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Effect of Organic Mulch Types on Common Biotic, Abiotic Factors and Components of Yield in Determinate and Indeterminate Tomato (*Lycopersicon esculentum* Mill) Commercial Cultivars

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Abstract: A field experiment was conducted during the dry season of September to December 2004 at the Sokoine University of Agriculture, Morogoro Tanzania, Horticultural plots to evaluate the effect of organic mulch types on biotic, abiotic factors and components of yield in two tomato commercial cultivars of different growth types. The two tomato cultivars were CALJ-VF (determinate) and Tengeru 97 (indeterminate). The experimental materials were laid out in a split plot design with 3 replications in which the two cultivars were the main plots and the mulch regimes were the sub-plots. The sub plot treatments consisted of the control in which there was no mulch applied, rice husk, grass and saw dust mulch. Plots were irrigated once per week after establishment up to fruit maturity in order to detect the treatment effects on moisture conservation. CALJ-VF significantly excelled Tengeru 97 on number of fruits, trusses and branching and with the least occurrence of cracked fruits. On the other hand, Tengeru 97 had significantly lower number of sun-scotched fruits and blossom end rot. Rice husk mulch was the best in enhancing crop performance, followed by dry grass and finally, saw dust. All the mulch regimes significantly excelled the control in reducing weeds and blossom end rot. Saw dust followed by rice husk however, had an added advantage of significantly controlling tomato yellow leaf curl virus. On the other hand, mulch treatments generally increased fruit worm and sun scotch on fruits.

Key words: Alternaria stem canker, blossom endrot, bored fruits, weed intensity, yellow leaf curl virus

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill) is the most popular vegetable. It is a vegetable of good nutritive value, containing good amounts of potassium, B-carotene (vitamin A) and vitamin C. It is very low in calories (100 g of edible portion of tomato contains only 20 kcal) and therefore it is a very important food for weight reducing diets especially when taken as raw salad[1]. It also possesses medicinal properties, for instance lycopene, the natural red pigment in tomatoes lowers blood pressure for hypertensions, reduces stroke and acute coronary events and prevents some forms of cancer by lessening damage caused by free radicals[2]. It is a common and important recipe for dishes particularly in relishes. Processed products include tomato sauce, juice, dried powder and chips[3]. It finds its use daily in the kitchen in households, hotels and institutions and in the processing industries. It is sold as fresh and processed products and therefore it is an important cash crop for both large and small-scale farmers.

The poor resource farmers in the target areas of Morogoro and Coast regions of Tanzania face problems of price fluctuations in tomato produce. The prices are particularly low during the normal growing cycles because there is a lot of tomato produced. The normal growing cycle is during the long rains of February to May. Thus production during dry but cool and hot off-season periods of June to January would ensure stabilized income to the subsistence farmers throughout the year[4]. However, off-season production of tomatoes in the study areas and indeed in Tanzania as a whole is usually associated with biotic and abiotic stresses. These include high occurrence of insects pests such as the tomato fruit

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worm (*Helicoverpa zea*) and white flies (*Bemisia tabaci*), diseases like tomato yellow leaf curl virus and alternaria stem canker, physiological disorders such as fruit cracks, sun scotch and blossom endrot. These problems are associated with the prevailing environment such as the dry spell, moisture shortage, high temperature and solar radiation regimes[5]. Weeds are a serious problem in tomato fields and involve a lot of labor and funds to get the crop free of weeds. Timely weeding particularly before the onset of flowering is important in order to realize increased yields and free the crop of insect vectors such as whiteflies[5].

Water stress particularly during off-season is a critical problem in tomato production. Replenishment of moisture through irrigation in tomato fields is very expensive and labor intensive, involving carrying of water in containers from the major water sources such as bore holes and streams. Irrigation water and erratic rains that may occur during off-season are quickly lost through evapotranspiration and leaves the soil dry within a very short time. Control of insect pests and diseases would involve the usage of synthetic chemicals such as karate or botanicals and fungicides. Synthetic chemicals in addition to being scarce and expensive in the rural areas are environmentally not safe. Usage of botanicals such as rotenone containing plants is currently being advocated to farmers; however, the intervention has not yet gained popularity because of unavailability of certain recommended botanicals in the local communities. Studies in the use of organic mulch to control various diseases, insect pests, physiological disorders, moisture and soil temperature optimization, nutrient replenishment and weed control have been reported by various researchers[6-11]. Organic mulch is easily available to the poor resource farmers and would provide a sustained approach to manage the stresses if they are found to be effective. However, different mulch types have different effectiveness; yet others have detrimental effects including higher occurrence of pests and reduced agronomic performance of the crop[10,12,13]. It is therefore important to investigate the relative effectiveness of mulch types available in the local areas for possible recommendation and use by farmers for higher net revenue from reduced production costs.

