RESEARCH ARTICLE

EFFECT OF DIFFERENT MULCHES AND BIOFERTILIZERS ON QUALITATIVE AND QUANTITATIVE ATTRIBUTES OF TOMATO

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Abstract: The present studies were carried out at Experimental Farm of the Dr Y S Parmar U H F, Horticulture Research Station, Kandaghat, Solan, Himachal Pradesh during Kharif season of 2011 and 2012 to find out the effect of mulches and biofertilizers on different genotypes of tomato. The experiment was laid out in Split-Split Plot Design (SSPD) comprising of 27 treatments having combinations of three genotypes (V_1-Naveen 2000$^+$, V_2-Sun-7711 and V_3-Solan Lalima), three mulches (M_0-No mulch, M_1-Pine needle mulch and M_2- black polyethylene) and three biofertilizers (B_0-recommended NPK, B_1-100 % NPK + *Azotobacter* (1g/plant) + PSB (1g/plant) and B_2-75 % NPK + *Azotobacter* (1g/plant) + PSB (1g/plant) replicated thrice. Among varieties, maximum yield was observed with the variety V_2 (Sun-7711), but the fruit quality characters were observed with the variety V_3 (Solan Lalima). Among the mulch materials the M_2 (Black polythene) and biofertilizers B_1 (100% NPK + *Azotobacter* (1g/plant) + PSB (1g/plant) were recorded to be the best regarding the fruit yield and quality. The first order interactions viz., varieties x mulch, biofertilizers x mulch and varieties x biofertilizers significantly affected most of the characters under study. Maximum fruit yield was obtained with treatment combinations of V_2M_2 (Sun-7711 applied with black polyethylene mulch), B_2M_2 (75% NPK + *Azotobacter* (1g/plant) + PSB (1g/plant) applied with black polyethylene mulch) and V_2B_2 (Sun-7711with 75 % NPK + *Azotobacter* (1g/plant) + PSB (1g/plant). Further in three factor interaction, the highest fruit yield (1037.33 q/ha) was obtained with the treatment combination of Sun-7711, 75% NPK + *Azotobacter* (1g/plant) + PSB (1g/plant) and black polyethylene mulch ($V_2B_2M_2$).

Keyword: Biofertilizers, Mulch, Genotypes, *Azotobacter*

INTRODUCTION

Tomato (*Solanum lycopersicum* L.), is one of the most important vegetable crops grown throughout the world. In Himachal Pradesh, tomato is being cultivated over an area of 10,000 hectares with total annual production of 400,000 MT (NHB, 2013). After green revolution, production of vegetables in our country has increased to great extent due to increased use of chemical fertilizers, use of high yielding varieties mainly hybrids and surplus usage of water resources. However, health and ecological hazards and depletion of non-renewable sources of energy etc. are some of the features of long term usage of unbalanced chemical fertilizers and poor management of resources. Hence, there is a need to think for alternative sources of safe fertilizers which may enhance crop yields without having adverse effects on soil properties and pollution free environment (Gajbhiye *et al*., 2003). The excessive use of nitrogenous fertilizers and imbalanced use of other fertilizers has resulted in yield saturation and deterioration of soil health. Proper and regular incorporation of farm organic wastes and bio-inoculants are of utmost importance in maintaining the fertility and productivity of agricultural soils (Yadav, 2009). Hence, there is urgent need for use of mulches to regulate the soil moisture and application of biofertilizers and major nutrients to enhance the production and quality of tomato under open field condition.

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MATERIAL AND METHOD

The present investigations were carried out at Experimental Farm of the Dr Y S Parmar U H F, Horticulture Research Station, Kandaghat, Solan, Himachal Pradesh during Kharif season of 2011 and 2012. The experiment was laid out in Split-Split Plot Design (SSPD) comprising of 27 treatments including combinations of varieties, biofertilizers and mulches. Raised nursery bed of 3x1m size was prepared by mixing of well rotten FYM in the soil @ 20kg per bed. The seeds were sown in the rows 5 cm apart. The complete dose of phosphorus and potassium and 1/3 dose of nitrogen was applied at the time of field preparation as basal dose. However, the rest of nitrogen was applied in two equal doses viz. one month after transplanting and again two month after transplanting. Well rotten farm yard manure was applied directly to the soil based upon the nitrogen content of FYM which was applied @ 25ton/ha before transplanting. One month seedlings were transplanted on flat and fine beds spaced at 30 cm from plant to plant and 90 cm from row to row thereby accommodating 18 plants in 4.86 square meter beds. Transplanting was done on 2nd April 2011 and 4th April 2012 followed by light irrigations for 3-4 days. Biofertilizers (*Azotobacter* and Phosphorus Solubilizing Bacteria - PSB) application was

done through soil application @ 1g per plant by thoroughly mixed with FYM. The biofertilizers were applied as per the treatments assigned at the time of first earthing up i.e. 30 -35 days after transplanting. Black polyethylene mulch of 50µ (200 gauge thickness) and dry pine needle mulch were applied in plots according to the treatment combinations. The data on fruit yield (number of fruits/ plant, kg/plant, kg/plot and q/ha), TSS by Erma Hand Refractometer, acidity, vitamin C and lycopene content as per method described by (Rangana, 8) were collected.

