RESPONSE OF TOMATO GENOTYPES TO DIFFERENT MULCHES AND BIOFERTILIZERS

Thesis

by

SANDEEP KUMAR SINGH

Submitted in partial fulfilment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

VEGETABLE SCIENCE

COLLEGE OF HORTICULTURE
Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan - 173 230 (H.P.), INDIA

2013

Tomato (*Solanum lycopersicum* L.)

Dedicated to

my

Beloved Parents

Dr Hem Raj Sharma
Sr. Scientist

Department of Vegetable Science
Horticulture Research Station, Kandaghat
Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan - 173 230 HP

CERTIFICATE - I

This is to certify that the thesis entitled, **"Response of tomato genotypes to different mulches and biofertilizers"**, submitted in partial fulfilment of the requirements for the award of degree of **DOCTOR OF PHILOSOPHY VEGETABLE SCIENCE** to Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan HP is a record of bonafide research work carried out by **Mr Sandeep Kumar Singh (H-2010-15-D)** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of investigations has been fully acknowledged.

Place: Nauni, Solan
Dated: Oct, 2013

(Dr Hem Raj Sharma)
Chairman Advisory Committee

CERTIFICATE - II

This is to certify that the thesis entitled, **"Response of tomato genotypes to different mulches and biofertilizers"**, submitted by **Mr Sandeep Kumar Singh (H-2010-15-D)** to Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan HP in partial fulfilment of the requirements for the award of degree of **DOCTOR OF PHILOSOPHY VEGETABLE SCIENCE** has been approved by the student's advisory committee after an oral examination of the same in collaboration with the external examiner.

Dr Hem Raj Sharma
(Sr. Scientist)
Chairman, Advisory Committee

External Examiner

Members of Advisory Committee

Dr Manish Kumar
(Professor)

Dr Upendar Singh
(SMS Soil Science)

Dr Arti Shukla
(SMS Plant Pathology)

Dr RK Dogra
(Assistant Scientist)

Professor and Head
Department of Vegetable Science

Dean's Nominee
(Dr)

Dean
College of Horticulture, UHF, Nauni, Solan (HP)

CERTIFICATE - III

This is to certify that all the mistakes and errors pointed out by the external examiner have been incorporated in the thesis entitled, **"Response of tomato genotypes to different mulches and biofertilizers",** submitted to Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan HP by **Mr Sandeep Kumar Singh (H-2010-15-D)** in partial fulfilment of the requirements for the award of degree of **DOCTOR OF PHILOSOPHY VEGETABLE SCIENCE**.

_____

(Dr Hem Raj Sharma)
Chairman, Advisory Committee

_____

(Dr ML Bhardwaj)
Professor and Head
Department of Vegetable Science
Dr YS Parmar UHF, Nauni Solan HP

ACKNOWLEDGEMENT

"JAI SHREE RAAM"

First and above all, I would like to thank God for the wisdom and perseverance that he bestwood upon me during my doctoral research and indeed throughout my life. There are three stages in the work of God - impossible, difficult and done. With immense, keeness, I thank Almightly to readily bring the third stage in and cherish my life with the power of knowledge and positive energy.

Every effort is motivated by an ambition and all ambitions have an inspiration behind.With celestial smiles, I owe the pride place to my loving and dearest parents, Shri Digvijai Singh and Smt. Geeta Devi for their constant guidance, prudent persuation, sincre prayers, selfless, sacrifice and heartiful blessing for accomplishing this task. I owe all my success to them only.

Anyone can "Start", But only throughout-bred will "Finish". I emphatically owe my profound gratitude to my chairman of advisory committee, Dr. H. R. Sharma, Sr. Scientist, Vegetable Science, H.R.S Kandaghat, whose kindness and co-operative ideas, spotless suggestion and constant encouragement is duly acknowledged in scripting this holograph.

I extend my sincere thanks to Dr. M. L. Bhardwaj (Prof. and Head, Department of Vegetable Science) for providing all the facilities required during my research work.

I am yet to find suitable words to express heartiest thanks to Dr. Manish Sharma, Dr. Upender Singh, Dr. Arti Shukla and Dr. Ashok K. Thakur the laudable members of my advisory committee for their everhelping attitude, valuable suggestions and impeccable decisions during the investigations.