Different mulch types have varying effectiveness for enhancing performance because of their different capacities in absorbing moisture due to their aggregate nature and in allowing air circulation[11,14,15]. For instance Rweyemamu *et al.*[7] reported that mulch was effective in controlling weeds, but rice husk was more effective than dry grass. According to studies by Carlson and Wilson[14], baggase and chopped palm were the best in controlling weeds; while juniper and blue spruce had adverse effects on bermuda weed without affecting production of tomato and radish. On the other hand, pine mulch was not recommended for use in tomato due to its adverse effects on soil pH, tomato plant health and production. Although cypress mulch inhibited fescue growth, it affected radish plant growth and production.

Limited studies are available on the effect of organic mulch in controlling Tomato Yellow Leaf Curl Virus (TYLCV). Yet, TYLCV is a serious disease in tomato fields during the dry season and where infection is severe; there may be total crop loss. The regimes of highly UV-reflective aluminum (metallized) mulch, that is, ultra-violet-reflective mulch reduced tomato spotted wilt virus disease by as much as 75% as compared to untreated black mulch[9]. Similarly, silver reflective mulch has been found to drive away white flies and many other insects[16]. However, metallic mulches are expensive and not available among the poor resource farmers and where available, their application in the field is cumbersome. They also don't provide the added advantage of organic matter in the soil as do organic mulch. However, studies on the effect of organic mulch in the control of tomato yellow leaf curl virus are scarce.

Fruit worm infestation is a serious problem in tomato fields in the study areas[4]. Early stage larvae enter fruit at the stem end and during development; caterpillars may emerge from one fruit and enter another. Their feeding results in a messy, watery, internal cavity filled with cast skins and feces[17]. Although studies have been conducted on effects of metallic mulch in the control of other types of pests, no similar studies exist on controlling the fruit worm using organic mulch. On the other hand, Tietjen[6] reported that inorganic mulch enhanced predatory beetles and spiders in tomato production.

Alternaria stem canker is a fungal disease that occurs on stems resulting to wilting and on fruits with consequent reduction of marketable fruits. It causes brown or black necrotic lesions on plants and sunken, grayish lesions on fruits. The fungus is present in crop residues, soil and infection takes place by wind, wounding and sprinkler irrigation[18]. Studies on mulch effects in the control of fungal diseases have been done elsewhere. Reduction in infection by early blight and anthracnose has been realized by application of metallic organic mulches[6,19,20]. This has been attributed to reduced infection by soil born fungi upon water splash from the soil through rain or deliberate irrigation systems. However, no similar studies have been conducted on the effect of organic mulch in controlling alternaria stem canker in tomato fields.

Fruit crack is a physiological disorder that renders tomato fruits unmarketable. This is largely due to various factors that include genetic, moisture, solar radiation and temperature regimes. Maintaining uniform water supply such as application of mulch and steady moisture supply, good foliage cover and use of resistant varieties has been found to reduce fruit crack[7,21]. However, little has been done to discern relative efficiencies of different organic mulch types in the control of tomato fruit cracks. Sun scotch is another physiological disorder in which symptoms appear as a yellow to white water soaked area on the side of the fruit exposed to the sun, making the fruit unmarketable. Measures have been suggested to minimize this problem; including protection of fruits from solar radiation such as having healthy foliage to shade fruits and application of adequate fertilizer[7,21]. No studies have yet been conducted to investigate the effects of mulch in reducing the occurrence of sun scotch in tomato.

In the tomato growing areas of the eastern and central agricultural zones of Tanzania, moisture stress during off-season could be alleviated by use of locally available low cost and sustainable husbandry packages that conserve soil moisture. For instance in the rice and tomato growing areas, rice mulch if proved effective, could provide a more sustainable approach in moisture conservation in tomato fields. The present study was carried out to investigate the effects of genetic backgrounds of tomato (determinate and indeterminate) and local mulch types in enhancing crop agronomic performance and control of the common biotic and abiotic factors in tomato fields. Results of this study are expected for recommendation in the study areas and other similar tomato growing locations aiming at raising net revenue through decreased production costs on a sustainable manner.

MATERIALS AND METHODS

The experiment was conducted at the Horticultural Unit of the Sokoine University of Agriculture, Morogoro, Tanzania. The area is located at 6°05'S, 35°37'E with an altitude of 525 m above sea level. The study was conducted in the field during the dry season, that is, September to December 2004. The soil at the trial site is clay loam.

Test materials consisted of two commercial cultivars of different growth habits viz., CALJ-VF (determinate) and Tengeru 97 (indeterminate) and 3 different organic mulch types and the control in which there was no mulch applied. Seeds were sown in the primary nursery then transplanted into the secondary nursery in soil blocks when seedlings were at the 2-leaf stage. Recommended cultural practices including irrigation and pest management were carried out regularly in both the primary and secondary nurseries. Sunken beds of 5×1 m were prepared in previously cultivated and leveled ground. Seedlings were transplanted to the main field at 75x60 cm spacing four weeks after sowing in the nursery. The distance between replications was 1 m while inter-plot space was maintained at 50 cm.