RESULT AND DSCUSSION

The results obtained on number of fruits/plant have been presented in Table 1a, 1b & 1c which shows significant effect of varieties, biofertilizers and mulch. The pooled data of both the years show that the variety V_3 (Solan Lalima) recorded maximum number of fruits/plant (38.00). Similarly number of fruits/plant was significantly affected by biofertilizers. The maximum number of fruits/plant (38.01) was observed with B_1. With regard to mulches, M_2 (Black polythene) recorded maximum number of fruits/plant (36.16). In V×B interaction, V_3B_2 gave the maximum number of fruits/plant (41.43). Biofertilizers and mulch interaction were also found significant for this traits. The maximum number of fruits/plant (39.80) was recorded with B_2 M_2. The V×M interaction was significant during both the year of study. The pooled data analysis show that V_3M_2 recorded maximum number of fruits/plant (39.82). Regarding second order interactions, i.e. V×B×M, the maximum number of fruits/plant (43.34) was recorded with $V_3B_1M_2$. This may be attributed to the genetic traits as reported by (Zaman *et al*., 12). The possible reason may be better proliferation of roots in organic manure, which helped in increased uptake of nutrients as well as plant growth hormones produced by microbes at root zone and also enhanced biological nitrogen fixation by the application of biofertilizers (Thakur *et al*., 9). The increased fruit number with black polythene mulch resulted in lesser weed number, less nutrient loss through leaching, thereby, resulting more fruits per plant (Bala, 2).

The results obtained on fruit yield has been presented in Table 1a, 1b & 1c which shows significant individual effect of varieties, biofertilizers and mulches. Highest fruit yield (3.00 kg/plant, 54.08 kg/plot and 890.13 q/ha) was observed with V_2 (Sun-7711). Biofertilizers affected the fruit yield significantly and B_2 recorded the highest yield (2.87 kg/plant, 51.69 kg/plot and 850.86 q/ha). Among various mulches, M_2 (Black polythene) showed the highest yield (2.83 kg/plant, 50.96 kg/plot and 838.90 q/ha). In V×B interactions, V_2B_2 recorded the maximum yield (3.28 kg/plant, 59.08 kg/plot and 972.52 q/ha). With regard to B×M interactions, B_2M_2 observed maximum yield (3.10 kg/plant, 55.78 kg/plot and 918.18 q/ha). Further, the treatment combination V_2M_2 recorded maximum yield (3.22 kg/plant, 57.90 kg/plot and 953.09 q/ha). In second order interaction, the treatment combination $V_2B_2M_2$ recorded maximum yield (3.50 kg/plant, 63.02 kg/plot and 1037.33 q/ha). The varietal effect may be attributed to its growth habit governed by genetic traits (Kumar *et al*., 4). Optimum supply of nutrients resulted in better absorption of water and nutrients along with improved physical environment, which ultimately enhanced fruit yield (Thakur *et al*., 9). Increased yield with biofertilizers application which might be due to better nutritional environment in the root zone which accelerated the process of cell division and hence fruit yield (Sharma *et al*., 8). The possible reason for increased fruit yield might be associated to better organic nitrogen utilization in the presence of biofertilizers, which enhanced biological nitrogen fixation, better development of root system and possible higher synthesis of plant growth hormones (Gajbhiye *et al*., 3). The increase in yield may be attributed due to higher soil temperature which improved the plant micro-climate, thus, helping in maximum plant growth and fruit setting in tomato.

The results obtained on fruit quality as presented in Table 2a, 2b & 2c show significant individual effect of varieties, biofertilizers and mulches. In individual effect, pooled data of both the years shows that V_3 (Solan Lalima) had maximum fruit TSS (5.02 ^{0}Brix), ascorbic acid (32.61 mg/100g) and lycopene content (2.67 mg/100) while maximum titratable acidity (0.51%) was recorded with V_1 (Naveen 2000$^+$). Among biofertilizers, B_1 recorded maximum TSS (4.79 ^{0}Brix), ascorbic acid (32.07 mg/100g) and lycopene content (2.65 mg/100g) while titratable acidity (0.49 %) was recorded highest with B_0. With regards to different mulches, M_2 (Black polythene) showed maximum fruit TSS (4.78 ^{0}Brix), ascorbic acid (32.77 mg/100g) and lycopene content (2.67 mg/100g) while M_0 recorded maximum titratable acidity (0.48%). The data in Table 2b revealed that in the interaction between variety and biofertilizers, treatment combination V_3B_1 recorded highest ascorbic acid (33.10 mg/100g) and lycopene content (2.86 mg/100g) while highest titratable acidity (0.53 %) was recorded with V_1B_0. Further treatment combination B_1M_2 recorded maximum ascorbic acid (33.27 mg/100g) and lycopene content (2.92 mg/100g) and maximum titratable acidity (0.51 %) was observed with B_0M_0. In the interaction between variety and mulch, treatment combination V_3M_2 recorded maximum ascorbic acid content (33.31 mg/100g) and lycopene content (2.94 mg/100g). The effect of these treatment combinations on fruit TSS was non significant. The second order interaction between varieties, biofertilizers and mulch also recorded significant differences for titratable acidity, ascorbic acid and lycopene content while non

