean air temperature regime was 18.7°C (night) to 25.6°C (day) inside the polyhouse which was optimum for plants growth and normal fruits production. Soil temperatures under both plastic mulches were constantly higher than under bare soil and grass mulch. Cost benefit analysis indicates the highest net benefit was obtained on grass mulch. Based on agronomic performance and economic analysis the result of the present study indicated that the superiority of Miya tomato variety grown at grass mulch under polyhouse growing condition. Therefore, application of grass mulch for tomato fruit yield using Miya variety is recommended for producers in the study area.

Key words: Mulch, polyhouse, tomato.

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is one of the most widely consumed vegetable crops in the world. It is

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eaten fresh or in a multiple of processed forms. The three major processed products are (i) tomato preserves (whole peeled tomato, tomato juice, tomato pulp, tomato puree, tomato paste and pickled tomatoes); (ii) dried tomato (tomato powder, tomato flakes and dried tomato fruits), and (iii) tomato-based foods (tomato soup, tomato sauces and ketchup) (Costal and Heuvelink, 2005).

Tomato can play an important role in human diet. It is a valuable source of vitamins A and C, as well as several minerals (Kaur and Kapoor, 2008) including calcium, iron, manganese, and particularly potassium (Hevrn and Post, 2004; Naika et al.,2005). It also contains lycopene, which is a carotenoid (a pigment involved in photosynthesis) and that gives red coloring to tomatoes (Kelley and Boyhan, 2010).

Crop productivity is influenced by the genetic characteristics of the cultivar, growing environment and management practices. Vegetable and flower production is significantly influenced by weather conditions. The extent of its production causes considerable fluctuations in its prices. A striking balance between all season availability of vegetables and the production system are major challenges for the modern technology of crop production. Recently, the protected cultivation is becoming an important production practices for creating favorable environment for the sustained growth of plant to realize its maximum potential even in adverse climatic conditions. Greenhouses, plastic tunnels, insect-proof net houses and shade nets are used as protective structures depending on the requirements and cost-effectiveness. Besides modifying the plant's environment, these protective structures provide protection against wind, rain and insects (Hasan and Singh, 2007).

Climate is the predominant factor that determines crop production. Therefore, growers who have the ability to modify growing environment condition have a competitive advantage over growers in the same region that do not have the ability to manipulate growing environment condition. Manipulation of environmental condition can be achieved through a variety of cultural practices (Read, 2007).Among the cultural practicesmulching is the one that involves placing organic or synthetic materials on the soil around plants to provide a more favorable environment for growth and production. Tomatoes, peppers, eggplants, vine crops and okra generally respond well to plastic mulches. Plastic mulches normally are used in conjunction with drip irrigation to maintain optimum soil moisture and for improved stand establishment (George, 2007).

Tomato offers considerable economic returns for farmers in tropical regions especially when grown during the wet season. However, yield of tomato varies according to the cultural management and also with the variety used. The application of appropriate field cultural management practices and the choice of cultivars are the two factors that affect the productivity of tomato. In the tropics, cultivation of most vegetables provides a major source of income and fresh food for small-scale growers.

However, conventional open field cultivation faces a number of problems particularly during wet seasons, hence, protected cultivation in the form of low-cost greenhouses and shelter structures offer the possibility of resolving the problem. The use of rain shelters or structure with plastic sheet roofing to protect plants from heavy rain is seen as a potential farming technique that would allow off-season production of tomatoes (Capuno et al., 2007).With establishment and expansion of small scale irrigation schemes production of horticultural crops in Amhara region of Ethiopia, like tomato and onion is showing relative progress, and yet this system is constrained by various factors. Lack of improved production experience among farmers' and inadequate extension support and unavailability of technological inputs, insect pests and diseases, substantial seasonal price fluctuation and postharvest loss are among the bottlenecks of this system. Year-round production practice is a key to avoid seasonal price fluctuation and maintain reasonable year round profit.

However, supply of crops like tomato and onion overwhelm the marketing during few months in the dry season, and as a result, the price of the crop drastically decreases. On the other hand, the same crops disappear from the market in the wet season. Disease prevailing during rainy season attributed to the shift of production. If this situation is to continue, forthcoming medium scale irrigation projects may not justify investment on processing plants that may need year round availability of certain commodities such as tomato (Adet Agricultural Research Center, 2003). These problems can be overcome by introducing new production techniques that involve integrated disease management methods and modification of the environment through protected cultivation that can include use of plastic shelters and mulch.

This will enable producers get year round income, with reliable market and higher prices. Better risk management against frost, hailstorm, soil erosion problem, production of cleaner and higher quality produce and efficiency of water use are also advantages of these technologies (Hevrn and Post, 2004). The problem to produce tomato during wet season was the background to conduct the present research. Therefore, the present study was conducted to compare the effect of different mulching materials on the fruit yield of tomato grown under polyhouse and to assess the performance of improved tomato varieties under mulch and polyhouse conditions.

