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Effect of Planting Techniques, Mulching and Training Systems on Major Diseases and Yield of Tomato

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ABSTRACT

The advancement in the modern technology in the agricultural area have proposed the various agro techniques to detect diseases in tomato plants. Studies were conducted consecutively during two *kharif* seasons of 2017-2018 and 2018-2019 to ascertain the effects of planting techniques, mulching and training systems on disease incidence and severily uckeye rot, *Fusarium* wilt and severity of *Alternaria* leaf blight and bacterial leaf spot and fruit yield of tomato (*Solanum lycopersicum* l.). In all four diseases, severity as well as incidence were higher in flat bed planting and also in plots without mulch and plants trained to three stem training system. Yield was found higher in raised bed planting along with black polythene mulch and two stem trained plants of the tomato crop.

Keywords *Alternaria* leaf blight, *Fusarium* wilt, Mulching, Planting technique, Tomato.

INTRODUCTION

Tomato is one of the important commercial vegetable crops grown in India. Buckeye rot, *Fusarium* wilt, *Alternaria* leaf blight and bacterial leaf spot are amongst the most destructive diseases of tomato. Buckeye rot pathogen identified as *Phytophthora nicotianae* (Breda de Haan) var *parasitica* (Dast.) Waterhouse appears on tomato under mid-hill conditions any time after May, when the warm and rainy season begins and continues till September or late fall. The fungus overwinters in the soil in the form of oospores or chlamydospores and can remain active in soil for at least one year without the support of a susceptible host. Maximum fruit infection under field conditions occurs at a temperature range of 20–25°C, RH > 80% and high rainfall conditions. The disease is not expected to occur below 20°C, though at 22.5°C or above, even a slight rainfall (10 mm) will result in disease appearance, which is expected to appear after 4 days of infection. The symptoms develop on

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fruits after 3-4 day of infection. Infected fruit become mummified and fall down on the ground. The sporangia produced on infected fruits, liberate zoospores which are again splashed by rain and cause secondary infection. *Fusarium* is one of the more troublesome genera of fungal plant pathogens, causing devastating diseases like *Fusarium* wilt and *Fusarium* root/stem rot in numerous economically important crops. It is one of the most serious diseases affecting tomato plants throughout the world, especially in upland areas (Charoenporn *et al.* 2010). *Fusarium* wilt is caused by *Fusarium oxysporum* Schlecht or *Fusarium solani*. Formae speciales of *F. oxysporum* can usually only cause *Fusarium vascular* wilt on one plant host species. The predominant hosts for *F. solani* are vegetable crops but some strains may be infectious to man. There are more than 100 *Fusarium vascular* wilt diseases worldwide (Burgess *et al.* 2008). Apart from causing diseases, they colonize outer cells of roots as harmless endophytes after the pathogen has killed the root tissues and others live as saprophytes in soil (Burgess *et al.* 2008). Some strains of *F. oxysporum* are not pathogenic and may even antagonize the growth of pathogenic strains and can be used as biological control agents (Fravel *et al.* 2003). All these diseases are important limiting factors for the tomato production and productivity in India. Such knowledge is needed for developing new strategies for ealy production of tomato. *Alternaria* leaf blight disease is caused by three different species of viz., *Alternaria solani, Alternaria alternata* and *Alternaria alternata* f.sp. *lycopersici*. *Alternaria* species survive in diseased plants debris and can persist for one to two years. Seed borne nature of *A. solani* has also been reported. Primary infection of lower leaves first takes place through conidia formed on crop debris in soil. Secondary spread of the disease occurs through conidia developed on primary spots. These conidia are blown by wind, water and insects to the neighbouring leaves of plants. The optimum temperature for infection of *A. solani* is 28 to 30^{o}C while for *A. alternata* f. sp. *lycopersici* and *A. alternata*, it ranges between 25–30 and 20–25^{o}C, respectively. Maximum dispersal of conidia occurs in advanced stages of disease development and in between 9 am and 12 noon. Bacterial leaf spot is caused by *Xanthomonas campestris* pv. *vesicatoria*. It causes symptoms throughout the above-ground portion of the plant including leaf spots, fruit spots and stem cankers. Since this bacterium cannot live in soil for more than a few weeks and survives as inoculum on plant debris, removal of dead plant material is a necessity. Environment plays a great role in bacterial spot of tomato. The bacterium requires high levels of humidity to such an extent that infected plants may not begin to show symptoms until several days after infection if ambient humidity is low. *Xanthomonas campestris* pv. *vesicatoria* is a big problem in greenhouses and nurseries where very high humidity and warm temperatures provide a good environment for the bacteria to grow and wet soils easily transmit the disease from plant to plant. The present study was undertaken to study the impact of certain agronomic practices on disease incidence/severity and tomato fruit yield in order to minimize hazardous use of fungicides and thus to save the environment.