significant effects were observed for fruit TSS. The pooled analysis of data in the experiment of both the years revealed that maximum titratable acidity (0.58%) was obtained with treatment combination $V_1B_0M_0$ while $V_3B_1M_2$ recorded maximum ascorbic acid (33.87 mg/100g) and lycopene content (3.13 mg/100g). The change in fruit quality with the varieties might be attributed to their genetic traits. The improvement in quality characters like TSS and titratable acidity content by application of biofertilizers might be due to their nutritional, stimulatory and therapeutic behavior as reported by (Thiikavally and Ramaswamy, 1999). Increased fruit TSS and titratable acidity with biofertilizers application. It might be due to proper and adequate provision of micro and macro nutrients (Gosavi *et al.*, 4). Biofertilizers also enhanced production of growth regulating substances as reported by (Parvathan and Vijayan, 7). The possible reason for improvement of fruit quality attributes with black polythene mulch might be that black polythene mulch provided favourable condition for growth and development of plants by conservation of moisture, optimum temperature and least weed growth (Kaur and Singh, 5; Ali and Gaur, 1).

Table 1a. Effect of different mulches and biofertilizers on different yield parameters of different genotypes in tomato.

Treatment combination	Number of fruit/plant			Yield (kg/plant)			Yield (kg/plot)			Yield (q/ha)		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
Varieties (V)												
V_1 (Naveen 2000$^+$)	29.70	29.99	29.85	2.28	2.39	2.34	41.07	43.06	42.07	676.07	708.87	692.47
V_2 (Sun-7711)	36.91	34.40	35.66	3.07	2.94	3.00	55.28	52.87	54.08	909.90	870.35	890.13
V_3 (Solan Lalima)	33.81	42.18	38.00	2.21	2.81	2.51	39.86	50.53	45.20	656.19	831.85	744.02
$CD_{0.05}$	**0.08**	**0.14**	**0.10**	**0.02**	**0.01**	**0.01**	**0.15**	**0.16**	**0.10**	**2.10**	**2.85**	**1.61**
Biofertilizers												
B_0 (NPK recommended)	28.38	31.59	29.99	2.09	2.36	2.22	37.70	42.39	40.04	620.56	697.73	659.14
B_1(100%NPK+*Azotobacter* (1g/plant)+PSB(1g/plant)	32.16	38.85	35.50	2.47	3.04	2.76	44.52	54.69	49.61	732.91	900.30	816.61
B_2 (75% NPK+*Azotobacter* (1g/plant)+PSB(1g/plant)	39.89	36.13	38.01	3.00	2.74	2.87	53.99	49.39	51.69	888.68	813.04	850.86
$CD_{0.05}$	**0.07**	**0.20**	**0.11**	**0.01**	**0.02**	**0.01**	**0.12**	**0.28**	**0.15**	**1.93**	**4.63**	**2.53**
Mulches (M)												
M_0 (No Mulch)	31.65	33.68	32.67	2.30	2.47	2.39	41.37	44.49	42.93	680.89	732.33	706.61
M_1 (Pine needle)	33.58	35.75	34.67	2.54	2.74	2.64	45.69	49.22	47.45	752.03	810.18	781.10
M_2 (Black polyethylene)	35.19	37.13	36.16	2.73	2.93	2.83	49.16	52.77	50.96	809.24	868.57	838.90
$CD_{0.05}$	**0.09**	**0.26**	**0.13**	**0.01**	**0.02**	**0.01**	**0.11**	**0.33**	**0.17**	**1.81**	**5.49**	**2.75**

Table 1. Effect of different interactions V x B, B x M and V x M on different yield parameters of different genotypes in tomato.