MATERIALS AND METHODS

Description of the study area

The experiment was conducted at Woramit Horticultural Crops Trial Site of Adet Agricultural Research Center during the rainy season in 2012 and 2013. Woramit is located in the North-western part of Bahir Dar town on the shore of Lake Tana in Ethiopia. The site has an altitude of 1800 mabove sea level. It has warm and humid microclimate with distinct dry and wet seasons. The soil is deep with red-brown color characterized as Nitosol. The mean daily maximum temperature is 29.5°C in April. The mean daily minimum temperature is 6.2°C in January. The area receives a mean annual rainfall of 800-1250 mm. Generally the agro-ecology is characterized as mid altitude (Baye, 2011).

Experimental materials

Two tomato varieties, namely, Cochoro and Miya, were used as experimental materials. Cochoro variety is characterized as a processing type tomato having compact and determinate growth habit type with strong stem. Miya is fresh market type, strong stem with indeterminate growth habit (MoARD, 2007). The mulch materials were black and white colored plastic sheets with 0.02 mm thicknesses and dried grass as organic mulch which was applied by spreading on the soil surface at the rate of 4 t/ha. The treatments were applied in polyhouse which had size of 12 m wide and 33 m length with 3 m height at the center. Two-thirds of the four sides of the polyhouse were covered with 0.15 mm thickness light transparent polyethylene sheet with 80% light transmission capacity starting from the ground. The remaining 1/3 upper portion of the walls was covered with insect proof net for ventilation. The frame of the polyhouse was made from bamboo and wood.

Treatment and experimental design

The experiment consists of eight treatments which were arranged in 4 x 2 factorial combinations. The first factor consists of four types of mulch namely; black plastic mulch (BPM), white plastic mulch (WPM), grass mulch (GM) and no mulch as a control and second factor consists of two tomato varieties namely Chochoro and Miya. The experiment was laid out as Randomized Complete Block Design (RCBD) with 3 replications.

Experimental procedure

Seedlings were raised on a seedbed inside a plastic tunnel in first week of June 2012 and 2013. To protect the seedlings from damping off, Ridomil® MZ 68 WG was sprayed on the nursery beds every two weeks at the rate of 2.5 kg per hectare. Land inside the naturally ventilated polyhouse was thoroughly dug to a depth of 20 to 25 cm one month prior to planting. Weeds and stubbles were removed and the soil pulverized through repeated cultivation. Finally raised beds were prepared for each replication with height of 25 cm to facilitate drainage.

One month old tomato seedlings were transplanted on 8.4 m^2 gross plot size (3 $\times$2.8 m) with spacing of 70 $\times$40 cm between rows and plants, respectively. Data were collected from randomly selected 16 plants per plot at the two central rows. The field was watered with drip irrigation system which is convenient for production under plastic mulch. Based on the national recommendation, P_2O_5 and Nitrogen fertilizer were applied at the rate of 92 and 64 kg ha^{-1}, respectively, in the form of diamonium phosphate (DAP) and Urea, respectively (Lemma, 2002). The whole rate of DAP (200 kg ha^{-1}) was applied at the time of transplanting while Urea (100 kg ha^{-1}) was applied in two splits, half at the time of transplanting and half at 45 days after transplanting with irrigation water. Fungal diseases and worms were controlled by the application of 2.5 kgha^{-1}Ridomil® MZ 68 WG and 0.75 liters ha^{-1} Selecron® 720 EC, respectively. Other agronomic management practices were applied according to the national recommendation for the crop (Lemma, 2002).The mulch materials were laid before transplanting and small transplanting hole was made on the plastic mulch for planting each seedling.

Trellis structure was prepared from wooden pole and wire to support each plant.

Data collection

Morpho-phenological data

In this experiment, data for days to 50% flowering, days to 50% fruiting and days to 50% maturity were recorded on plot basis, while others that is, number of flowers per cluster, number of fruits per cluster and fruit set were collected and recorded from 10 randomly selected plants of the two middle rows of each plot.

Days to 50% flowering (DAFl 50%): Recorded as number of days from transplanting to flowering of 50% of plants in each plot.

Days to 50% fruiting (DAFr 50%): Recorded asnumber of days from the date of transplanting to date of 50% of plants bear fruit in each plot.

Days to maturity (DAM 50%): Recorded as numbers of days from the date of transplanting to date of 50% of the plant in each plot have physiologically matured fruits for the first time.

Plant height (PLH)(cm): The mean height of the plants were taken from the ground level to the tip of upper most part of 10 randomly selected plants at flowering, fruit setting, at first harvest and at final harvest.

Number of primary branches per plant (NPBPP): Number ofbranches extended from the main stem was recorded on 10 randomly selected plants in harvestable rows at flowering stage.

Number of secondary branches per plant (NSBPP): Number ofbranches extended from the primary branches was recorded on 10 randomly selected plants in harvestable rows at flowering stage.