MATERIALS AND METHODS

The field experiments were conducted consecutively during two *kharif* seasons of 2017-18 and 2018-19 to determine the effects of planting techniques, mulching and training systyems on the incidence and severity of buckeye rot, wilt, rust, *Alternaria* leaf blight, bacterial leaf spot and fruit yield of tomato. Experiment was conducted in Randomized Block Design (Factorial) with three replications. The plot size of 1.8 × 6.3 m and a spacing of 90 cm × 30 cm was followed. The height of the raised beds was 15 cm above the ground level and two beds were separated by 45 cm from proper drainage. Two planting techniques (raised bed and flat bed), 3 mulching levels (black mulch, silver/black mulch and no mulch) and 2 training systems (two stem and three stem training system) were tested during both the crop seasons. The recommended cultural practices and plant protection measures were followed as per package of practices right from sowing up to harvesting. In order to record the occurrence of the disease, observations were recorded periodically. The incidence of Buckeye rot was recorded as per cent of infected fruits in ten randomly marked plants at each harvest and average incidence was worked out with the following derivation.

$$\text{Incidence of buckeye rot (\%)} = \frac{\text{Number of infected fruits per plot}}{\text{Total number of fruits per plot}} \times 100$$

The leaf blight severity in different treatments was recorded as per the scale given by Shekhawat and Chakarvarti (1974) as shown below:

Scale used for recording severity of *Alternaria* leaf blight (%)

Grade	(%) Plant area infected by the disease	Category
0	0.00	Highly resistant
1	10.1-15.0	Resistant
2	15.1-30.0	Moderately resistant
3	30.1-50.0	Moderately susceptible
4	50.1-75.0	Susceptible
5	75.1 and above	Highly susceptible

The disease severity was worked out according to Mckinney (1923) as given below :

$$\text{Disease severity (\%)} = \frac{\text{Sum of all the disease ratings}}{\text{Total number of ratings} \times \text{Maximum disease grade}} \times 100$$

The bacterial leaf spot severity in different treatments was recorded as per the scale given by Shekhawat and Chakarvarti (1976) mentioned below in the table:

Scale used for recording severity of bacterial leaf spot (%)

Grade	(%) Plant area infected by the disease	Category
0	0	Highly resistant
1	0.1-5.0	Resistant
2	5.1-10	Moderately resistant
3	10.1-25	Moderately susceptible
4	25.1-50	Susceptible
5	>50	Highly susceptible

The disease severity was worked out according to Mckinney (1923) as given below :

$$\text{Disease severity (\%)} = \frac{\text{Sum of all the disease ratings}}{\text{Total number of ratings} \times \text{Maximum disease grade}} \times 100$$

The incidence of *Fusarium* wilt was recorded as per cent infected plants in ten randomly marked plants and average incidence was worked out with the following derivation.

$$\text{Disease incidence (\%)} = \frac{\text{Number of diseased plants}}{\text{Total number of plants observed}} \times 100$$

Yield per plot was calculated by pooling the weight of the all the fruits harvested from all every picking in a given plot and was expressed in kilogram.

RESULTS AND DISCUSSION

The data presented in Tables 1, 2, 3 and 4 revealed the significant effects for the individual factor. It is very much clear from the data that the flat bed planting, beds without mulch along with the plants trained to three stem training system showed maximum incidence as well as severity of the diseases for both the years for buckeye rot (4.19, 4.45 and 4.09 %), *Alternaria* leaf blight (3.80, 4.01 and 3.67 %), *Fusarium* wilt (2.38, 2.47 and 2.33 %) and bacterial leaf spot (3.45, 3.62 and 3.36 %) and as well as when the data was pooled for both the consecutive years. The interaction effects for the different observations were also found to be significant for all the characters. The interaction effects were also found to be significant. The treatment module P2M3T2 (flat bed planting, no mulch and three stem training system) represented maximum (4.60, 4.12, 2.59 and 3.83 %) incidence/severity for the above described diseases and lesser yield per plot (105.26 kg/plot) as compared to the treatment module P1M1T1 (3.86, 2.80, 1.84 and 2.60 %) which represented the maximum value (140.71 kg/plot) for the yield per plot. Various reasons were proposed by the researchers regarding

Table 1. Effect of planting methods, mulches and training systems on incidence of buckeye rot and severity of *Alternaria* leaf blight in tomato crop. *The figures in parentheses represent square root transformed values.