Treatment combination	Number of fruit/plant			Yield (kg/plant)			Yield (kg/plot)			Yield (q/ha)		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
V_1B_0	24.51	25.71	25.11	1.86	1.98	1.92	33.54	35.59	34.56	552.06	585.87	568.96
V_1B_1	28.95	32.99	30.97	2.26	2.72	2.49	40.70	49.00	44.85	669.90	806.56	738.23
V_1B_2	35.65	31.28	33.46	2.72	2.48	2.60	48.98	44.60	46.79	806.25	734.17	770.21
V_2B_0	31.53	31.30	31.41	2.57	2.63	2.60	46.31	47.40	46.85	762.27	780.19	771.23
V_2B_1	35.32	37.51	36.41	2.99	3.27	3.13	53.83	58.75	56.29	886.16	967.08	926.63
V_2B_2	43.90	34.38	39.14	3.65	2.92	3.28	65.69	52.47	59.08	1081.26	863.78	972.52
V_3B_0	29.10	37.77	33.44	1.85	2.46	2.15	33.25	44.17	38.71	547.35	727.13	637.24
V_3B_1	32.21	46.04	39.12	2.17	3.13	2.65	39.04	56.33	47.69	642.67	927.26	784.96
V_3B_2	40.11	42.74	41.43	2.63	2.84	2.73	47.30	51.10	49.20	778.54	841.15	809.85
$CD_{0.05}$	**0.13**	**0.35**	**0.18**	**0.01**	**0.02**	**0.01**	**0.20**	**0.48**	**0.27**	**3.35**	**8.02**	**4.38**
B_0M_0	26.80	30.26	28.53	1.92	2.19	2.05	34.54	39.34	36.94	568.52	647.56	608.04
B_0M_1	28.27	31.77	30.02	2.09	2.36	2.23	37.70	42.51	40.10	620.57	699.76	660.16
B_0M_2	30.07	32.74	31.41	2.27	2.52	2.39	40.86	45.31	43.09	672.60	745.86	709.23
B_1M_0	30.54	36.73	33.63	2.25	2.74	2.50	40.51	49.34	44.92	666.74	812.12	739.43
B_1M_1	32.30	38.88	35.59	2.49	3.05	2.77	44.88	54.88	49.88	738.85	903.32	821.09
B_1M_2	33.64	40.93	37.28	2.68	3.33	3.00	48.18	59.87	54.02	793.13	985.47	889.30
B_2M_0	37.61	34.05	35.83	2.73	2.49	2.61	49.05	44.79	46.92	807.40	737.29	772.35
B_2M_1	40.18	36.61	38.39	3.03	2.79	2.91	54.47	50.27	52.37	896.68	827.44	862.06
B_2M_2	41.87	37.73	39.80	3.25	2.95	3.10	58.44	53.12	55.78	961.97	874.38	918.18
$CD_{0.05}$	**0.15**	**0.45**	**0.22**	**0.01**	**0.03**	**0.02**	**0.19**	**0.58**	**0.29**	**3.13**	**9.50**	**4.76**
V_1M_0	28.40	28.19	28.30	2.10	2.15	2.13	37.84	38.75	38.30	622.91	637.93	630.42
V_1M_1	29.64	30.10	29.87	2.29	2.41	2.35	41.14	43.40	42.27	677.23	714.36	695.80
V_1M_2	31.06	31.68	31.38	2.46	2.61	2.54	44.23	47.04	45.63	728.07	774.31	751.19
V_2M_0	35.05	33.02	34.04	2.84	2.74	2.79	51.09	49.27	50.18	840.91	811.03	825.97

V_2M_1	36.67	34.59	35.63	3.06	2.96	3.01	55.01	53.28	54.15	905.55	877.10	891.32
V_2M_2	39.02	35.57	37.30	3.32	3.12	3.22	59.73	56.07	57.90	983.24	922.93	953.09
V_3M_0	31.50	39.83	35.66	1.95	2.52	2.24	35.17	45.44	40.30	578.84	748.01	663.43
V_3M_1	34.43	42.56	38.50	2.27	2.83	2.55	40.90	50.97	45.94	673.33	839.06	756.20
V_3M_2	35.49	44.14	39.82	2.42	3.06	2.74	43.52	55.19	49.35	716.39	908.46	812.43
$CD_{0.05}$	**0.15**	**0.45**	**0.22**	**0.01**	**0.03**	**0.02**	**0.19**	**0.58**	**0.29**	**3.13**	**9.50**	**4.76**

Table 1c. Effect of V x B x M interaction on different yield parameters of different genotypes in tomato