Yield and yield related parameters

Number of cluster per plant (NCPP): Recorded by counting total number of clusters per plant from 10 randomly selected plants at fully matured stage.

Number of flower per cluster (NFlPC): Recorded by counting total number of flowers per cluster from 10 randomly selected clusters at at blooming period.

Number of fruits per cluster (NFrPC): It was recorded by counting total number of fruits per cluster from five randomly selected plants at red ripening stage of a fruit using cluster used for flower count.

Fruit set (%): Determined by counting mature fruits developed on flower clusters counted for number of flower per cluster were calculated as follows:

$$\text{Fruit set (\%)} = \frac{\text{NFrPC}}{\text{NFlPC}} \text{ x } 100$$

Where: NFrPC- Number of fruit per cluster and NFlPC-Number of flower per cluster.

Marketable fruit yield (t ha^{-1}): Recorded by weighing all harvests of marketable fruits from the two middle rows of each plot and calculated to tons per hectare.

Unmarketable fruit yield (t ha^{-1}): Recorded by weighing all harvests of unmarketable fruits from the two middle rows of each plot and calculated to tons per hectare considering the reason for un-marketability.

Total fruit yield (t ha^{-1}): Recorded by weighing all harvests of marketable and unmarketable fruits from the two middle rows of each plot and calculated to tons per hectare considering the reason for un-marketability.

Data analysis

Analysis of variances (ANOVA) were computed using SAS (9.00 version) software. The two years data were subjected to analysis of variance and variance homogeneity test (using Bartlett`s test) was conducted for each attributes separately before the two years data were subjected to the combined analysis over years. Duncan Multiple Range Test (DMRT) at 5% probability level was carried out for means separation.

RESULTS AND DISCUSSION

Morpho-phenological traits

The analysis of variance result revealed that all morhoo-phenological attributes viz. plant height, days to 50% plant flowering, fruit setting and maturity were significantly influenced by the growing season (year) except number of branches per plant. These traits were also significantly affected by both mulch and variety. The mulch, variety and year interaction influenced only plant height, number of primary and secondary branches. All possible two way interactions (Mulch x Variety, Mulch x Year and Variety x Year) influenced plant height, number of primary and secondary branches per plant (Table 1).

White plastic mulch recorded the highest plant height value followed by black plastic mulch: However, the values were not significantly different between the mulch materials. On the other hand, plants grown on grass mulch and no mulch recorded significantly lowest plant height values (Table 2). This could be due to the effect lower soil temperature produced at grass mulch and no mulch as compared to plastic mulch treatments (Table 6). Significantly taller plant height difference was observed in white plastic mulch might be due to higher soil temperature increasing effect of 2.54 and 1.42°C as compared to grass mulch and no mulch treatment, respectively. Earlier study suggested that a two degree rise in temperature can result in a doubling of tomato seedling shoot growth (Taber and Smith, 2009). Taber and Gansemar (2011) also observed that organic mulches keep the soil cooler with retardation of tomato growth via slower cell division and cell maturation. Regarding varieties, Cochoro scored significantly highest plant height value compared to Miya. Plants grown during 2013 scored significantly highest plant height value compared to plants grown during 2012 (Table 2).

Plants grown with white plastic mulch were earlier (shorter duration of growth phase) in terms of flowering, fruit set and maturity as compared to grass mulch and un-mulched treatments (Table 3). Likewise Incalcaterra et al. (2004) reported that early flowering plants were grown under plastic mulched plots than plants grown on bare soil. The result was also in agreement with Melek and Atilla (2009) who reported that the earliest flowering and fruit formation were first observed with white mulch, followed by black mulch application as compared to control. Soil temperature might be contributed for this earliness in the current study. It is supported by Arin and Sozer (2001) finding that the shortest time for harvest was recorded in transparent polythene mulch which also at par with black polyethylene mulch. White and black plastic mulches gave earlier flowers by 6 days, respectively compared to no mulch and grass mulch treatment, respectively. Generally, in the current study, tomato plants grown under white plastic mulch hastened reproductive phase (flowering fruit setting and fruit maturity) when compared to plants grown under the remaining treatments. Significantly higher mean soil temperature was obtained for white plastic mulch forced plants to flower earlier. White plastic mulch followed by black plastic mulch exhibited the highest mean soil temperatures (Table 6). Lamont (1999) reported that mulches ameliorated soil hydrothermal regime, improved vegetative growth, advanced flowering and fruit yield of tomato plants compared to bare soil. The result is supported by Ham et al. (1991) who reported that plants grown under plastic mulches started flowering 9 days earlier than those grown without mulch. Regarding varieties, significantly shorter number of days to flowering, fruit setting and fruit maturity was observed in Miya as compared to Cochoro variety.