Treatments	Incidence of buckeye rot (%) 2017-2018	2018-2019	Pooled	Severity of *Alternaria* leaf blight (%) 2017-2018	2018-2019	Pooled
Planting methods (P)						
P_1	15.73 (3.95)	14.09 (3.74)	14.91 (3.85)	10.94 (3.28)	11.87 (3.41)	11.40 (3.35)
P_2	18.84 (4.33)	16.44 (4.04)	17.64 (4.19)	13.65 (3.69)	15.30 (3.90)	14.48 (3.80)
$CD_{0.05}$	0.04	0.03	0.02	0.07	0.03	0.03
Mulches (M)						
M_1	15.04 (3.87)	13.27 (3.64)	14.15 (3.76)	10.41 (3.21)	11.39 (3.35)	10.90 (3.28)
M_2	15.76 (3.96)	13.97 (3.73)	14.87 (3.85)	11.40 (3.36)	12.26 (3.49)	11.83 (3.43)
M_3	21.06 (4.59)	18.54 (4.30)	19.80 (4.45)	15.07 (3.88)	17.11 (4.13)	16.09 (4.01)
$CD_{0.05}$	0.05	0.04	0.03	0.09	0.04	0.04
Training systems (T)						
T_1	16.71 (4.07)	14.65 (3.81)	15.68 (3.94)	11.80 (3.40)	12.86 (3.55)	12.33 (3.48)
T_2	17.86 (4.21)	15.87 (3.97)	16.87 (4.09)	12.79 (3.56)	14.31 (3.76)	13.55 (3.67)
$CD_{0.05}$	0.04	0.03	0.02	0.07	0.03	0.03

the maximum incidence and severity of the diseases and lesser fruit yield.

The increased yield of tomato fruits on raised beds may be due to higher soil organic matter content along with higher phosphorus and potassium levels. This may be because of increased enzymatic activity of microorganisms which consequently facilitated the mineralization of organic matter (Daza *et al.* 2016), whereas, Aykas *et al*. (2005) were of the opinion that soil compaction in the flat beds decreased nutrients which were mineralized from the soil organic matter. In the present case also, less soil compaction and increased oxygen intake from the atmosphere might have helped the plant to perform better resulting into conditions that favors better growth and higher yield. Other reasons for increased yield on raised beds could be longer growing period, warming up of the bed, improved drainage, better management of water, fertilizers, mulch and other soil amendments and reduced foot trafficing (Berle and Westerfield 2013). The present results are in line with the findings of Kumar *et al.* (2001) in tomato, Locher *et al.* (2003) in sweet pepper, and Bahadur *et al.* (2013) in tomato. Angmo *et al.* (2018) were of opinion that reduced competition with weeds, higher soil temperature,

Table 2. Effect of P × M × T interaction on incidence of buckeye rot and severity of *Alternaria* leaf blight in tomato crop. *The figures in parentheses represent square root transformed values.

Treatment combination	Incidence of buckeye rot (%) 2017-2018	2018-2019	Pooled	Severity of *Alternaria* leaf blight (%) 2017-2018	2018-2019	Pooled
$P_1M_1T_1$	12.83 (3.58)	11.14 (3.34)	11.99 (3.46)	7.53 (2.74)	8.14 (2.85)	7.84 (2.80)
$P_1M_1T_2$	14.38 (3.79)	13.04 (3.61)	13.71 (3.70)	9.43 (3.07)	10.05 (3.17)	9.74 (3.12)
$P_1M_2T_1$	13.61 (3.69)	12.13 (3.48)	12.87 (3.59)	8.47 (2.90)	9.14 (3.02)	8.81 (2.97)
$P_1M_2T_2$	14.44 (3.80)	13.33 (3.65)	13.89 (3.73)	11.51 (3.39)	11.64 (3.41)	11.58 (3.40)
$P_1M_3T_1$	19.19 (4.38)	17.05 (4.13)	18.12 (4.26)	14.23 (3.77)	15.95 (3.99)	15.09 (3.88)
$P_1M_3T_2$	19.95 (4.47)	17.82 (4.22)	18.88 (4.35)	14.45 (3.80)	16.29 (4.04)	15.37 (3.92)
$P_2M_1T_1$	15.54 (3.94)	13.53 (3.68)	14.54 (3.81)	12.04 (3.47)	12.89 (3.59)	12.47 (3.53)
$P_2M_1T_2$	17.40 (4.17)	15.37 (3.92)	16.38 (4.05)	12.64 (3.55)	14.45 (3.80)	13.55 (3.68)
$P_2M_2T_1$	16.62 (4.08)	14.38 (3.79)	15.50 (3.94)	12.52 (3.54)	13.15 (3.62)	12.83 (3.58)
$P_2M_2T_2$	16.62 (4.08)	14.38 (3.79)	15.50 (4.15)	12.52 (3.54)	13.15 (3.62)	12.83 (3.58)
$P_2M_3T_1$	18.38 (4.29)	16.04 (4.00)	17.21 (4.15)	13.10 (3.62)	15.10 (3.89)	14.10 (3.75)
$P_2M_3T_2$	22.64 (4.76)	19.62 (4.43)	21.13 (4.60)	15.63 (3.95)	18.31 (4.28)	16.97 (4.12)
$CD_{0.05}$	NS	NS	0.06	NS	NS	NS