Treatment combination	Number of fruit/plant			Yield (kg/plant)			Yield (kg/plot)			Yield (q/ha)		
	2011	**2012**	**Pooled**	**2011**	**2012**	**Pooled**	**2011**	**2012**	**Pooled**	**2011**	**2012**	**Pooled**
$V_1B_0M_0$	23.63	24.45	24.04	1.74	1.82	1.78	31.28	32.78	32.03	514.96	539.57	527.27
$V_1B_0M_1$	24.45	26.14	25.30	1.86	1.99	1.93	33.52	35.88	34.70	551.69	590.54	571.12
$V_1B_0M_2$	25.46	26.54	26.00	1.99	2.12	2.05	35.81	38.12	36.97	589.52	627.50	608.51
$V_1B_1M_0$	27.24	31.28	29.26	2.05	2.43	2.24	36.85	43.79	40.32	606.62	720.78	663.70
$V_1B_1M_1$	29.11	32.50	30.81	2.29	2.71	2.50	41.14	48.69	44.92	677.27	801.54	739.41
$V_1B_1M_2$	30.49	35.20	32.85	2.45	3.03	2.74	44.09	54.51	49.30	725.80	897.36	811.58
$V_1B_2M_0$	34.34	28.84	31.59	2.52	2.21	2.36	45.39	39.70	42.54	747.13	653.44	700.29
$V_1B_2M_1$	35.37	31.67	33.52	2.71	2.53	2.62	48.77	45.62	47.19	802.73	751.00	776.86
$V_1B_2M_2$	37.24	33.32	35.28	2.93	2.69	2.81	52.79	48.48	50.63	868.90	798.08	833.49
$V_2B_0M_0$	29.83	29.67	29.75	2.36	2.44	2.40	42.54	43.87	43.20	700.26	722.11	711.18
$V_2B_0M_1$	31.19	31.52	31.35	2.56	2.65	2.61	46.15	47.73	46.94	759.59	785.60	772.59
$V_2B_0M_2$	33.56	32.71	33.13	2.79	2.81	2.80	50.24	50.60	50.42	826.98	832.86	829.92
$V_2B_1M_0$	33.80	36.16	34.98	2.79	3.05	2.92	50.21	54.85	52.53	826.58	902.81	864.69
$V_2B_1M_1$	35.02	37.56	36.29	2.96	3.27	3.12	53.27	58.90	56.08	876.82	969.53	923.17
$V_2B_1M_2$	37.14	38.81	37.98	3.22	3.47	3.35	58.02	62.51	60.26	955.10	1028.92	992.01
$V_2B_2M_0$	41.53	33.25	37.39	3.36	2.73	3.04	60.50	49.10	54.80	995.90	808.17	902.03
$V_2B_2M_1$	43.80	34.69	39.25	3.65	2.96	3.30	65.62	53.23	59.43	1080.23	876.18	978.20
$V_2B_2M_2$	46.37	35.20	40.78	3.94	3.06	3.50	70.93	55.10	63.02	1167.65	907.01	1037.33
$V_3B_0M_0$	26.94	36.68	31.81	1.65	2.30	1.98	29.79	41.37	35.58	490.33	681.01	585.67
$V_3B_0M_1$	29.17	37.64	33.41	1.86	2.44	2.15	33.44	43.93	38.68	550.42	723.15	636.78
$V_3B_0M_2$	31.19	38.99	35.09	2.03	2.62	2.33	36.53	47.22	41.87	601.30	777.22	689.26
$V_3B_1M_0$	30.58	42.74	36.66	1.91	2.74	2.33	34.45	49.37	41.91	567.03	812.75	689.89
$V_3B_1M_1$	32.76	46.60	39.68	2.24	3.17	2.70	40.25	57.04	48.64	662.48	938.89	800.69
$V_3B_1M_2$	33.28	48.77	41.03	2.36	3.48	2.92	42.43	62.58	52.51	698.51	1030.12	864.32
$V_3B_2M_0$	36.97	40.07	38.52	2.29	2.53	2.41	41.26	45.58	43.42	679.17	750.28	714.72
$V_3B_2M_1$	41.37	43.46	42.42	2.72	2.89	2.81	49.03	51.95	50.49	807.08	855.14	831.11
$V_3B_2M_2$	42.00	44.67	43.34	2.87	3.10	2.98	51.60	55.77	53.68	849.36	918.04	883.70
$CD_{0.05}$	**0.26**	**0.77**	**0.38**	**0.02**	**0.03**	**0.03**	**0.33**	**0.58**	**0.50**	**5.41**	**19.46**	**8.26**

Table 2a. Effect of different mulches and biofertilizers on number of days to first flowering and first harvest, harvest duration and plant height of different genotypes in tomato.

