

Effect of biofertilizers and mulch on growth, yield and quality of tomato in mid-hills of Himachal Pradesh

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ABSTRACT

Investigations were carried out at experimental farm of the Horticultural Research Station, Kandaghat, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan during the year 2011 and 2012. The experiment comprised three treatments of genotypes, V_1 (Naveen 2000⁺), V_2 (Sun-7711) and V_3 (Solan Lalima), three treatments of mulch M_0 (no mulch), M_1 (pine needle mulch) and M_2 (black polyethylene) and three treatments of biofertilizers B_0 (recommended NPK), B_1 (100% NPK + *Azotobacter* 1 g/plant + PSB 1 g/plant) and B_2 (75% NPK + *Azotobacter* 1 g/plant + PSB 1 g/plant). Thus there were 27 treatment combinations replicated thrice in split-split plot design. Among varieties maximum yield and quality parameters were observed in V_2 . Among the mulch materials and biofertilizers M_2 and B_1 respectively were recorded to be the best regarding quantitative and qualitative parameters. Maximum fruit yield was obtained in treatment combinations of V_2M_2 , B_2M_2 and V_2B_2 . In three factor interaction the highest fruit yield was obtained in the treatment combination of $V_2B_2M_2$.

Keywords: Genotypes; mulch; biofertilizer; yield

INTRODUCTION

Tomato, *Solanum lycopersicum* L. is one of the most important vegetable crops belonging to the family Solanaceae. Tomato fruits are good source of vitamin A and C and contain antioxidant such as lycopene which prevents cancer (Chauhan 1983). In India it is grown on an area of 876410

hectares with a production of 17848160 MT. In Himachal Pradesh tomato is being cultivated over an area of 10000 hectares with total production of 400000 MT (Anon 2013). Due to adverse effects of chemical fertilizers there is a need for alternative sources of safe fertilizers (Gajbhiye et al 2003). *Azotobacter* is considered important not only for its nitrogen fixing

efficiency but also for its ability to produce antibacterial, antifungal compound and growth regulators. Likewise PSB is effective in improving phosphorus use efficiency (Kumar and Srivastava 2006). Tomato farming has also the problem of low productivity due to inadequate soil moisture present in plant root zone at the time of critical growth stages, particularly in May-June whereas in tomato fruit production during rainy season ie June-August the high moisture availability poses a problem of luxuriant weed growth and increases the incidence of diseases. Hence there is urgent need for use of mulch and application of biofertilizers to regulate the soil moisture and major nutrients to enhance the production and quality of tomato under open field conditions.

MATERIAL and METHODS

The trial was conducted during summer 2011 and 2012 at the experimental farm of Horticultural Research Station, Kandaghat, Solan situated 30-50° N latitude, 77.8°E longitude and 1435 m amsl. The experiment was laid out in split-split plot design (SSPD) comprising 27 treatments including combinations of varieties, biofertilizers and mulch. Raised

nursery beds of 3 x 1 m size were prepared by mixing well rotten FYM in the soil @ 20 kg per bed. The seeds were sown 5 cm apart in rows. 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 and two months after transplanting. FYM was applied @ 25 tons/ha before transplanting. One month seedlings were transplanted at 30 x 90 cm accommodating 18 plants in 4.86 square meter beds. Transplanting was done on 2 April 2011 and 4 April 2012 followed by light irrigation for 3-4 days. Biofertilizers (*Azotobacter* and PSB) application was done through soil application @ 1 g per plant thoroughly mixed with FYM. The biofertilizers were applied at the time of first earthing up ie 30-35 days after transplanting. Black polyethylene mulch of 50 µ (200 gauge thickness) and dry pine needle mulch were applied in plots according to the treatment combinations. Lycopene content and ascorbic acid of ripe tomato fruits were determined according to method described by Rangana (2005). The ascorbic acid content was calculated using the following formula:

$$\text{Ascorbic acid (mg/100 g fresh tissue)} = \frac{\text{Titre} \times \text{dye factor} \times \text{volume made up}}{\text{Aliquot of extract taken for estimation} \times \text{volume of sample taken for estimation}} \times 100$$