Table 3. Effect of planting methods, mulches and training systems on severity of bacterial leaf spot and incidence of *Fusarium* wilt in tomato. *The figures in parentheses represent square root transformed values.

Treatments	Severity of bacterial leaf spot (%) 2017-2018	2018-2019	Pooled	Incidence of *Fusarium* wilt (%) 2017-2018	2018-2019	Pooled
Planting methods (P)						
P_1	5.01 (2.23)	4.56 (2.13)	4.78 (2.18)	9.24 (3.02)	9.91 (3.13)	9.57 (3.08)
P_2	5.94 (2.43)	5.44 (2.33)	5.69 (2.38)	11.43 (3.37)	12.45 (3.52)	11.94 (3.45)
$CD_{0.05}$	0.04	0.06	0.03	0.03	0.03	0.02
Mulches (M)						
M_1	4.83 (2.19)	4.46 (2.10)	4.64 (2.15)	8.55 (2.91)	9.86 (3.13)	9.21 (3.02)
M_2	5.18 (2.27)	4.70 (2.17)	4.94 (2.22)	9.49 (3.07)	10.43 (3.22)	9.96 (3.15)
M_3	6.43 (2.53)	5.85 (2.41)	6.14 (2.47)	12.97 (3.60)	13.24 (3.64)	13.10 (3.62)
$CD_{0.05}$	0.05	0.08	0.04	0.04	0.03	0.03
Training systems (T)						
T_1	5.34 (2.30)	4.70 (2.16)	5.02 (2.23)	9.75 (3.10)	10.48 (3.22)	10.12 (3.16)
T_2	5.61 (2.36)	5.31 (2.30)	5.46 (2.33)	10.92 (3.29)	11.88 (3.44)	11.40 (3.36)
$CD_{0.05}$	0.04	0.06	0.03	0.03	0.03	0.02

reduced attack of soil pathogens and breakdown of phytotoxic substances are responsible for higher yield in the plants grown on black mulch. Our results are in agreement with those obtained by *Ashrafuzzaman et al.* (2011) in chilli. Ara *et al.* (2007) also recorded higher yield in two stem pruned plants as compared to single stem pruned. The present results are in conformity with those of Lim and Chen (1989). The plants pruned to two stem recorded an increase of 5.09% yield of fruits as compared to those which were trained to three stem training system. This could be due to the competition for assimilates between the growing fruits. Razzak *et al.* (2013) in cucumber reported reduced fruit size and low yield in three stem training system. This could be due to reduced fruit size and weight in three stem training system because of reduced assimilates availability in the source and increased demand in the sink.

Raised bed method of planting offer better conditions for the plant to grow since they warm up more quickly and drain better. In the present case, better

Table 4. Effect of P × M × T interaction on severity of bacterial leaf spot and incidence of *Fusarium wilt* in tomato.*The figures in parentheses represent square root transformed values. P : Planting methods, M : Mulching treatments, T : Training systems, P_1 : Raised bed planting method, P_2 : Flat bed planting method, M_1 : Black polythene mulch, M_2 : Silver/black polythene mulch, M_3 : No mulch, T_1 : Two stem training system, T_2 : Three stem training system.