I am also thankful to all my teachers, particularly, Dr. A. K. Sharma, Dr. H. D. Sharma, Dr. Ramesh Bhardwaj, Dr. Sandeep Kansal, Dr. K. S. Thakur, Dr. Meenu Gupta, Dr. Shivpraatap Singh and Dr. Santosh Kumari for their valuable suggestions.

The co-operation and assistance extended by the office staff, field workers and library staff are thankfully acknowledged.

Heartiest thanks are due to Dr. J. K. Gupta for providing their indispensable and timely help during my project work.

This manuscript would be incomplete if I don't express my heartiest gratitude to my best friends Nidhika, Ashutosh, Harish Sir, Kishore and Yamini, who always stood by me in times of need and encouraged me to achive this goal.

The moral support and ever ready helping nature of my friends is also acknowledged. Words alone can not express my sense of gratitude and affection to my seniors, friends and juniors, Rohit sir, Sandeep sir, Amit sir, Prabal mam, Manish sir, Sandeep, Nidish, Sanjay, Durgesh, Prince, Ankur, Sagar, Nipun, Nisha, Anupama, Rakesh, Fateh, Kunju, Balkar, Kairon, Gagandeep. Their Jovial company and unfailing encouraged made my Ph.D. programme a reminiscence. The moment shared with them will always be cherished by me.

Lastly, I wish to express my sincre thanks to my Grandfather (Shri Ranjeet Singh) from my schooling days onwards and well wishers, who have always guided me the right way to reach up this level in my life.

To err is human. So all the mistakes are mine

Place: Nauni, Solan
Date: **(Sandeep Kumar Singh)**

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ABBREVIATIONS

%	:	Percent
/	:	Per
@	:	At the rate of
µ	:	Micron
^{0} B	:	Degree Brix
^{0} C	:	Degree Celsius
cm	:	Centimeter
dSm^{-1}	:	Desi siman per meter
EC	:	Electrical conductivity
et al.	:	Co-workers
FYM	:	Farm yard manure
g	:	Gram
ha	:	hectare
K	:	Potash
Kg	:	Kilogram
Km	:	Kilometer
l	:	liter
m	:	Meter
Mg	:	Milligram
ml	:	milliliter
mm	:	Millimeter
MT	:	Metric tonnes
N	:	Nitrogen
OC	:	Organic carbon
P	:	Phosphorus
pH	:	Potential of hydrogen
PSB	:	Phosphate solubilizing bacteria
q	:	Quintal
r	:	Replication
SSPD	:	Split-split plot design

Chapter-1

INTRODUCTION

Tomato (*Solanum lycopersicum* L.), a solanaceous vegetable, originated in Peruvian and Mexican region (Tigchelaar, 1986). It is one of the most important vegetable crops grown throughout the world. It is suggested that the name tomato came from the Nahutal Language of Mexico. In France the tomato fruit was called "*Pomme d' amour*" or Love apple. In Italy it was called "Pomi d' amour" or Golden apple. Following its European introduction and acceptance, tomato cultivation spread throughout the world, especially during the 20^{th} century. British are believed to have introduced it probably in early nineteen (1828) century and promoted its cultivation in mid and lower hills of North India (Seshadri and Chatterji, 1996).

Tomato is recognized globally for its nutraceutical values. It is a good source of minerals, vitamins and organic acids, essential amino acids and dietary fibers. It is a rich source of vitamin-A (4.04mg/100g), vitamin-C (15-30mg/100g), total soluble solids (4-7%), acidity (7.5-10mg/100ml) and lycopene (1.82-5.24mg/100g). It is cooked as a vegetable alone or mixed with other vegetables. The ripe fruits are taken as raw or made into salads, soups, preserve, pickles, ketchup, puree, paste and many other products (Chadha, 2001). Because of its high nutritive value, it is sometimes called as "Poor man's orange". Lycopene has been found as the most powerful antioxidant that helps to keep cholesterol down and bolster resistance to cancer (Watznman, 2000).

In India, tomato is grown on 8,76,410 hectares with an annual of production of 17,848,160 MT. In Himachal Pradesh, tomato is being cultivated over an area of 10,000 hectares with total annual production of 400,000 MT (NHB, 2013).