RESULTS and DISCUSSION

Effect on growth

Harvest duration (days): The results presented in Table 1a show significant individual effects of varieties, biofertilizers and mulch. Variety V_2 exhibited maximum harvest duration (81.83 days) while V_1 recorded minimum harvest duration (70.02 days). This may be attributed to the genetic traits as reported by Kumar et al (2004). Among different biofertilizers B_1 recorded maximum (76.98 days) and B_0 noticed minimum harvest duration (74.11 days). Longer harvest duration obtained by the use of biofertilizers might be attributed to longer vegetative growth. The possible reason for longer harvest duration may be the improvement in growth related attributes due to certain growth promoting substances secreted by biofertilizers which might have led to better root and shoot development (Chattoo et al 2007). Similar results have also been reported in tomato by Thakur et al (2010) and Singh (2012). Maximum harvest duration (76.79 days) was obtained in M_2 while M_0 recorded minimum harvest duration (74.25 days). The first order interactions $V \times B$, $B \times M$ and $V \times M$ were also found significant for this character and results have been presented in Table 1b. In $V \times B$ interaction treatment combination V_2B_1 registered maximum (82.63) days for harvest duration whereas minimum (68.66) was found with V_1B_0 . The interaction effect between biofertilizers and mulch material on

this trait was found to be significant and the maximum harvest duration (77.91 days) was obtained in B_1M_2 and minimum (72.79 days) in B_0M_0 . V_2M_2 exhibited maximum (82.86) days for harvest duration while V_1M_0 recorded minimum (68.39) days. Maximum harvest duration (83.16 days) was observed with treatment combination $V_2B_2M_2$. However minimum harvest duration (67.46 days) was recorded with treatment combination $V_1B_0M_0$ (Table 1c).

Plant height: The results presented in Table (1a) show that the variety V_3 had maximum (2.26 m) while V_1 recorded minimum plant height of 1.98 m. This may be attributed to the genetic traits as reported by Zaman et al (2011). Among different biofertilizers B_2 recorded maximum (2.17 m) and B_0 minimum plant height (2.09 m). The decomposition of organic matter by these microbial inoculants with the subsequent releases of available nutrients to the plants from the soil resulted in increased growth of the plants (Thakur et al 2010). Another possible reason for increased plant height as result of biofertilizers application may be attributed to better proliferation of roots which helped in increased uptake of nutrients as well as plant growth hormones produced by microbes at root zone (Gajbhiye et al 2003). Similarly plant height was significantly affected by various mulching treatments. The maximum plant height (2.32 m) was observed with black polythene mulch while M_0 (No mulch) gave minimum plant height (2.00 m). The possible

Table 1a. Effect of mulch material and biofertilizers on harvest duration, plant height, TSS and acidity of tomato genotypes

Treatment	Harvest duration (days)			Plant height (m)			TSS (°Brix)			Acidity (%)		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
Variety												
V ₁	68.34	71.69	70.02	2.00	1.95	1.98	4.12	4.26	4.19	0.52 (1.23)	0.49 (1.22)	0.51 (1.23)
V ₂	81.10	82.55	81.83	2.27	2.13	2.20	4.41	4.57	4.49	0.47 (1.21)	0.45 (1.20)	0.46 (1.21)
V ₃	74.22	75.37	74.80	2.32	2.20	2.26	4.98	5.05	5.02	0.40 (1.18)	0.39 (1.18)	0.39 (1.18)
CD _{0.05}	1.81	0.36	0.99	0.01	0.02	0.01	0.22	0.21	0.20	0.01	0.02	0.01
Biofertilizer												
B ₀	73.57	74.65	74.11	2.13	2.05	2.09	4.27	4.39	4.33	0.49 (1.22)	0.48 (1.22)	0.49 (1.22)
B ₁	75.80	78.16	76.98	2.20	2.10	2.12	4.74	4.86	4.80	0.44 (1.19)	0.41 (1.19)	0.43 (1.19)
B ₂	74.30	76.80	75.55	2.24	2.13	2.17	4.51	4.63	4.57	0.46 (1.21)	0.44 (1.20)	0.45 (1.20)
CD _{0.05}	0.52	0.73	0.51	0.02	0.01	0.01	0.14	0.11	0.12	0.01	0.01	0.01
Mulch												
M ₀	73.33	75.18	74.25	2.04	1.96	2.00	4.26	4.41	4.34	0.49 (1.22)	0.47 (1.21)	0.48 (1.22)
M ₁	74.54	76.65	75.59	2.16	2.07	2.12	4.52	4.63	4.58	0.47 (1.21)	0.45 (1.20)	0.46 (1.21)
M ₂	75.80	77.79	76.79	2.38	2.25	2.32	4.73	4.83	4.78	0.44 (1.19)	0.41 (1.19)	0.42 (1.19)
CD _{0.05}	0.34	0.45	0.31	0.01	0.02	0.01	0.08	0.09	0.08	0.01	0.02	0.01