Generally, plants grown during 2012 significantly earlier in terms of plant phenology compared to plants grown during 2013. Significantly highest number of primary branches per plant were recorded when Cochoro variety grown without mulch (3.40) followed by black plastic mulch in the year 2013. Cochoro variety grown with grass mulch produced significantly highest number of secondary branch (31.66) in the year 2013 as compared to other treatment combinations in both years. On the other hand, the lowest number of primary branches per plant was recorded when Miya variety grown on other than white plastic mulch (2.16) in the year 2012. Similarly, the lowest number of secondary branches per plant was recorded in Miya variety grown with white plastic mulch in the year 2013. Generally, few numbers of branches were recorded for both varieties treated with white plastic mulch (Table 3). This might be due to soil temperature difference among mulch treatments. During the experiment period white plastic mulch treatment recorded the highest mean soil temperature (27.06°C) as well as the minimum (23.60°C) and maximum (32.79°C) soil temperature (Table 6). Optimum root temperature for mineral uptake and tomato growth is about 25°C (Teasdal and Abdul-Baki, 1995).

Table 1. Mean squares from combined analysis of variance over two years for tomato plant growth, phenology and yield.

Source of variation	DF	PLH	NPBPP	NSBPP	DAFl (50%)	DAFr (50%)	DAM (50%)	NCPP	NFrPC	NFlPC	Fruit set	MYPH	UMYPH	TYPH
Mulch	3	421.82**	0.210*	49.89**	95.63**	481.63**	153.24**	220.39**	4.78**	3.51**	529.26**	661535171**	1621664	657410696**
Variety	1	1109.76**	2.475**	273.60**	82.68**	432.00**	63.02*	201.72**	19.21**	0.05	4169.13**	2188892120**	35760114**	1665098725**
Replication	2	73.31	0.003	0.69	36.64**	21.58	42.06*	5.38	0.25	0.02	47.53	94633208	23188719*	147462123
Year	1	103.25*	0.075	18.00	88.02**	65.33*	77.52*	18.57*	0.52*	0.46	62.66	5719450	36003649**	13023199
Mulch x Variety	3	26.11	0.982**	196.37**	0.24	8.66	53.40**	27.66**	0.84**	5.65**	351.65**	64973329	4069902	66860657
Mulch x Year	3	57.21	0.145*	46.58**	1.57	0.88	2.24	61.51**	0.08	0.12	17.31	39345729	257132	35561773
Variety x Year	1	42.56	0.091	26.40*	0.02	2.08	0.02	28.21*	1.21**	0.002	89.21	408042634*	21386903*	616263887**
Mulch x Variety x Year	3	35.86	0.135*	57.24**	0.13	5.19	0.29	0.52	0.19	0.99**	20.33	92186146	5228557	125819345
Error	30	24.30	0.041	4.27	4.09	9.40	9.95	3.89	0.085	0.125	33.26	51129147	3067461	57351570
CV (%)		4.36	8.08	10.47	6.05	5.45	3.54	9.01	8.04	5.63	9.32	13.99	30.60	13.33
R^2		0.80	0.85	0.91	0.81	0.88	0.74	0.91	0.94	0.89	0.88	0.78	0.65	0.75

*, ** Significant at P<0.05 and P<0.01), respectively. DF = Degree of freedom; PLH=plant height; NPBPP=number of primary branch per plant; NSBPP=number of secondary branch per plant; DAFl (50%)=days to 50% flowering; DAFr (50%)= days to 50% fruiting; DAM (50%)=days to 50% fruit maturity; NCPP=number of cluster per plant; NFrPC=number of fruit per cluster; NFlPC=number of flower per cluster; MYPH=marketable yield per hectare; UMYPH=unmarketable yield per hectare;TYPH=total yield per hectare.

Yield and yield related traits

The analysis of variance result revealed that yield and yield related attributes such as number of cluster per plant, number of fruits per cluster and unmarketable fruit yield per hectare were significantly influenced by the growing season (year). Yield and yield related traits such as number of cluster per plant, number of flower per cluster, number of fruits per cluster, percent fruit set, marketable fruit yield per hectare and total yield per hectare were significantly affected by both mulch and variety. The mulch, variety and year interaction influenced only number of flower per cluster. All possible two way interactions (Mulch x Variety, Mulch x Year and Variety x Year) influenced all yield and yield related traits measured (Table 1).

Significantly highest number of cluster (30.33) was registered in Cochoro variety grown without mulch. In the present study, the combinations of mulched and un-mulched Cochoro variety had higher number of clusters as compared to the combination of mulched and un-mulched Miya variety (Table 5). This may indicate differences in genotypic responses differently to the number of cluster per plant in polyhouse condition.

John et al. (2005) justified this difference that varieties have inherent potential for production of cluster and consequently more fruits. Number of cluster is one of the major criteria to select variety or treatment application for higher tomato yield and preferable fruit size. Interaction of variety and year was also significant on cluster per plant (Table 4). Cochoro variety grown in the year 2013 produced the highest cluster per plant followed by the same variety grown in the year 2012. Significantly higher number of flower per cluster was recorded for Cochoro plants grown with grass mulch (7.84).