Treatment combination	Severity of bacterial leaf spot (%) 2017-2018	2018-2019	Pooled	Incidence of *Fusarium* wilt (%) 2017-2018	2018-2019	Pooled
$P_1M_1T_1$	3.61 (1.90)	3.14 (1.77)	3.38 (1.84)	6.44 (2.54)	7.07 (2.66)	6.76 (2.60)
$P_1M_1T_2$	4.90 (2.21)	4.75 (2.17)	4.36 (2.19)	8.36 (2.89)	9.46 (3.08)	8.91 (2.98)
$P_1M_2T_1$	4.59 (2.14)	4.14 (2.03)	4.36 (2.09)	7.69 (2.77)	8.11 (2.85)	7.90 (2.81)
$P_1M_2T_2$	4.92 (2.22)	4.79 (2.19)	4.86 (2.20)	8.93 (2.99)	10.21 (3.20)	9.57 (3.09)
$P_1M_3T_1$	6.01 (2.45)	5.12 (2.26)	5.57 (2.36)	11.50 (3.54)	12.01 (3.47)	11.76 (3.43)
$P_1M_3T_2$	6.02 (2.45)	5.40 (2.32)	5.71 (2.39)	12.52 (3.03)	12.59 (3.55)	12.56 (3.54)
$P_2M_1T_1$	5.32 (2.31)	4.83 (2.20)	5.08 (2.25)	9.17 (3.20)	11.06 (3.32)	10.11 (3.18)
$P_2M_1T_2$	5.47 (2.34)	5.12 (2.26)	5.30 (2.30)	10.24 (3.20)	11.87 (3.44)	11.05 (3.32)
$P_2M_2T_1$	5.44 (2.33)	4.89 (2.21)	5.17 (2.27)	10.16 (3.19)	11.41 (3.38)	10.79 (3.28)
$P_2M_2T_2$	5.44 (2.33)	4.89 (2.21)	5.17 (2.27)	10.16 (3.19)	11.41 (3.38)	10.79 (3.28)
$P_2M_3T_1$	5.75 (2.40)	4.96 (2.23)	5.36 (2.31)	11.17 (3.34)	12.00 (3.46)	11.58 (3.40)
$P_2M_3T_2$	5.44 (2.33)	6.80 (2.61)	6.69 (2.59)	14.29 (3.78)	15.13 (3.89)	14.71 (3.83)
$CD_{0.05}$	0.10	0.15	0.07	NS	0.07	0.05

drainage conditions coupled with quick warming of the upper layer as well as beneath of the soil might have created conditions which are not suitable for the development of various disease causing organisms. This might have resulted into less growth of the germinating spores and insufficient disease causing inoculum. Similar are the findings of Sharma *et al.* (2016) who observed that the disease incidence in the bell pepper plants grown on raised beds and ridges were low as compared to the flat beds.

The results of present study also revealed low incidence of buckeye rot in different treatments may be due to the prevalence of non-congenial environmental conditions. However, the incidence was comparatively less in the black polythene as compared to the others. The reduced buckeye rot incidence with black polythene mulch may be due to the fact that mulches mitigate the harmful effect of soil borne fungi and create a barrier to the pathogen which causes the disease. The results are in conformity with the findings of Mehta *et al.* (2010) in tomato. The plastic mulching acts as a barrier between soil and plant and keeps away the foliage and fruits from soil contact. Mulch also prevents soil splash on lower canopy as soil often consist disease causing conidial spores (Bhujbal *et al*. 2015). Mulching (black polythene or other) resulted in increased temperature in soil ecosystem which proves to be lethal to tomato wilt pathogen. Mulching is basically an addition of a thick layer of mulch on the soil surface to help control weeds, optimize soil moisture and keep the soil cooler which influence plant response to *Fusarium* wilt incidence. It helps in disease control by standing as a barrier between the plant parts above the ground and plant pathogen in the soil. Since it helps to control weeds, it also helps in altering the environment for these pathogens thereby creating unfavorable conditions for them and controlling diseases. In order to avoid splashing soil borne diseases on tomato leaves during watering, mulching of the plant is advised. The results are in line with the findings of Caroline and Olubukola (2013) in tomato. Bala (2012) also observed that the black polyethylene mulch proved to be most effective to lowest incidence of buckeye rot and minimum Alternaria blight severity. Lyimo *et al.* (1998) also studied the effect of mulching and staking on the development of early and late leaf blight of tomato caused by *Alternaria solani* and *Phytophthora infestans* respectively. They reported that mulching and staking significantly reduced the incidence of early and late blight by 5 to 20% as compared to unmulched and unstaked control.

In two stem training system, incidence of the disease was low because the plants were more erect as compared to three stem training system and foliage and fruits up to a height of 15–20 cm were removed which could avoid the moist and stagnant air conditions for the pathogen to perpetuate. This might be the suitable reason for less buckeye rot incidence in two stem trained plants. On the other hand, less number of branches will provides more passage of air and sunlight towards the soil and less suffocative conditions might have resulted into less disease spread. Similar findings on various diseases have also been reported by Mehta *et al*. (2010) in tomato crop.

Authors contribution

S and YR S designed the experiment and conducted the study. S and PB analyzed the data and wrote the manuscript. YR S and S wrote the results and discussion. All the authors contributed equally.

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