Table 1b. Effect of interactions variety × biofertilizer, biofertilizer × mulch and variety × mulch on harvest duration, plant height, TSS and acidity in tomato genotypes

Treatment	Harvest duration (days)			Plant height (m)			TSS (°Brix)			Acidity (%)		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
V ₁ B ₀	67.41	69.90	68.66	1.91	1.88	1.89	3.88	4.04	3.96	0.53 (1.24)	0.54 (1.24)	0.53 (1.24)
V ₁ B ₁	69.16	73.51	71.34	2.12	2.06	2.09	4.37	4.49	4.43	0.45 (1.21)	0.47 (1.21)	0.45 (1.21)
V ₁ B ₂	68.44	71.66	70.05	1.96	1.91	1.94	4.12	4.25	4.19	0.51 (1.23)	0.51 (1.23)	0.51 (1.23)
V ₂ B ₀	80.83	81.37	81.10	2.19	2.10	2.15	4.26	4.39	4.33	0.48 (1.20)	0.49 (1.22)	0.48 (1.20)
V ₂ B ₁	82.00	83.26	82.63	2.16	2.07	2.11	4.54	4.72	4.63	0.42 (1.19)	0.44 (1.20)	0.42 (1.19)
V ₂ B ₂	80.49	83.02	81.76	2.45	2.22	2.34	4.44	4.59	4.52	0.43 (1.19)	0.45 (1.20)	0.43 (1.19)
V ₃ B ₀	72.45	72.68	72.57	2.30	2.15	2.23	4.67	4.74	4.70	0.43 (1.19)	0.43 (1.19)	0.43 (1.19)
V ₃ B ₁	76.23	77.71	76.97	2.33	2.27	2.30	5.30	5.36	5.33	0.36 (1.17)	0.36 (1.17)	0.36 (1.17)
V ₃ B ₂	73.98	75.73	74.85	2.32	2.16	2.24	4.97	5.05	5.01	0.38 (1.17)	0.39 (1.18)	0.38 (1.17)
CD _{0.05}	0.90	1.26	0.89	0.02	0.01	0.01	NS	NS	NS	0.02	0.01	0.02
B ₀ M ₀	71.83	73.76	72.79	2.00	1.93	1.97	4.03	4.20	4.12	0.51 (1.23)	0.52 (1.23)	0.51 (1.23)
B ₀ M ₁	73.75	74.68	74.22	2.09	1.99	2.04	4.28	4.38	4.33	0.49 (1.22)	0.49 (1.22)	0.49 (1.22)
B ₀ M ₂	75.12	75.52	75.32	2.31	2.22	2.27	4.50	4.58	4.54	0.45 (1.21)	0.46 (1.21)	0.45 (1.21)
B ₁ M ₀	75.24	76.68	75.96	2.01	1.93	1.97	4.47	4.61	4.55	0.45 (1.20)	0.46 (1.20)	0.45 (1.20)
B ₁ M ₁	75.63	78.49	77.06	2.18	2.13	2.15	4.77	4.85	4.81	0.42 (1.19)	0.43 (1.19)	0.42 (1.19)
B ₁ M ₂	76.51	79.30	77.91	2.43	2.33	2.38	4.97	5.12	5.04	0.37 (1.17)	0.39 (1.17)	0.37 (1.17)
B ₂ M ₀	72.91	75.08	73.99	2.10	2.01	2.05	4.29	4.42	4.36	0.46 (1.21)	0.47 (1.21)	0.46 (1.21)
B ₂ M ₁	74.23	76.78	75.51	2.22	2.09	2.16	4.52	4.67	4.60	0.44 (1.20)	0.45 (1.20)	0.44 (1.20)
B ₂ M ₂	75.76	78.55	77.16	2.41	2.20	2.30	4.72	4.79	4.76	0.41 (1.19)	0.42 (1.19)	0.41 (1.19)
CD _{0.05}	0.60	0.76	0.54	0.01	0.01	0.01	NS	NS	NS	0.01	0.02	0.01
V ₁ M ₀	66.72	70.07	68.39	1.89	1.84	1.87	3.90	3.99	3.95	0.54 (1.24)	0.54 (1.23)	0.54 (1.24)
V ₁ M ₁	68.57	71.81	70.19	1.94	1.88	1.91	4.12	4.27	4.20	0.51 (1.23)	0.52 (1.24)	0.51 (1.23)
V ₁ M ₂	69.73	73.19	71.46	2.16	2.13	2.15	4.35	4.51	4.44	0.45 (1.20)	0.47 (1.21)	0.45 (1.20)
V ₂ M ₀	80.07	81.98	81.03	2.11	2.01	2.06	4.19	4.42	4.31	0.47 (1.21)	0.49 (1.22)	0.47 (1.21)
V ₂ M ₁	80.71	82.48	81.59	2.30	2.14	2.22	4.43	4.55	4.49	0.45 (1.20)	0.46 (1.21)	0.45 (1.20)
V ₂ M ₂	82.53	83.19	82.86	2.40	2.24	2.32	4.61	4.74	4.68	0.42 (1.19)	0.43 (1.19)	0.42 (1.19)
V ₃ M ₀	73.19	73.47	73.33	2.11	2.02	2.07	4.69	4.83	4.77	0.41 (1.19)	0.42 (1.19)	0.41 (1.19)
V ₃ M ₁	74.34	75.65	75.00	2.25	2.19	2.22	5.02	5.08	5.05	0.39 (1.18)	0.39 (1.18)	0.39 (1.18)
V ₃ M ₂	75.13	76.99	76.06	2.58	2.38	2.48	5.22	5.23	5.23	0.37 (1.17)	0.37 (1.17)	0.37 (1.17)
CD _{0.05}	0.60	0.76	0.54	0.01	0.01	0.01	NS	NS	NS	0.01	0.02	0.01