The mulches consisted of dry grass, rice husk, wood shavings and the control. The experimental materials were laid out in a split plot arrangement with three replications. The main plots were the two tomato cultivars while the mulch regimes constituted the sub plots. Mulch was applied for wood shavings, rice husk and dry grass at 5, 10 and 15 cm depth, respectively making sure that the soil is fully covered[22]. One weeding was done after scoring for the weed intensity in order to rescue the crop from total failure.

A single stake was used to support the indeterminate variety (Tengeru 97) and suckers were removed to maintain a single stem. After two weeks of transplanting, nitrogen fertilizer in the form of urea was applied at a rate of 55.2 kg N ha^{-1}. Irrigation was carried out once per week in order to discern differences in mulch regimes in the control of moisture retention and loss. Karate and Dithane M-45 were sprayed at recommended rates once during the growing cycle to reduce pests to economic injury level.

Data were collected on diseases, physiological disorders, insect pests, weed intensity; and components of yield. The latter consisted of number of fruits per truss and per plant, marketable and total fruit number and weight per unit area. Diseases scored were Alternaria stem canker, tomato yellow leaf curl virus severities; while insect infestation data were on number of fruits bored by fruit worm. Physiological disorders were scored for number of fruits with cracks, sun scotch and blossom end rot.

Collected data were analyzed for ANOVA[23]. Statistical model for ANOVA was as follows:

$$Yijk = u + Ri + Vj + (Ea) + Tk + (VxT)jk + (Eb)$$

Where:

Yijk	=	Response
u	=	Overall mean
Ri	=	ith replication effect
Vj	=	jth variety effect
Ea	=	Main plot error
(VxT)jk	=	Interaction between jth variety and kth treatment.
(Eb)	=	Experimental error.

RESULTS

Components of yield: Significant variety effects were observed for numbers of total and marketable fruits, trusses per plant, branches and fruit size (Table 1).

Table 1: ANOVA summary for yield components (Mean squares given)

Sources of variation	df	No. of marketable fruits/m^2	Weight of Marketable fruits/m^2 (g)	No. of fruits/ truss	No. of trusses/ plant	No. of fruits/ plant	Branches/plant	Fruit size (1-5) scale
Replication	2	472.00	1791495.80	1.30	16.70	57.50	1.80	0.17
Variety	1	7848.20*	2107522.70	0.67	181.50*	1232.7*	92.0*	9.38***
Error (a).	2	132.80	763672.50	1.00	8.00	33.80	1.80	0.001
Treatment	3	2568.50***	797752.30	1.40*	27.20***	130.60***	0.82	0.60
Var. x Treat.	3	410.30	564500.80	1.10*	13.20***	29.70*	0.82	0.04
Error	12	215.50	494241.10	0.24	0.78	5.40	0.57	0.19
Total	23							
CV (%)		27.30	26.20	14.60	12.00	14.40		17.90
R^2		0.87	0.85	0.79	0.97	0.97		0.83

*, **, *** = p <0.05, 0.01 and 0.001, respectively

Table 2: ANOVA summary for biotic and abiotic factors (Mean squares given)

Source of variation	df	No. of cracked fruits/m^2	No. of fruits scotched/m^2	No. of fruits bored/m^2	Weed intensity (1-4 scale)	Severity of leaf curl (%)	Stem canker (%)	Severity of blossom end rot (%)
Replication	2	6.30	118.60	1.10	0.29	88.60	198.80	80.40
Variety	1	117.00*	7385.00*	100.00	0.17	2340.40	1040.20	1276.00**
Error (a).	2	6.30	82.50	6.50	0.29	207.40	236.50	16.80
Treatment	3	1.20	631.60**	88.50**	5.60***	608.20*	157.10	1548.90***
Var.x Treat.	3	1.15	418.04*	46.71*	0.06	232.15	65.50	9.38
Error (b)	12	3.40	77.00	8.40	0.29	150.60	78.40	72.10
Total	12	23						
CV (%)		83.50	40.10	59.40	20.90	28.00	13.70	28.70
R^2		0.79	0.92	0.84	0.84	0.75	0.73	0.88

*, **, *** = p <0.05, 0.01 and 0.001, respectively

Table 3: Effect of tomato varieties on biotic and abiotic factors

Variable/ variety	No. of fruits cracked/m^2	No. of fruits scotched/m^2	No. of fruits bored/m^2	Weed intensity (Scale: 1-4)	Leaf curl severity (%)	Severity of stem canker (%)	Blossom end rot (%)
CAL-JFV	0.00	39.40	6.90	2.50	5.38	58.00	36.90
Tengeru 97	4.40	4.30	2.80	2.70	33.00	71.20	22.30
x	1.190	21.85	4.85	2.60	19.19	64.60	29.60
SEx	0.725	2.669	0.736	0.156	4.157	4.439	1.183
$LSD_{0.05}$	2.99	11.02	NS	NS	NS	NS	4.89

Table 4: Effect of tomato varieties on yield and yield components

Variables/ varieties	No. of marketable fruits/m^2	Weight of Marketable fruits/m^2 (g)	No. of fruits/ truss	No. of trusses/ plant	No. of fruits/ plant	Branches/plant	Fruit size (1-5 scale)
CAL-JFV	72.00	2975.50	3.50	10.1	23.30	4.90	1.80
Tengeru 97	35.80	2382.80	3.20	4.6	9.00	1.00	3.10
X	53.90	2679.15	3.35	7.35	16.15	2.95	2.45
SEx	3.327	252.268	0.289	0.816	1.678	0.387	0.009
$LSD_{0.05}$	13.73	NS	NS	3.37	6.93	1.60	0.04

Similarly, mulch treatments had significant effects on numbers of marketable fruits and fruits per truss; trusses and fruits per plant. Variety and mulch treatments interacted significantly on numbers of trusses and fruits.