Treatment combination	TSS (^{0}Brix)			Titratable acidity (%)			Ascorbic acid (mg/100g)			Lycopene content (mg/100g)		
	2011	**2012**	**Pooled**	**2011**	**2012**	**Pooled**	**2011**	**2012**	**Pooled**	**2011**	**2012**	**Pooled**
Varieties (V)												
V_1 (Naveen 2000$^+$)	4.12	4.26	4.19	0.52 (1.23)	0.49 (1.22)	0.51 (1.23)	30.34	31.13	30.73	2.44	2.49	2.47
V_2 (Sun-7711)	4.41	4.57	4.49	0.47 (1.21)	0.45 (1.20)	0.46 (1.21)	30.95	31.74	31.35	2.20	2.27	2.23
V_3 (Solan Lalima)	4.98	5.05	5.02	0.40 (1.18)	0.39 (1.18)	0.39 (1.18)	32.22	33.01	32.61	2.64	2.71	2.67
$CD_{0.05}$	**0.22**	**0.21**	**0.20**	**0.01**	**0.02**	**0.01**	**0.07**	**0.06**	**0.01**	**0.01**	**0.02**	**0.01**
Biofertilizers												
B_0 (NPK recommended)	4.27	4.39	4.33	0.49 (1.22)	0.48 (1.22)	0.49 (1.22)	30.61	31.40	31.00	2.24	2.30	2.27
B_1(100%NPK+*Azotobacter* (1g/plant)+PSB(1g/plant)	4.74	4.86	4.80	0.44 (1.19)	0.41 (1.19)	0.43 (1.19)	31.67	32.46	32.07	2.60	2.69	2.65
B_2 (75% NPK+*Azotobacter* (1g/plant)+PSB(1g/plant)	4.51	4.63	4.57	0.46 (1.21)	0.44 (1.20)	0.45 (1.20)	31.23	32.02	31.63	2.43	2.47	2.45
$CD_{0.05}$	**0.14**	**0.11**	**0.12**	**0.02**	**0.01**	**0.01**	**0.02**	**0.03**	**0.02**	**0.02**	**0.01**	**0.01**
Mulches (M)												

M_0 (No Mulch)	4.26	4.41	4.34	0.49 (1.22)	0.47 (1.21)	0.48 (1.22)	29.68	30.47	30.07	2.22	2.29	2.23
M_1 (Pine needle)	4.52	4.63	4.58	0.47 (1.21)	0.45 (1.20)	0.46 (1.21)	31.45	32.24	31.85	2.38	2.45	2. 47
M_2 (Black polyethylene)	4.73	4.83	4.78	0.44 (1.19)	0.41 (1.19)	0.42 (1.19)	32.38	33.17	32.77	2.67	2.72	2.67
$CD_{0.05}$	**0.08**	**0.09**	**0.08**	**0.01**	**0.02**	**0.01**	**0.03**	**0.03**	**0.02**	**0.01**	**0.02**	**0.01**

Table 2b. Effect of different interactions V x B, B x M and V x M number of days to first flowering and first harvest, harvest duration and plant height in tomato.