Table 1c. Effect of variety $\times$ biofertilizer $\times$ mulch interaction on harvest duration, plant height, TSS and acidity in tomato

Treatment	Harvest duration (days)			Plant height (m)			TSS (°Brix)			Acidity (%)		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
V ₁ B ₀ M ₀	65.61	69.31	67.46	1.79	1.82	1.81	3.58	3.78	3.68	0.59 (1.26)	0.58 (1.25)	0.58 (1.257)
V ₁ B ₀ M ₁	67.49	69.43	68.46	1.75	1.78	1.76	3.88	4.03	3.96	0.56 (1.25)	0.53 (1.24)	0.54 (1.241)
V ₁ B ₀ M ₂	69.15	70.96	70.05	2.10	2.12	2.11	4.17	4.31	4.24	0.51 (1.23)	0.49 (1.22)	0.50 (1.225)
V ₁ B ₁ M ₀	67.95	70.61	69.28	1.95	2.02	1.99	4.11	4.23	4.17	0.52 (1.23)	0.50 (1.22)	0.51 (1.229)
V ₁ B ₁ M ₁	70.01	74.24	72.13	2.01	2.12	2.06	4.38	4.49	4.44	0.49 (1.23)	0.47 (1.21)	0.49 (1.221)
V ₁ B ₁ M ₂	69.53	75.67	72.60	2.22	2.22	2.22	4.61	4.76	4.69	0.47 (1.21)	0.39 (1.18)	0.42 (1.194)
V ₁ B ₂ M ₀	66.60	70.28	68.44	1.79	1.81	1.80	4.01	3.96	3.99	0.46 (1.23)	0.55 (1.24)	0.53 (1.238)
V ₁ B ₂ M ₁	68.22	71.76	69.99	1.87	1.91	1.89	4.09	4.30	4.19	0.43 (1.24)	0.52 (1.23)	0.52 (1.236)
V ₁ B ₂ M ₂	70.50	72.93	71.72	2.08	2.15	2.12	4.27	4.48	4.38	0.41 (1.23)	0.46 (1.21)	0.48 (1.215)
V ₂ B ₀ M ₀	79.11	81.07	80.09	2.00	2.03	2.01	4.06	4.24	4.15	0.52 (1.24)	0.50 (1.22)	0.51 (1.229)
V ₂ B ₀ M ₁	80.97	81.20	81.09	2.10	2.23	2.17	4.26	4.38	4.32	0.50 (1.22)	0.50 (1.23)	0.50 (1.225)
V ₂ B ₀ M ₂	82.40	81.85	82.13	2.20	2.32	2.26	4.46	4.55	4.51	0.46 (1.21)	0.46 (1.21)	0.47 (1.211)
V ₂ B ₁ M ₀	81.29	83.50	82.40	1.79	1.94	1.87	4.34	4.56	4.45	0.49 (1.23)	0.46 (1.21)	0.48 (1.217)
V ₂ B ₁ M ₁	81.45	82.92	82.18	2.14	2.21	2.17	4.55	4.69	4.62	0.46 (1.21)	0.42 (1.19)	0.44 (1.200)
V ₂ B ₁ M ₂	83.26	83.35	83.31	2.28	2.32	2.30	4.73	4.92	4.83	0.40 (1.18)	0.38 (1.18)	0.39 (1.179)
V ₂ B ₂ M ₀	79.82	81.39	80.60	2.24	2.36	2.30	4.20	4.46	4.33	0.38 (1.23)	0.45 (1.20)	0.48 (1.215)