Biotic and abiotic factors: Differences between varieties were observed for numbers of cracked and scotched fruits; and blossom end rot incidence. Similarly, significant mulch effects were observed for numbers of scotched and bored fruits, weed intensity and severity of leaf curl and blossom end rot incidence. Significant interaction between varieties and mulch treatments was observed for sun scotch on fruits and bored fruits (Table 2).

Mean effects of varieties on biotic and abiotic factors: CALJ-VF was significantly better than Tengeru 97 on having virtually no fruits cracked. Though not significantly, it also had lower severities of leaf curl and alternaria stem canker. On the other hand, Tengeru 97 significantly excelled CALJ-VF by having lesser occurrence of scotched fruits and blossom end rot. The former had also lower incidence of bored fruits though not significantly (Table 3).

Mean effects of varieties on components of yield variables: CALJ-VF significantly excelled Tengeru 97 in numbers of marketable fruits, trusses, total fruits and branches per plant. On the other hand, Tengeru 97 produced significantly larger fruits than CALJ-VF. Although CALJ-VF had higher values over Tengeru 97 on weight of marketable fruits and number of fruits per truss, it was not significantly so (Table 4).

Table 5: Effect of mulch types on yield and yield components

Variables/ mulch	No. of marketable fruits/m^2	Weight of Marketable fruits/m^2 (g)	No. of fruits/ truss	No. trusses/ plant	No. fruits/ plant	Branches per plant	Fruit size (1-5 scale)
Rice husk	78.30	3956.00	3.80	10.20	82.30	7.70	2.70
Saw dust	59.70	3074.80	3.00	7.00	76.80	7.70	2.70
Dry grass	48.80	2474.80	3.70	7.20	76.70	7.30	2.50
Control	28.80	1209.20	2.80	5.00	64.30	7.50	2.00
X	53.90	2678.70	3.33	7.35	75.03	7.55	2.58
SEx(+/-)	5.993	287.008	0.20	0.361	0.949	0.308	0.178
$LSD_{0.05}$	15.36	735.66	0.51	0.92	2.43	NS	0.46

Table 6: Effect of mulch types on biotic and abiotic factors

Variables /mulch	No. of fruits cracked/m^2	No. of fruits scotched/m^2	No. of fruits bored/m^2	Weed intensity (Scale: 1-4)	Leaf curl severity (%)	Severity of stem canker (%)	Blossom end rot (%)
Rice husk	2.20	31.30	8.30	1.80	37.00	59.70	18.80
Saw dust	2.00	13.20	2.20	2.30	34.00	69.00	20.70
Dry grass	2.80	30.20	8.00	2.20	49.20	60.70	25.70
Control	1.80	12.80	1.00	4.00	55.30	69.00	53.30
x	2.20	21.90	4.90	2.60	43.90	64.60	29.60
SEx	0.753	3.582	1.183	0.220	5.010	3.615	3.467
$LSD_{0.05}$	1.36	9.18	3.03	0.56	12.84	9.27	8.89

Mean effects of mulch regimes on components of yield: Rice husk and dry grass were better than the control in all the components of yield studied except branches per plant viz., weight and numbers of marketable fruits per plant, fruits per truss and per plant, trusses per plant and fruit size. Similarly, saw dust mulch significantly excelled the control in all the components of yield variables except number of fruits per truss and branches per plant. Thus, mulch had no effect on branching of tomatoes (Table 5).

Mean effects of mulch regimes on biotic and abiotic factors: Rice husk was significantly better than the control in reducing weeds, tomato yellow leaf curl, stem canker and blossom end rot; followed by saw dust mulch that significantly controlled weeds, leaf curl and blossom end rot (Table 6). Dry grass had the least performance in significantly controlling only two factors, namely, weeds and blossom end rot. All mulch regimes were significantly better than the control in reducing weeds and blossom end rot.