The current study result agreed with Kayum et al. (2008) who reported that using straw mulch produced the highest number of fruits and flower clusters per plant. Flower per cluster helps to estimate the potential of fruit set for a certain variety or a given treatment application. In this study, the higher number of flower per cluster obtained from grass mulch may be contributed by the prevailing of significant lower soil temperature under grass mulch. During the experimentation period grass mulch treatment recorded the lowest mean soil temperature of 24.50°C. On the other hand, higher soil temperature under plastic mulches coupled with high air temperature inside the polyhouse might have affected plants not to produce more number of flowers per cluster particularly in Cochoro variety (Table 6 and Figure 1). Yama et al. (2006) clarified that tolerance of tomato varieties to higher temperature condition inthe polyhouse varies.

The result indicates that statistically highest number of fruits per cluster was recorded for Miya variety grown with grass mulch (4.90) and the same variety grown with black plastic mulch (4.81) (Table 5). Similarly Kayum et al. (2008) reported that mulching with straw produced the highest

Table 2. Effect of mulch, variety and year on tomato growth, phenology and yield.

Parameter	PLH (cm)	DAFl (50%)	DAFr (50%)	DAM (50%)	MYPH (t ha^{-1})	UMYPH (t ha^{-1})	TYPH (t ha^{-1})
Mulch							
BPM	116.35^{a}	32.75^{b}	56.00^{b}	89.58^{b}	52.29^{b}	5.22	57.50^{b}
WPM	118.85^{a}	29.66^{c}	47.33^{c}	84.16^{c}	47.36^{bc}	6.09	53.45^{bc}
GM	105.70^{c}	35.66^{a}	60.33^{a}	92.75^{a}	60.90^{a}	5.86	66.76^{a}
No mulch	110.35^{b}	35.50^{a}	61.16^{a}	89.75^{b}	43.76^{c}	5.73	49.49^{c}
SE±	2.96	1.41	3.16	1.78	3.71	0.18	3.70
Significance	**	**	**	**	**	ns	**
Variety							
Cochoro	117.62^{a}	34.70^{a}	59.20^{a}	90.20^{a}	44.32^{b}	6.59^{a}	50.91^{b}
Miya	108.00^{b}	32.08^{b}	53.20^{b}	87.91^{b}	57.83^{a}	4.86^{b}	62.69^{a}
SE±	4.81	1.31	3.00	1.14	6.75	0.87	5.89
Significance	**	**	**	*	**	**	**
Year							
2012	111.35^{b}	32.04^{b}	55.04^{b}	87.79^{b}	50.73	6.59^{a}	57.32
2013	114.28^{a}	34.75^{a}	57.37^{a}	90.33^{a}	51.42	4.86^{b}	56.28
SE±	1.47	1.35	1.16	1.27	0.35	0.87	0.52
Significance	*	**	*	*	ns	**	ns

Means in columns with the same letter in each trait are not significantly different. BPM= black plastic mulch, WPM= white plastic mulch and GM= grass mulch; PLH=plant height; DAFl (50%)=days to 50% flowering; DAFr (50%)= days to 50% fruiting; DAM (50%)=days to 50% fruit maturity; MYPH=marketable yield per hectare; UMYPH=unmarketable yield per hectare; TYPH=total yield per hectare.

Table 3. Interaction effect of mulch, variety and year on tomato plant growth.

Variety \ Trait	Mulch \ Year	NPB 2012	NPB 2013	NSB 2012	NSB 2013	NFlPC 2012	NFlPC 2013
Cochoro	BPM	2.43^{bc}	2.30^{c}	16.66^{def}	11.73^{fg}	5.53^{fg}	4.80^{g}
	WPM	2.73^{ab}	2.50^{bc}	24.23^{b}	21.86^{bcd}	5.46^{fg}	5.86^{defg}
	GM	2.60^{b}	3.16^{a}	22.20^{bcd}	31.66^{a}	7.84^{ab}	8.00^{a}
	No mulch	2.93^{ab}	3.40^{a}	24.90^{b}	23.76^{b}	5.97^{cdef}	7.00^{abc}
Miya	BPM	2.63^{b}	2.80^{ab}	19.76^{bcde}	23.33^{bc}	6.08^{cdef}	6.80^{bcd}
	WPM	2.16^{c}	2.00^{c}	18.73^{bcde}	9.13^{g}	6.26^{cdef}	6.66^{cde}
	GM	2.23^{c}	2.26^{c}	19.00^{bcde}	16.80^{def}	6.20^{cdef}	6.16^{cdef}
	No mulch	2.20^{c}	2.20^{c}	17.26^{cdef}	14.73^{efg}	6.04^{cdef}	5.70^{efg}
SE±		0.10		1.38		0.21	
Significance		*		**		**	

Means in columns with the same letter in each trait are not significantly different. BPM= black plastic mulch, WPM= white plastic mulch and GM= grass mulch NPB=number of primary branch; NSB=number of secondary branch; NFlPC=number of flower per cluster.

number of clusters and fruits per plant. Cochoro variety plants grown with both plastic mulches recorded the lowest number of fruits per cluster. Highest soil temperature received under both plastic mulches coupled with the higher air temperature inside the polyhouse affected plants to produce lowest number of fruits per cluster. In the current study, the combination of mulch and un-mulch with Miya variety was excellent in terms of fruit per cluster as compared to the combination of mulch and un-mulch with Cochoro variety. This indicates that

Table 4. Interaction effect of variety and year on tomato plant growth, yield and yield component.