V ₂ B ₂ M ₁	79.71	83.31	81.51	2.19	2.45	2.32	4.49	4.57	4.53	0.37 (1.21)	0.44 (1.19)	0.45 (1.203)
V ₂ B ₂ M ₂	81.94	84.38	83.16	2.22	2.55	2.39	4.64	4.76	4.70	0.35 (1.20)	0.41 (1.19)	0.43 (1.194)
V ₃ B ₀ M ₀	70.76	70.91	70.83	2.01	2.15	2.08	4.44	4.59	4.52	0.52 (1.21)	0.45 (1.20)	0.46 (1.207)
V ₃ B ₀ M ₁	72.80	73.40	73.10	2.11	2.25	2.18	4.70	4.73	4.72	0.53 (1.19)	0.43 (1.19)	0.43 (1.196)
V ₃ B ₀ M ₂	73.81	73.74	73.78	2.35	2.49	2.42	4.86	4.90	4.88	0.50 (1.19)	0.41 (1.18)	0.41 (1.187)
V ₃ B ₁ M ₀	76.50	75.94	76.22	2.06	2.06	2.06	4.98	5.06	5.02	0.51 (1.17)	0.38 (1.17)	0.38 (1.175)
V ₃ B ₁ M ₁	75.44	78.30	76.87	2.25	2.20	2.23	5.36	5.36	5.36	0.45 (1.16)	0.37 (1.17)	0.37 (1.169)
V ₃ B ₁ M ₂	76.74	78.88	77.81	2.50	2.73	2.61	5.56	5.67	5.61	0.44 (1.16)	0.34 (1.16)	0.35 (1.160)
V ₃ B ₂ M ₀	72.32	73.57	72.95	1.99	2.13	2.06	4.68	4.85	4.76	0.42 (1.19)	0.40 (1.18)	0.41 (1.187)
V ₃ B ₂ M ₁	74.78	75.26	75.02	2.21	2.30	2.25	5.00	5.16	5.08	0.39 (1.18)	0.37 (1.17)	0.38 (1.175)
V ₃ B ₂ M ₂	74.84	78.35	76.60	2.29	2.52	2.40	5.24	5.13	5.18	0.37 (1.17)	0.36 (1.17)	0.37 (1.169)
CD _{0.05}	1.03	1.36	0.93	0.01	0.02	0.02	NS	NS	NS	0.02	0.01	0.02

reason may be more favourable soil moisture and more favorable conditions which produced vigorous growth during a comparatively shorter period (Grewal and Singh 1974). Singh and Mishra (1973) reported maximum plant height under black polythene treatment which may be probably due to the increase in soil temperature and conserving more soil moisture. The increased plant height may be due to continuous availability of fertilizer nutrients throughout the crop growth period under ideal soil moisture regimes. The data in Table 1b reveal that treatment combinations V_2B_2 , B_1M_2 and V_3M_2 recorded maximum plant height of 2.34, 2.38 and 2.48 m respectively. The maximum plant height (2.61 m) was obtained with treatment combination $V_3B_1M_2$ (Table 1c).