DISCUSSION

The significant varietal differences exhibited on some of the components of yield of tomato suggest potential for exploiting inherent superiority of tomato genotypes for production or use of germplasm in breeding programmes. Thus, CALJ-VF has an inherent potential for production of trusses and consequently more fruits of better quality. The superiority of CALJ-VF in production of higher numbers of fruits and consequently more weight of fruits is based on more branches retained on CALJ-VF as a result of non-pruning and plants maintained as multiple stems. On the contrary, Tengeru 97 is an indeterminate variety that is usually pruned to maintain a single stem that in turn, reduces the number of fruits per plant. Similar findings were reported by Tietjen[6] and Bitala[24] when working with determinate and indeterminate varieties of tomato. The larger fruit size of Tengeru 97 (indeterminate) was attributed to lesser number of fruits, branches and trusses from the single stems. This evidently resulted to lesser competition for assimilates as compared to more fruits produced from multiple stems and branches of the CALJ-VF variety.

Varieties of tomato can be selected for their superiority in cracking, sun scotch and blossom end rot resistance characteristics of fruits as evidenced by the significant varietal effects on these traits. Thus, CALJ-VF can be used in breeding programmes or selected for cultivation in order to meet the fruit quality market demands. Cracking behavior is a varietal characteristic that can be exploited by crop developers[21]. High amounts of total soluble solids in tomato fruits make them suffer less moisture fluctuation and render them less prone to crack[25]. In areas where more susceptible varieties are predominantly used for production, farmers are advised to pick affected fruits early in order to avoid predisposing the fruits and hence spread of early blight and other fruit rots[26]. Varieties developed for hot arid climates have been found to have high levels of cracking if they are subjected to humid wet conditions. Erratic moisture condition changes cause radial concentric cracking on tomato fruits, rendering them less marketable[27]. Thus, differential environments of culture from those originally intended for production during developing of a variety may cause fruit cracking. In this study, Tengeru 97 was originally bred for the cool, high altitude environments. However, the present investigation was conducted in the Coast and Morogoro regions (0-450 m above sea level) with characteristically hot and humid environments, possibly

accounting for the higher occurrence of fruit cracks. On the other hand Tengeru 97, an indeterminate variety, suffered less to fruit sun scotch than the determinate CalJ-VF. Tomato plants with excessive pruning or those with no plant support are more prone to fruit sun burn[28]. In the present investigation, the non supported determinate bushy CalJ-VF with its fruits on the ground was more vulnerable because it exposed fruits to the immediate heat reflected from the ground more than those higher up in the canopy of the off ground supported indeterminate Tengeru 97. All garden tomatoes, determinate as well as indeterminate, must be supported off the ground in some manner to prevent loss of fruits to rots and sunburn[25].

The relatively higher levels of damage of fruits by fruit worms in CALJ-VF as compared to Tengeru 97 could as well be attributed to the different growth types of the two varieties. CALJ-VF, being determinate, trails on the soil surface and produces multiple branches predisposing fruits to the pest. According to AVRDC[26], female worms lay eggs on the leaf surfaces and hence, on bushy plants, worms find more habitats resulting to higher infestation rates. For the indeterminate types, studies should be conducted to find the optimum level of pruning that will reduce fruit worms to sufficient levels without adversely affecting yield. It is also important to apply low cost, effective and safer pesticides for controlling the pest since fruits infested by the fruit worm reduce the market value. Various control measures against the worms have been proposed including hand picking, use of botanicals such as rotenone, ryania, insecticidal oils, traps and *Bacillus thuringiensis*[29]. In Tanzania, a more sustainable approach would be the use of resistant /tolerant varieties and or rotenone contained in *Tephrosia vogelii*. The latter grows wild in various areas of Tanzania and can be planted from seed. It possess no environmental or health risks since it decomposes easily in sunshine into carbon dioxide and water[30]. Alternaria stem canker is a fungal disease that infects a plant particularly after being predisposed by wounding[31]. The relatively higher levels of infection in Tengeru 97 is evidently due to petiole pruning of the indeterminate variety, creating wounds that predisposed it to the fungus entry[32]. Watterson[33] reported that some varieties of tomato are resistant to stem canker; and thus both optimum husbandry and choice of appropriate varieties should be done against infection by the fungus. Tengeru 97 was more resistant to blossom endrot and hence could be a variety of choice in environments favoring this disorder. Blossom end rot is a result of poor availability of calcium into the distal portions of the fruits due to several factors that include erratic supply of moisture[31]. Similarly, Hansen[34] reported varietal differences in tomato on susceptibility to blossom endrot under similar conditions of growth. Thus, Tengeru 97 contains the background that makes it less prone to blossom end rot and search for more resistant varieties should continue. Crop developers should therefore aim at pyramiding desirable genes for resistance to the biotic and abiotic factors through crossing of the two types of tomato. This should be followed by subsequent selection of segregates with optimum combinations of traits.