Tomato is an important cash crop of vegetable growers in the mid hills of Himachal Pradesh. Owing to high temperature and rains in summer and

monsoon, this crop can not be commercially grown in the North Indian plains from June to October and the tomato produced in the mid hill regions of Himachal Pradesh finds ready market in the plains fetching premium prices.

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).

In this regard, biofertilizers many help in improving biological activities of desirable microorganisms in the soil and also improve the crop yield and quality of produce. The microorganisms like *Azotobacter* is considered important not only for their nitrogen fixing efficiency, but also for its ability to produce antibacterial and antifungal compounds and growth regulators. Likewise, some phosphate solubilizing microbes like PSB (Phosphate solubilizing bacteria) is found to be most effective in improving the phosphorous use efficiency (Kumar and Srivastava, 2006).

Furthermore, 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, i.e. June-August, the high moisture availability poses a problem of luxuriant weed growth and increase the incidence of soil-borne

diseases, particularly buckeye rot caused by *Phytophthora nicotianae* var. *parasitica* (Mehta, 2010).

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.

The consumer, at present, is more concerned about the quality and the producer also needs a production system that can provide higher yields of quality fruits. Cultivation of tomato in summer and rainy season is affected due to excessive rainfall, windstorm and higher incidence of diseases and insect pests. Therefore, special practices are needed to increase summer and rainy season tomato production so as to increase the cash flow to the farm families. Production of tomato during rainy season is highly remunerative and need oriented. For this purpose, indeterminate tomato varieties/hybrids are best suited, however, the yield of quality fruits can be improved by manifesting various practices viz., mulching and biofertilizers in proper combination.

Keeping this in view, the above consideration entitled "Response of Tomato Genotypes to Different Mulches and Biofertilizers" were carried out with the following objectives:

i) To study the performance of different genotypes for yield and other horticultural traits
ii) To find out the effect of different mulch materials on productivity and quality of tomato
iii) To find out the effect of different biofertilizers on productivity and quality of tomato
iv) To find out the combined effect of different genotypes, mulches and biofertilizers on tomato production

Chapter-2

REVIEW OF LITERATURE

The enhancement of production merely by increasing the area under a crop to feed ever increasing population is not feasible as land being the fixed entity. Therefore, the remedy lies upon exploiting full genetic potential of available varieties/hybrids by adoption of different production techniques to enhance productivity. Thus, the present investigations were carried out to find out the response of tomato genotypes to different mulches and biofertilizers. The literature available on the effect of mulches and biofertilizers on yield and quality of tomato is being reviewed under the succeeding heads.

2.1 Effect of biofertilizers on growth, fruit yield and quality of tomato
2.2 Effect of mulches on growth, fruit yield and quality of tomato
2.3 Effect of biofertilizers and mulches on soil properties
2.4 Effect of biofertilizers and mulches on diseases incidence/severity

2.1 EFFECT OF BIOFERTILIZERS ON GROWTH, FRUIT YIELD AND QUALITY OF TOMATO

Mishustin and Naumova (1962) reported in a field trial that *Azotobacter chroococcum* can be used to inoculate seeds or roots of crop plants for increasing yields. Accelerated growth of tomato with inoculation of *Azotobacter* was also reported by Jackson *et al.* (1964).

Azcon *et al*. (1974) from Spain reported that tomato gave highest yields when inoculated with mixture of *Azotobacter spp*. + *Agrobacterium spp*. at seedling stage and NPK application at inoculation and flowering time.

Badaway and Amer (1974) in a pot trial experiment reported that seeds of tomato inoculated with *Azotobacter chroococcum* increased plant height, fresh and dry weight by 24, 36 and 100 per cent, respectively as compared to untreated control.

Azcon and Barea (1975) reported that the roots of tomato seedlings when treated with culture supernant of *Azotobacter vinelandi* and *Azotobacter beijerinckii* accelerated plant growth and increased fruit yield.

Bagyaraj and Menge (1978) conducted an experiment at California and reported that the dry weight of tomato shoots was increased with inoculation of *Azotobacter chroococcum*.

Antipchuk *et al.* (1982) reported that in containers and field trials, the inoculation of different *Azotobacter* strains to the soil resulted in higher fruit sugar, vitamin C content and fruit yield in tomato.