Number of fruits/plant: The results obtained on number of fruits per plant have been presented in Tables 2a, 2b and 2c. The pooled data of both the years show that the variety V_3 recorded maximum (38.00) while V_1 recorded minimum (29.85) number of fruits per plant. This may be attributed to the genetic traits as reported by Kumar et al (2004). Among biofertilizers the maximum number of fruits per plant (38.01) was observed in B_2 while minimum (29.99) in B_0 . 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 2010, Gajbhiye et al 2003). Among mulch material, M_2 recorded maximum (36.16) while M_0 recorded minimum (32.67) number of fruits/plant. The increased fruit number with black polythene mulch resulted in lesser weed number and less nutrient loss through leaching thereby resulting in more fruits per plant (Bala 2012). Increase in fruit number with the use of black polythene mulch was also reported by Singh (2005). V_3B_2 gave the maximum number of fruits/plant (41.43) followed by V_2B_2 and V_3B_1 recording 39.14 and 39.12 number of fruits/plant respectively. The maximum number of fruits/plant (39.80) was recorded with B_2M_2 which was followed by B_2M_1 and B_1M_2 recording 38.39 and 37.28 number of fruits/plant respectively. V_3M_2 recorded maximum (39.82) while V_1M_0 recorded minimum number of fruits per plant (28.30). Similarly maximum number of fruits per plant (43.34) was recorded in $V_3B_1M_2$ and the minimum (24.04) in $V_1B_0M_0$.

Yield: The results obtained on fruit yield have been presented in Tables 2a, 2b and 2c. Highest fruit yield (3.00 kg/plant, 54.08 kg/plot and 890.13 q/ha) was observed in V_2 and lowest (2.34 kg/plant, 42.07 kg/plot and 692.47 q/ha) in V_1 . The varietal effect may be attributed to its growth habit governed by genetic traits (Kumar et al 2004, Zaman et al 2011). B_2 recorded the highest (2.87 kg/plant, 51.69 kg/plot and 850.86 q/ha) and B_0 the lowest (2.22

kg/plant, 40.04 kg/plot and 659.14 q/ha) yield. 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 2010). Sharma et al (2010) reported increased yield with biofertilizers application which might be due to better nutritional environment in the root zone that accelerated the process of cell division and hence fruit yield. 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 2003). Among various mulch materials M_2 recorded the highest (2.83 kg/plant, 50.96 kg/plot and 838.90 q/ha) while M_0 lowest (2.39 kg/plant, 42.93 kg/plot and 706.61 q/ha) yield. The increased yield under black polythene mulch has been reported by Hedau et al (2001) and Bala (2012). The increase in yield may be attributed to higher soil temperature which improved the plant micro-climate thus helping in maximum plant growth and fruit setting in tomato. Similar findings were reported by Channabavanna et al (1989) and Ubaidullah et al (2002). V_2B_2 gave the maximum (3.28 kg/plant, 59.08 kg/plot and 972.52 q/ha) and V_1B_0 minimum (1.92 kg/plant, 34.56 kg/plot and 568.96 q/ha) yield. B_2M_2 resulted in maximum (3.10 kg/plant, 55.78 kg/plot and 918.18 q/ha) and B_0M_0 in minimum (2.05

kg/plant, 36.94 kg/plot, 608.04 q/ha) yield. The treatment combination V_2M_2 recorded maximum (3.22 kg/plant, 57.90 kg/plot and 953.09 q/ha) yield whereas V_1M_0 the minimum (2.13 kg/plant, 38.30 kg/plot, 630.42 q/ha). In second order interaction $V_2B_2M_2$ recorded maximum (3.50 kg/plant, 63.02 kg/plot and 1037.33 q/ha) and $V_1B_0M_0$ the minimum (1.78 kg/plant, 32.03 kg/plot and 527.27 q/ha) yield.