In general, mulching seemed to promote better performance of the tomato varieties in most of the yield components[10]. Organic mulch has been found to have multiple advantages in culture, resulting to enhanced physiological efficiency of plants. These advantages include safe and rapid expansion of roots, soil moisture conservation and suppression of weeds, no till environment and hence minimizing leaching, erosion and maintain soil structure, optimizing soil temperature and enriching the soil with organic matter[19]. Tomato like any other horticultural crop needs intensive application of nutrients and moisture. Utilization of nutrients in the soil depends on efficient mobilization, which in turn, is a function of moisture availability. Thus, mulch has a direct impact on plant performance by supplying moisture and an indirect impact on nutrient availability through enhanced mobilization of nutrients from the soil. Farmers should therefore be encouraged to apply mulch as a husbandry practice for moisture availability during off-season. In their effects on components of yield, rice husk and dry grass were more effective, followed by sawdust. It is therefore recommended that in the rice and tomato growing areas, farmers should conserve rice husk after milling and use as mulch for a more sustainable approach in tomato production. Other investigations have indicated that organic mulches differ in their effectiveness in enhancing physiological efficiency of tomatoes. This was found to be due to differences in the supply of nutrients, absorbing moisture, supply of humus and in allowing air circulation[10,27,35,36]. Thus, the superiority of rice husk and dry grass over saw dust mulch used in the study suggests that the former possess desirable attributes of organic mulch as compared to the latter[7,15,37]. In areas where rice is not grown, saw dust can as well be used in tomato fields. However, the high C : N ratio associated with saw dust[7] and its soil surface crusting effect [38]; makes it more preferable to use in garden path. Similarly, with dry grass mulch, there is risk of spreading weed seeds in tomato fields especially if the mulch is obtained from reproductively matured plants. Tietjen[6] suggested that mulch containing weed or grass seeds, rhizomes and other propagate should be avoided, or otherwise heat-

treated in order to prevent weed spread. Mulch can be allowed to heat over 140°F for 24-48 h in plastic bags to kill seeds and rhizomes[39]. Investigations are needed in the farmers' situation to see for how long solar radiation can be used using plastic bags to kill weed seeds and rhizomes contained in mulch and also, the growth stages of grass to be harvested that will provide sufficient mulch without the risk of spreading weeds.

All the mulch regimes used were effective in controlling weeds and blossom end rot. Organic mulch has been found to prevent weeds from sprouting[40]. The mechanism of weed control from mulch application has been attributed to blockage of sunlight and or release of allelochemicals with herbicidal properties[41]. Different types of organic mulch have been found to have different allelopathic effects. In an experiment on mulch treatment in tomato, juniper and blue spruce had adverse effects on bermuda weed without affecting production of tomato and radish[41]. On the other hand, pine mulch was not recommended for use in tomato due to its adverse effects on soil pH and tomato plant health and production. Cypress mulch, although inhibited fescue growth, it affected radish plant growth and production. However, when farmers use mulch, they usually don't select the type of grass or plant they use. They make random selections and thus the relative effects of mulch under the farmers' fields cannot specifically be attributed to type of plant used. It is however important to identify the different types of potential mulch available in specific areas and controlled experiments done to assess their relative effects including their combinations. Fruit sun scotch in tomato is an abiotic disorder that reduces the market value of harvested tomatoes. Rice husk had more fruits affected by sun scotch, followed by dry grass; saw dust and the control in that order. It is therefore suggested that mulch, except sawdust, has a detrimental effect in having higher sun scotch damage. Saw dust however, did not differ significantly from the control in having the lowest sun scotch rate. The findings suggest that rice husk, by being more effective in controlling soil moisture with a more favorable soil temperature, is due to more heat/light reflected with consequent negative effects on fruits above the ground. Similar explanations could apply to the lesser effectiveness of sawdust in controlling soil moisture loss and optimum temperature but with lesser negative effects on sun scotch. Thus, the control in which there was no mulch applied, fruits were affected to a lesser extent, probably due to a lesser amount of solar energy reflected from the ground. More concerted research is needed to confirm the mechanism of differential effects of mulch types on sun scotching in tomato fruits.

The present investigation suggests that mulching, particularly with rice husk and dry grass; promote the occurrence of fruit worm infestation in tomatoes. On the other hand, saw dust was as better as the control in having lower rates of the fruit worm. It is therefore evident that rice husk and dry grass provide optimum micro environments for development of the bollworm in tomato fields. Bearing the advantages of rice husk and dry grass in enhancing yield components, farmers should use low cost, effective and safer pesticides to control the fruit worm while using rice and grass mulch. The use of botanicals such as *Tephrosia vogelii* has been advocated elsewhere as being effective and generally safe[42]. Generally, all the mulch types were significantly better than the control in the reduction of blossom endrot evidently due to better moisture retention as compared to the control and hence enhanced availability of calcium in the fruits[10,34]. The present investigation entailed mulching regimes in which irrigation was done once a week after crop establishment. Thus, the control plots where no mulch was applied resulted to severe blossom endrot due to more pronounced moisture stress conditions. Mulching reduced the severity of tomato yellow leaf curl virus and particularly so with sawdust mulch followed by rice husk. The control plots in which there was no mulch experienced the highest viral infection severity because weeds provided optimum environment for the vector, the white fruit fly, *Bemisia tabaci*[43]. Because of better weed control of mulched plots, viral infection was lower and thus farmers should use mulching with an added advantage of reducing the severity of yellow leaf curl virus. Mulching studies involving metallic mulches indicated that silver reflective mulch drives away aphids, white flies and other insects and thus reduced the incidence and severity of viral diseases in tomato[16]. With organic mulch, in addition to leaf curl reduction from reduced weed infestation; further studies need to be conducted to ascertain other possible mechanisms of viral infection reduction.