Treatment combination	**TSS (^{0}Brix)**			**Titratable acidity (%)**			**Ascorbic acid (mg/100g)**			**Lycopene content (mg/100g)**		
	2011	**2012**	**Pooled**	**2011**	**2012**	**Pooled**	**2011**	**2012**	**Pooled**	**2011**	**2012**	**Pooled**
$V_1 B_0$	3.88	4.04	3.96	0.53 (1.24)	0.54 (1.24)	0.53 (1.24)	29.74	30.53	30.14	2.20	2.26	2.23
$V_1 B_1$	4.37	4.49	4.43	0.45 (1.21)	0.47 (1.21)	0.45 (1.21)	30.89	31.68	31.29	2.67	2.73	2.70
$V_1 B_2$	4.12	4.25	4.19	0.51 (1.23)	0.51 (1.23)	0.51 (1.23)	30.38	31.17	30.78	2.44	2.48	2.46
$V_2 B_0$	4.26	4.39	4.33	0.48 (1.20)	0.49 (1.22)	0.48 (1.20)	30.44	31.23	30.83	2.04	2.10	2.07
$V_2 B_1$	4.54	4.72	4.63	0.42 (1.19)	0.44 (1.20)	0.42 (1.19)	31.41	32.20	31.80	2.33	2.42	2.38
$V_2 B_2$	4.44	4.59	4.52	0.43 (1.19)	0.45 (1.20)	0.43 (1.19)	31.01	31.80	31.41	2.21	2.28	2.24
$V_3 B_0$	4.67	4.74	4.70	0.43 (1.19)	0.43 (1.19)	0.43 (1.19)	31.65	32.44	32.05	2.48	2.54	2.51
$V_3 B_1$	5.30	5.36	5.33	0.36 (1.17)	0.36 (1.17)	0.36 (1.17)	32.71	33.50	33.10	2.79	2.92	2.86
$V_3 B_2$	4.97	5.05	5.01	0.38 (1.17)	0.39 (1.18)	0.38 (1.17)	32.29	33.08	32.69	2.64	2.66	2.65
$CD_{0.05}$	**NS**	**NS**	**NS**	**0.02**	**0.01**	**0.02**	**0.04**	**0.05**	**0.03**	**0.01**	**0.02**	**0.01**
$B_0 M_0$	4.03	4.20	4.12	0.51 (1.23)	0.52 (1.23)	0.51 (1.23)	29.13	29.92	29.52	2.09	2.16	2.13
$B_0 M_1$	4.28	4.38	4.33	0.49 (1.22)	0.49 (1.22)	0.49 (1.22)	30.93	31.72	31.33	2.18	2.25	2.22
$B_0 M_2$	4.50	4.58	4.54	0.45 (1.21)	0.46 (1.21)	0.45 (1.21)	31.77	32.56	32.16	2.45	2.50	2.48
$B_1 M_0$	4.47	4.61	4.55	0.45 (1.20)	0.46 (1.20)	0.45 (1.20)	30.23	31.02	30.62	2.35	2.44	2.40
$B_1 M_1$	4.77	4.85	4.81	0.42 (1.19)	0.43 (1.19)	0.42 (1.19)	31.90	32.69	32.30	2.56	2.67	2.61
$B_1 M_2$	4.97	5.12	5.04	0.37 (1.17)	0.39 (1.17)	0.37 (1.17)	32.87	33.66	33.27	2.88	2.96	2.92
$B_2 M_0$	4.29	4.42	4.36	0.46 (1.21)	0.47 (1.21)	0.46 (1.21)	29.68	30.47	30.08	2.22	2.28	2.26
$B_2 M_1$	4.52	4.67	4.60	0.44 (1.20)	0.45 (1.20)	0.44 (1.20)	31.52	32.31	31.92	2.39	2.44	2.42
$B_2 M_2$	4.72	4.79	4.76	0.41 (1.19)	0.42 (1.19)	0.41 (1.19)	32.49	33.28	32.88	2.67	2.70	2.69
$CD_{0.05}$	**NS**	**NS**	**NS**	**0.01**	**0.02**	**0.01**	**0.05**	**0.05**	**0.04**	**0.02**	**0.01**	**0.01**
$V_1 M_0$	3.90	3.99	3.95	0.54 (1.24)	0.54 (1.23)	0.54 (1.24)	28.55	29.34	28.94	2.25	2.29	2.28
$V_1 M_1$	4.12	4.27	4.20	0.51 (1.23)	0.52 (1.24)	0.51 (1.23)	30.80	31.59	31.20	2.38	2.45	2.42
$V_1 M_2$	4.35	4.51	4.44	0.45 (1.20)	0.47 (1.21)	0.45 (1.20)	31.66	32.45	32.06	2.67	2.73	2.70
$V_2 M_0$	4.19	4.42	4.31	0.47 (1.21)	0.49 (1.22)	0.47 (1.21)	28.91	29.70	29.30	2.04	2.15	2.09
$V_2 M_1$	4.43	4.55	4.49	0.45 (1.20)	0.46 (1.21)	0.45 (1.20)	31.39	32.18	31.79	2.13	2.19	2.16
$V_2 M_2$	4.61	4.74	4.68	0.42 (1.19)	0.43 (1.19)	0.42 (1.19)	32.56	33.35	32.95	2.41	2.46	2.44
$V_3 M_0$	4.69	4.83	4.77	0.41 (1.19)	0.42 (1.19)	0.41 (1.19)	31.58	32.37	31.98	2.38	2.44	2.41
$V_3 M_1$	5.02	5.08	5.05	0.39 (1.18)	0.39 (1.18)	0.39 (1.18)	32.16	32.95	32.56	2.62	2.71	2.67
$V_3 M_2$	5.22	5.23	5.23	0.37 (1.17)	0.37 (1.17)	0.37 (1.17)	32.91	33.70	33.31	2.91	2.97	2.94
$CD_{0.05}$	**NS**	**NS**	**NS**	**0.01**	**0.02**	**0.01**	**0.05**	**0.05**	**0.04**	**0.01**	**0.02**	**0.01**

Table 2c. Effect of V x B x M interaction number of days to first flowering and first harvest, harvest duration and plant height in tomato.

Treatment combination	**TSS (^{0}Brix)**			**Titratable acidity (%)**			**Ascorbic acid (mg/100g)**			**Lycopene content (mg/100g)**		
	2011	**2012**	**Pooled**	**2011**	**2012**	**Pooled**	**2011**	**2012**	**Pooled**	**2011**	**2012**	**Pooled**
$V_1B_0M_0$	3.58	3.78	3.68	0.59 (1.26)	0.58 (1.25)	0.58 (1.257)	28.14	28.93	28.53	2.09	2.16	2.13