Variety	Year	NCPP	NFrPC	MYPH(t ha^{-1})	UMYPH (t ha^{-1})	TYPH (t ha^{-1})
Cochoro	2012	23.79^{a}	3.26^{b}	41.06^{c}	6.78^{a}	47.85^{c}
	2013	24.08^{a}	2.74^{c}	47.58^{bc}	6.39^{a}	53.97^{bc}
Miya	2012	21.20^{b}	4.21^{a}	60.40^{a}	6.39^{a}	66.79^{a}
	2013	18.45^{c}	4.32^{a}	55.26^{ab}	3.33^{b}	58.59^{ab}
SE±		1.31	0.38	4.25	0.80	3.99
Significance		**	**	*	*	**

Means in columns with the same letter in each trait are not significantly different; NCPP=number of cluster per plant; NFrPC=number of fruit per cluster; MYPH=marketable yield per hectare; UMYPH=unmarketable yield per hectare;TYPH=total yield per hectare.

Table 5. Interaction effect of mulch and variety on tomato yield component.

Variety	Mulch	DAM (50%)	NCPP	NFlPC	NFrPC	Fruit set (%)
Cochoro	BPM	91.33^{bc}	19.61^{bcd}	5.16^{d}	2.78^{d}	53.88^{cd}
	WPM	86.00^{d}	26.88^{a}	5.66^{d}	2.49^{d}	43.36^{d}
	GM	95.66^{a}	18.91^{cd}	7.92^{a}	3.93^{b}	49.62^{cd}
	No mulch	91.60^{cd}	30.33^{b}	6.48^{b}	2.81^{d}	43.99^{cd}
Miya	BPM	87.83^{cd}	15.85^{d}	6.44^{b}	4.81^{a}	74.68^{a}
	WPM	82.33e	21.46^{bc}	6.46^{b}	3.36^{c}	52.05^{bc}
	GM	89.83^{bc}	18.86^{cd}	6.18^{bc}	4.90^{a}	79.29^{a}
	No mulch	87.83^{b}	23.16^{a}	5.87^{c}	4.00^{b}	68.12^{b}
SE±		1.42	1.68	0.29	0.33	4.94
Significance		**	**	**	**	**

Means in columns with the same letter in each trait are not significantly different. BPM= black plastic mulch, WPM= white plastic mulch and GM= grass mulch; DAM (50%) =days to 50% fruit maturity; NCPP=number of cluster per plant; NFlPC=number of flower per cluster; NFrPC=number of fruit per cluster.

Table 6. Effect of mulching material on soil temperature (^{o}C) at 10 cm depth combined over years.

Treatment	July(°C)	August(°C)	September(°C)	Mean(°C)	Minimum(°C)	Maximum(°C)
BPM	27.45^{b}	25.59^{ab}	25.99^{a}	26.34^{b}	23.27^{ab}	30.93^{b}
WPM	28.62^{a}	25.93^{a}	26.62^{a}	27.06^{a}	23.60^{a}	32.79^{a}
GM	24.84^{d}	24.27^{c}	24.40^{b}	24.50^{d}	22.08^{c}	27.45^{d}
No mulch	26.14^{c}	25.02^{b}	25.73^{a}	25.63^{c}	22.86^{b}	29.48^{c}
SE±	0.82	0.36	0.47	0.55	0.33	1.13
Significance	**	**	**	**	**	**
Year						
2012	26.21^{b}	23.92^{b}	24.46^{b}	24.86^{b}	22.27^{b}	29.04^{b}
2013	27.33^{a}	26.50^{a}	26.92^{a}	26.92^{a}	23.64^{a}	31.30^{a}
SE±	0.56	1.29	1.23	1.03	0.69	1.13
Significance	**	**	**	**	**	**
CV(%)	2.50	3.04	4.11	2.70	3.23	4.33

* and ** significant at P≤0.05 and P≤0.01, BPM= black plastic mulch, WPM= white plastic mulch and GM= grass mulch. Means in columns with the same letter are non-significant each other at ≤ 0.05.

variety may contribute for the highest production of fruits under different environmental conditions. Yama et al. (2006) and Parvej et al. (2010) confirmed there is a great variation among tomato varieties regarding number of