Tomato varieties can be selected for their superiority in yield components and resistance to biotic and abiotic stresses. Thus, Tengeru 97 (indeterminate) possess background for resistance to sun scotch, blossom endrot and to a lesser extent, fruit worm damage while CALJ-VF (determinate) had appreciable levels of resistance to fruit crack and to a lesser extent, leaf curl virus and stem canker. Organic mulch is effective in controlling weed and blossom end rot with saw dust having an added advantage of significantly reducing tomato yellow leaf curl infection. Rice husk and dry grass were the best in enhancing crop performance; however, they have higher rates of fruit worm infestation. Further studies are recommended to find out the mechanism of increased fruit worm infestation with organic mulching.

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REFERENCES

1. Ismail, M.K., 2005. The Facts of Tomato. http:www.bawarchi.com/health/tomato.html. Downloaded 06/29/2005.
2. Ross, I., 2003. Health; Israel Scientists see Red Tomato Pigments Lowers Blood Pressure. http://www.israel 12/c.org/bin/en.jsp. Downloaded 06/29/2005.
3. http://aggie-horticulture.tamu.edu/plantanswers/publications/vegetabletravellers/tomato.html. Tomato paste. Downloaded 06/29/2005.
4. Baseline Survey Report, 2004. Project No. 008. Promotion of tomato production, processing and marketing for enhancing poverty alleviation in Morogoro rural and Kisarawe districts. FOCAL programme. Sokoine University of Agriculture, Morogoro, Tanzania, pp: 48.
5. FAO., 1988. Vegetable production under arid and semi arid conditions in Africa. Rome, pp: 434.
6. Tietjen, W.H., 1995. The effect of staking versus ground culture on tomato post-harvest losses (Abstract). Hortic. Sci., 30: 755. http://www.attra.org/attra-pub/ tomato.html. Revised March, 1999. Downloaded 06/29/2005.
7. Rweyemamu, C.L., K.P. Sibuga and L.S. Mulungu, 1998. Mulch Effects on Soil Properties, Weed Infestation and Tomato (Lycopersicon esculentum Mill) Yield in Morogoro. In: Proceedings of Promotion of Agricultural Production in Tanzania (Eds. Kinabo, J., G. Kifaro, A. Temu and S. Mbaga). Third Faculty of Agriculture Annual Scientific Research Conference. Sokoine University of Agriculture, Morogoro, Tanzania 6-8th May, 1998.
8. Kemble, J.M., L.M. Kurtis and T.W. Tyson, 2000. Guide to commercial staked tomato production in Alabama. Pub ID:ANR-1156, pp: 12. http://www.aces.edu/pubs/docs/A/ANR-1156/.Downloaded 06/29/2005.
9. Momol, M.T., T.E. Funderburk, S. Olson and J. Stavisky, 2002. Management of Tomato Spotted Wilt Virus (TSWV) on tomatoes with UV-reflective mulch and Acibenzolar-S-methyl. thrips and tospoviruses. In: Proceedings of the 7th International Symposium on Thysanoptera. Australian National Insect Collection. Canberra, pp: 111-116.
10. Khan, M., T.H. Chattha and R. Hayat, 2005. Growth and Yield Response of Tomato (*Lycopersicon esculentum* L.) to organic and inorganic mulches. Asian J. Plant Sci., 4: 128-131.
11. Mozumder, S.N., M. Moniruzzaman, M.R. Islam, S.M. Faisal and M.A.R. Sarkar, 2005. Effect of Irrigation and Mulch on Bushbean Production in the Hill Valley. Asian J. Plant Sci., 4: 275-278.
12. Bustani, B. and K. Damo, 1984. Insects in Vegetables. Periodical Expert Books Agency. Delhi. pp: 356.
13. Gethsemane Garden Center, 2002. Mulching. http://www.gethsemanegardens.com/almanac.mulchingtext.html. Downloaded 11/17/2004.
14. Carlson, A.G and T.J. Wilson, 1997. Effect of organic mulch on tomato production. Ghana J. Agric. Sci., 30: 45-52.
15. Ariyarathne, H.M., 1989. Effect of staking method and mulching on tomato production. http://www.arc-avrdc.org/pdffilesHmaryathne[7-N]pdf. Downloaded 02/12/2005.
16. http//325.scifstore.com/module/store/vbc/1996. Sweet Tomato Test Garden: Category Mulch. Downloaded 06/29/2005.
17. Zalom, F.G., J.T. Trumble, C.F. Fouche and C.G. Summers, 2003. How to manage pests: UC Pest management guidelines: Tomato UC ANR Publication 3470. Insects and Mites. http://axp.ipm.ucdavis.edu/PMG/r783300111.html. Downloaded 06/29/2005.
18. http:aggie-horticulture.tamu.edu/tomatoproblem solver/ripefruit/8a.html. Preventive Fungicides. Downloaded 06/27/2005.
19. Weiss, P.H., 1998-2004. Poison-free agriculture. htpp://www.truehealth.org/tomatree.html. Downloaded 06/29/2005.
20. http://amos.shop.com/amos/cc/main/catalog/pcd/7065793/ccsyn/261. Downloaded 06/15/2005.
21. http://www.nysaes.cornell.edu/recommends/27frameset.html. Integrated Crop and Pest Management Guidelines for Commercial Vegetable Production. A Cornell Cooperative Extension Publication 2005. Chapter 27. Downloaded 06/16/2005.
22. Tindall, J.A., R.B. Beverly and D.E. Radcliffe, 1991. Mulch Effect on Soil Properties and Tomato Growth using Micro-propagation. Agron. J., 83: 1028-1034.
23. Aronson, M. and A.L. Aronson, 1990. SAS System: A Programmer's Guide. Pub-McGraw-Hill. pp: 322.
24. Bitala, M.F., 2001. The effect of pruning on growth and yield of tomato. Undergraduate thesis unpublished: BSc. Horticulture, Sokoine University of Agriculture, Morogoro, Tanzania, pp: 23.
25. MSUcares, 2005. Vegetables: Varieties. htpp://msucares.com/lawn/garden/vegetables/ list/tomato.html. Downloaded 06/29/2005.