$V_1B_0M_1$	3.88	4.03	3.96	0.56 (1.25)	0.53 (1.24)	0.54 (1.241)	30.11	30.90	30.51	2.13	2.22	2.18
$V_1B_0M_2$	4.17	4.31	4.24	0.51 (1.23)	0.49 (1.22)	0.50 (1.225)	30.97	31.76	31.37	2.37	2.41	2.39
$V_1B_1M_0$	4.11	4.23	4.17	0.52 (1.23)	0.50 (1.22)	0.51 (1.229)	29.01	29.80	29.41	2.45	2.47	2.46
$V_1B_1M_1$	4.38	4.49	4.44	0.49 (1.23)	0.47 (1.21)	0.49 (1.221)	31.39	32.18	31.79	2.61	2.67	2.64
$V_1B_1M_2$	4.61	4.76	4.69	0.47 (1.21)	0.39 (1.18)	0.42 (1.194)	32.27	33.06	32.67	2.95	3.05	3.00
$V_1B_2M_0$	4.01	3.96	3.99	0.46 (1.23)	0.55 (1.24)	0.53 (1.238)	28.49	29.28	28.89	2.21	2.25	2.23
$V_1B_2M_1$	4.09	4.30	4.19	0.43 (1.24)	0.52 (1.23)	0.52 (1.236)	30.91	31.70	31.31	2.40	2.45	2.43
$V_1B_2M_2$	4.27	4.48	4.38	0.41 (1.23)	0.46 (1.21)	0.48 (1.215)	31.74	32.53	32.14	2.70	2.74	2.72
$V_2B_0M_0$	4.06	4.24	4.15	0.52 (1.24)	0.50 (1.22)	0.51 (1.229)	28.17	28.96	28.56	1.93	1.99	1.96
$V_2B_0M_1$	4.26	4.38	4.32	0.50 (1.22)	0.50 (1.23)	0.50 (1.225)	31.03	31.82	31.43	2.00	2.07	2.03
$V_2B_0M_2$	4.46	4.55	4.51	0.46 (1.21)	0.46 (1.21)	0.47 (1.211)	32.11	32.90	32.51	2.20	2.25	2.23
$V_2B_1M_0$	4.34	4.56	4.45	0.49 (1.23)	0.46 (1.21)	0.48 (1.217)	29.62	30.41	30.02	2.13	2.27	2.20
$V_2B_1M_1$	4.55	4.69	4.62	0.46 (1.21)	0.42 (1.19)	0.44 (1.200)	31.72	32.51	32.12	2.25	2.32	2.28
$V_2B_1M_2$	4.73	4.92	4.83	0.40 (1.18)	0.38 (1.18)	0.39 (1.179)	32.88	33.67	33.27	2.61	2.66	2.64
$V_2B_2M_0$	4.20	4.46	4.33	0.38 (1.23)	0.45 (1.20)	0.48 (1.215)	28.93	29.72	29.33	2.05	2.17	2.11
$V_2B_2M_1$	4.49	4.57	4.53	0.37 (1.21)	0.44 (1.19)	0.45 (1.203)	31.42	32.21	31.82	2.15	2.20	2.17
$V_2B_2M_2$	4.64	4.76	4.70	0.35 (1.20)	0.41 (1.19)	0.43 (1.194)	32.68	33.47	33.08	2.42	2.46	2.44
$V_3B_0M_0$	4.44	4.59	4.52	0.52 (1.21)	0.45 (1.20)	0.46 (1.207)	31.08	31.87	31.48	2.27	2.32	2.30
$V_3B_0M_1$	4.70	4.73	4.72	0.53 (1.19)	0.43 (1.19)	0.43 (1.196)	31.64	32.43	32.04	2.40	2.46	2.43
$V_3B_0M_2$	4.86	4.90	4.88	0.50 (1.19)	0.41 (1.18)	0.41 (1.187)	32.22	33.01	32.62	2.78	2.83	2.81
$V_3B_1M_0$	4.98	5.06	5.02	0.51 (1.17)	0.38 (1.17)	0.38 (1.175)	32.05	32.84	32.45	2.47	2.58	2.53
$V_3B_1M_1$	5.36	5.36	5.36	0.45 (1.16)	0.37 (1.17)	0.37 (1.169)	32.60	33.39	33.00	2.82	3.01	2.92
$V_3B_1M_2$	5.56	5.67	5.61	0.44 (1.16)	0.34 (1.16)	0.35 (1.160)	33.47	34.26	33.87	3.07	3.18	3.13
$V_3B_2M_0$	4.68	4.85	4.76	0.42 (1.19)	0.40 (1.18)	0.41 (1.187)	31.61	32.40	32.01	2.41	2.42	2.42
$V_3B_2M_1$	5.00	5.16	5.08	0.39 (1.18)	0.37 (1.17)	0.38 (1.175)	32.24	33.03	32.63	2.63	2.66	2.64
$V_3B_2M_2$	5.24	5.13	5.18	0.37 (1.17)	0.36(1 .17)	0.37 (1.169)	33.04	33.83	33.43	2.89	2.90	2.89
$CD_{0.05}$	**NS**	**NS**	**NS**	**0.02**	**0.01**	**0.02**	**0.09**	**0.08**	**0.08**	**0.02**	**0.02**	**0.01**

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