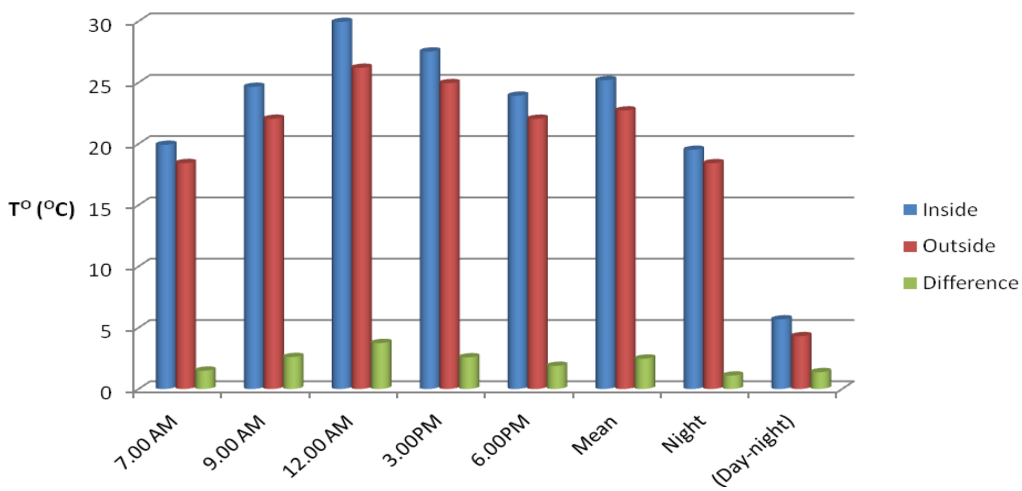

Figure 1. Mean day and night air temperature difference between inside and outside the polyhouse combined over years.

fruits per cluster. Interaction of variety and year was also found significant. Miya variety grown in both years significantly score highest fruits per plant (Table 4).

The maximum fruit set was registered for Miya variety grown with grass mulch (79.29%) and the same variety grown with black plastic (74.68%). On the other hand, Cochoro variety grown with white plastic mulch exhibited the lowest fruit set (43.36). The result indicates that effect of variety may be contributed a lot rather than mulch (Table 5). Yama et al. (2006) reported the highest fruit set (93.9%) for NSITH-162 and the lowest fruit set (83.1%) for Avinash- 2 tomato variety. The investigator suggested that the difference might be due to the adaptability of the variety in the local environment and tolerance to high temperature inside the polyhouse.

The result indicates that significantly highest marketable tomato fruits yield was obtained from plants grown with grass mulch treatment (60.90 t ha^{-1}) followed by plants grown under black plastic mulch (52.29 t ha^{-1}) (Table 2). The result agreed with report of Wahome et al. (2001) who found highest marketable fruit yield was observed in tomato mulched with grass followed by black polythene mulched plants. The non-mulched plants had the lowest fruit yield. The superiority of grass and black plastic mulches are also in agreement with Siborlabane (2000) in which rice husk and black plastic mulches were the best among the mulching materials in producing better yield and quality fresh market tomatoes. In the present study, increment in tomato fruit yield under grass mulch may be further explained by reduction of maximum root zone temperature. During the experiment period grass mulch recorded the lowest mean (24.52°C) soil temperature compared to the remaining mulch and control treatment (Table 6). According to Teasdal and Abdul-Baki (1995) optimum root temperature for mineral uptake and growth of tomato plants is about 25°C.

In line with, Yama et al. (2006) the potential of tomato varieties to tolerate high temperature condition of the polyhouse was different. Considering the varietal performance, significantly higher marketable fruit yield was obtained from Miya variety (57.82 t ha^{-1}) as compared to Cochoro variety (44.32 t ha^{-1}) under polyhouse condition (Table 2). Interaction effect of variety and year was also found significant. The highest marketable and total fruit yield was obtained when Miya variety was produced in both years (Table 4).

The yields produced from plants grown with grass mulch were higher than from plants grown with mulching and non mulching treatments. This higher tomato yield obtained under grass in the present study was associated with profound root growth for maximum interception of roots for water and nutrient absorption in the soil under these mulching materials. The result was supported by Moorby and Graves (1998) who reported that the greater growth was associated with a larger leaf area and total dry matter production, increased length of the root system of tomato and the absorption of larger amounts of N, P and K. According to Richard (1992) when air to root zone temperature differences increase (that is, are positive), root elongation rates increase. In the present study, air to root temperature difference was found higher under grass plastic mulch as compared other mulching treatments. Air temperature at mid day was found constant (27°C) (Figure 1) when grass mulch treatment scored the lowest soil temperature (24.5°C) (Table 6) during cropping season inside the polyhouse as compared to other mulch treatments. The present study has indicated the benefits of mulching material on tomato yield. Mulching material resulted up to 23.43% fruit yield increment as compared to bare soil. The results of Wang et al. (2010) in case of bell pepper observed that the application of organic mulch combined with plastic mulch

Table 7. Costs and returns to produce tomato under polyhouse condition (300 m^2).