26. AVRDC, 1990. Vegetable production training manual Asian vegetable. Research and Development Center, Shanhua. Tainan, pp: 447.
27. http://Oregonstate.edu/Dept/NWREC/tomato.html. Commercial Vegetable Production Guidelines. Last revised Aug. 6, 2003. Downloaded 06/15/2005.
28. http://MSUcares.com/lawn/garden/vegetables/list/tomato.html. Vegetable Varieties: Tomato. Last modified 20 June, 2005. Downloaded 06/27/2005.
29. Klier, K., 1993. Tomato plant problems. http://home.earthlink.net/shelly.johnson/tomato.html. Downloaded 06/29/2005.
30. http://www.dfw.state.or.US/ODF html/InfoCntrfish/DiamondLake/Rotenone.html. Updated Febr. 25, 2004. Diamond Lake Questions and Answers about Rotenone. Downloaded 06/22/2005.
31. Watterson, J.C., 1985. Tomato disease: A practical guide for seeds men, growers and agricultural advisors. Petoseed C., Inc. Breeders-Growers, pp: 47.
32. Davis, R.M., G. Miyao, K.V. Subbarao and J.J. Stappleton, 2003. UC IPM Pest management guidelines: Tomato. UC ANR Publication. http://www.ipm.ucdavis.edu/PMG/ r783101311.html. Downloaded 06/25/2005.
33. Jones, J.B., J.P. Jones, R.E. Stall and T.A. Zitter, 1993. Compendium of Tomato Diseases. APS Press New York, pp: 73.
34. Hansen, M.A., 2000. Blossom end rot of tomato. Virginia Cooperative Extension. Knowledge of the Commonwealth. Virginia State University. Publication No. 450-703. http://www.ext.vt.edu/pubs/plantdiseasefs/450-703.html. Downloaded 06/25/2005.
35. Lilian, M., 2003. Field evaluation of determinate tomatoes under zero input. B.Sc. Thesis, Sokoine University of Agriculture, Morogoro, Tanzania, pp: 28.
36. http://www.thewaterwisegarden.com/mulching.htm. Mulch for Organic Gardening. Garden 1999-2005. ABN 949118111923. Last updated 15 June, 2005. Downloaded 06/16/2005.
37. Mulungu, L.S., S.O.W.M. Reuben, A.A.A. Manyama, L.B. Mbilinyi and J. Godwin, 1995. Tomato multilocation trial report. In: Franco-Tanzania Horticultural Development Project. Sokoine University of Agriculture, Morogoro, Tanzania, pp: 30.
38. Diane, R., 2004. Mulches for the Home Vegetable Garden. Horticulture Virginia Tech. Publication number 426-326. Available at http://www.ext.vt.edu/pubs/envirohort/426-326.html. Downloaded 02/12/2005.
39. Roberts, R.E., 2005. Growing Tomato Caged or Trellised. http://lubbock.tamu.edu/ horticulture/docs/tomatoes C-T.html. Downloaded 06/15/2005.
40. http:www.organic gardening.com/feature/0,7518,sl-5-16-193,00.html. Organic Gardening: Tomato Growing Tips. Downloaded 06/16/2005.
41. http://oas.ucok.edu/OJAS/01/papers/bfimple 01.htm. A Study of the Allelopathic Properties of Garden Mulches. Downloaded 06/15/2005.3
42. IPM DANIDA, 2003. Integrated Pest Management for a Healthy Environment. http://www.ipmthailand.org/en/components/botanicals.htm.Downloaded 05/19/2005.
43. FAO, 1988. Vegetable production under arid and semi-arid conditions in Africa. Rome, pp: 434.