Quality: The results obtained on fruit quality as presented in Table 1a, 1b and 1c show significant effects of varieties, biofertilizers and mulch. Pooled data of both the years show that V_3 had maximum fruit TSS (5.02°Brix) while maximum titratable acidity (0.51%) was recorded in V_1 . Among biofertilizers B_1 recorded maximum TSS (4.79°Brix) and B_0 recorded highest titratable acidity (0.49%). M_2 showed maximum fruit TSS (4.78°Brix) while M_0 recorded maximum titratable acidity (0.48%). The data in Table 1b reveal that the TSS under variety x biofertilizer and biofertilizer x mulch combinations was at par among all the treatments. The maximum titratable acidity (0.53%) was recorded in V_1B_0 being at par with V_1B_2 . V_1M_0 resulted in maximum titratable acidity (0.54%). The pooled analysis of data in the experiment of both the years reveal that maximum titratable acidity (0.58%) was obtained with treatment combination $V_1B_0M_0$. The change in fruit quality with the varieties might be attributed to their genetic traits. The improvement in quality characters like

Table 2a. Effect of mulch material and biofertilizers on yield parameters of tomato genotypes

Treatment	# fruits/plant			Yield (kg/plant)			Yield (kg/plot)			Yield (q/ha)		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
Variety												
V ₁	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	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	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
Biofertilizer												
B ₀	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	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	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
Mulch												
M ₀	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	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	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 2b. Effect of interactions variety $\times$ biofertilizer, biofertilizer $\times$ mulch and variety $\times$ mulch on yield parameters of tomato genotypes

Treatment	# fruits/plant			Yield (kg/plant)			Yield (kg/plot)			Yield (q/ha)		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
V ₁ B 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 ₁ B 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 ₁ B 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 ₂ B 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 ₂ B 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 ₂ B 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 ₃ B 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 ₃ B 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 ₃ B 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 ₀ M 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 ₀ M 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 ₀ M 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 ₁ M 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 ₁ M 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 ₁ M 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 ₂ M 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 ₂ M 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 ₂ M 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	4.46
V ₁ M 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 ₁ M 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 ₁ M 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 ₂ M 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 ₂ M 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 ₂ M 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 ₃ M 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 ₃ M 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 ₃ M 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 2c. Effect of variety $\times$ biofertilizer $\times$ mulch interaction on yield parameters of tomato genotypes

Treatment	# fruits/plant			Yield (kg/plant)			Yield (kg/plot)			Yield (q/ha)		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
V ₁ B ₀ M 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 ₁ B ₀ M 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 ₁ B ₀ M 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 ₁ B ₁ M 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 ₁ B ₁ M 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 ₁ B ₁ M 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 ₁ B ₂ M 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 ₁ B ₂ M 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 ₁ B ₂ M 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 ₂ B ₀ M 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 ₂ B ₀ M 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 ₂ B ₀ M 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 ₂ B ₁ M 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 ₂ B ₁ M 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 ₂ B ₁ M 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 ₂ B ₂ M 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 ₂ B ₂ M 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 ₂ B ₂ M 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 ₃ B ₀ M 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 ₃ B ₀ M 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 ₃ B ₀ M 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 ₃ B ₁ M 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 ₃ B ₁ M 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 ₃ B ₁ M 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 ₃ B ₂ M 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 ₃ B ₂ M 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 ₃ B ₂ M 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

TSS and titratable acidity content by application of biofertilizers might be due to their nutritional, stimulatory and therapeutic behavior. Increased fruit TSS and titratable acidity were recorded with biofertilizers application. It might be due to proper and adequate provision of micro- and macro-nutrients (Gosavi et al 2010). Biofertilizers also enhanced production of growth regulating substances as reported by Parvathan and Vijayan (1989). The possible reason for improvement in fruit quality attributes with black polythene mulch might be that black polythene mulch provided favourable conditions for growth and development of plants by conservation of moisture, optimum temperature and least weed growth (Kaur and Singh 2009, Ali and Gaur 2007).

CONCLUSION

Based on the results of two years experimentation it seems quite logical to conclude that variety V₃ (Solan Lalima) observed maximum growth, yield and quality. Among the biofertilizers and mulch material used B₂ (75% NPK+ Azotobacter (1 g/plant)+ PSB (1 g/plant) and M₂ (black polythene) were recorded to be the best regarding the growth, yield and quality attributes of tomato.

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