Treatment	Marketable fruit yield (kg/300 m^2)	Gross benefit (Birr)	Total cost (Birr)	Net benefit (Birr)	MRR (%)
No mulch	1312.65	19689.75	16931.00	2758.75	-
GM	1826.70	27400.50	17231.00	10169.50	2470
WPM	1420.95	21314.25	17951.00	3363.25	-945 D
BPM	1568.55	23528.25	18311.00	5217.25	515

During the experimentation period field price of tomato produce was 15.00 birr/kg due to the absence of tomato produce in the areas in summer. **D**-Dominance analysis carried out listing the treatment total costs in increasing order. Then any treatment that has net benefits that are less or equal to those of the treatments with low total costs was dominated.

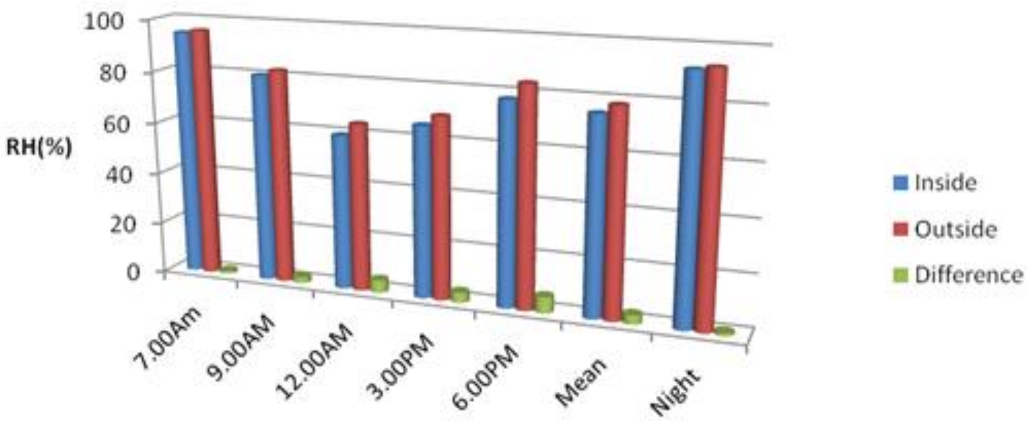

Figure 2. Mean day and night RH (%) difference between inside and outside the polyhouse combined over years.

significantly improve yield and quality in terms of large fruits.

The effect of mulch color on tomato plant growth and yield vary according to the geographical location and season (Decoteau et al., 1988). In the current study, the highest fruit yield obtained using black plastic mulch as compared to white plastic mulch are attributed to favorable lower soil temperature under black plastic mulch (Table 2). In agreement with Nkansah and Ito (1995) finding that maximum tomato yields were obtained at a night air and root-zone temperature combination of 18 and 24°C, respectively, This author concluded root temperature reduced photosynthesis under too high or too low air temperature conditions. In the present study, mean minimum night air temperature was found 18°C (Figure 1) and 24.50°C mean soil temperature under grass mulch treatment during the experimentation period (Table 6).

In the current study the overall unmarketable yield was found low ranged from 5-6.60 t ha^{-1} by the main effect mulch, variety and year (Table 2). This might be due to conducive relative humidity created inside the polyhouse (59 to 86 %) (Figure 2). Read (2007) concluded that relative humidity above 90 % can also cause developmental of fruit disorders, related to localized calcium deficiency and promote outbreak of fungal diseases.

Cost-benefit analysis

In order to recommend for the producers, it is necessary to estimate the minimum rate of return acceptable to producers in the recommendation domain by organizing experimental data and information about the costs and benefits of various alternative treatments.

The highest net benefit was obtained from grass mulch 10169.5 birr with a marginal rate of return 2470% (Table 7). This means that for every 1.00 birr invested for grass mulch application in the polyhouse, producers can expect to recover the 1.00 birr and obtain additional 24.70 birr. According to USAID (2009) report in India, a typical traditional tomato farm of 500 square meters would generate an estimated annual income of Rs. 10,000 to 20,000 as compared to estimated annual income from similar sized polyhouse which was ranged from Rs. 45,000 to 50,000.

According to CIMMT (1988), the minimum acceptable marginal rate of return (MRR %) should be between 50 and 100%. The present study indicated that MRR was found much greater than 100%. In general, from the cost-benefit analysis, there are clear evidences that applying grass mulch increased marketable tomato fruit yield significantly, hence resulting in big economic returns.

CONCLUSIONS AND RECOMMENDATION

Application of mulching material significantly influences on tomato plant growth, fruit yield and root zone soil temperature. Regarding varieties, Miya perform best significantly in terms of earliness (flowering, setting and maturity), fruit yield (marketable and total fruit yield). Similarly economic analysis of the study indicated there are clear evidences that applying grass mulch increased marketable tomato fruit yield significantly hence resulting in big economic returns. The result of the study indicates the superiority of using grass mulch together with Miya variety for tomato production in the rainy season under polyhouse condition. Therefore, application of grass mulch for tomato yield using Miya variety is recommended for producers in the study area.

Conflict of Interests

The authors have not declared any conflict of interests.

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