Kumarswamy and Madalageri (1990) concluded from their studies in tomato that *Azotobacter* in combination with 30 kg N per hectare recorded a marketable yield of 42.09 t/ha as compared to 41.52 t/ha achieved by application of 60 kg N per hectare alone. Further, *Azotobacter* treated plants produced fruits with high TSS (8.46%) and ascorbic acid (32.91 mg/100g) content.

Subbiah (1990) studied the effect of biofertilizers on tomato and revealed that interaction of N and *Azospirillum brasilense* not only saved 50 per cent of the recommended N rate but also improved N use efficiency and increased the yield in tomato.

Martinez *et al*. (1993) in his studies reported that soil preparation with *Azotobacter chroococcum* increased tomato seed germination by 33-46 %, shortened the period between sowing and transplanting by 5-7 days, increased number of flowers and fruits, improved fruit quality and increased the yield by 38-60%.

Raverkar and Bhandari (1995) reported from their experiment at Solan that the inoculation of tomato seedling with *Azotobacter chroococcum* obtained the higher tomato yield at different levels of nitrogen and also reported the saving of 40-50 kg N ha^{-1}.

Sanhita *et al*. (1995) while working with tomato crop at Varanasi found that *Azotobacte*r inoculation significantly increased seedling emergence rate, total

dry weight and increased root and shoot length and also significantly reduced disease incidence and severity of damping off of seedling.

Ranganathan and Rani (1996) conducted pot experiment using inceptisol or alfisol soil and found higher yields of tomato cultivar Co 3 with the inoculation of *Azospirillum* (2 kg/ha) along with NPK (100:50:30 kg/ha).

Barakart and Gabr (1998) revealed that tomato cv. Castle Rock showed increased seedling growth and higher fruit yields through inoculation with biofertilizers along with 240 kg N/ha.

Hameedunnisa (1998) treated the seeds of tomato cv. Arka Vikas with *Azotobacter* and found that fruit yield was highest from those plants whose seeds were inoculated.

Kim *et al.* (1998) in an experiment on tomato revealed that PSB and *Mycorrhiza* helped in increasing the N and P uptake along with increased plants growth in tomato plants.

Duraisamy *et al.* (1999) revealed that soil application of *Azospirillum brasilense* @ 2 kg/ha to tomato cv. Paiyur-1 resulted in higher fruit yield as compared to inorganic amendments.

Olsen *et al*. (1999) conducted a pot experiment under green house on tomato cv. Floradade and found that the growth response of the tomato crop to colonization by an established mycorrhizal mycelium appeared to depend on a critical balance of P and C supply and the increased uptake of P as a result of colonization with VAM and hence resulted in increased growth.

Chaurasia *et al.* (2001) carried out an experiment in which eight tomato hybrids were inoculated with *Azotobacter* @ 15 kg/ha with N, P and K @ 150, 60 and 80 kg/ha, respectively and found that soil application of *Azotobacter* enhanced the shelf life of tomato by 3-5 days when harvested at breaker stage and also the soil application/seedling inoculation with *Azotobacter* before transplanting significantly prolonged the shelf life of tomato at least for 2 days, depending on variety than by soil application alone.

Sharma and Thakur (2001) conducted a field trial on tomato at Solan and revealed that when tomato cv. Yashwant was treated with *Azotobacter* in combination with various levels of N, resulted in significant improvement in plant height, number of branches, fruits per plant, fruit yield per plot and per hectare.

Subramanian *et al.* (2001) in a field experiment inoculated the tomato plants with *Mycorrhiza* and revealed that fruit quality of tomato was improved by mycorrhizal interaction under drought stress and also the mycorrhizal association was more beneficial under severe drought stress than under mild or no drought stress.

Harikrishna *et al*. (2002) conducted an experiment to determine the effect of integrated nutrient management on tomato cv. Megha (L-15) yield. Treatment combinations comprised: 25, 50, 75 and 100% recommended dose of nitrogen (RDN), recommended dose of fertilizers (115:100:60 NPK kg/ha), *Azospirillum* and farmyard manure (FYM) 25t/ha. P was given either as rock phosphate (RP), single superphosphate (SSP) or Phosphate Solubilizing Bacteria. The highest fruit yield (54.32 t/ha) was recorded upon treatment with FYM + 75% RDN and recommended dose of phosphorus (RDP) (P as SSP) + recommended dose of potassium (RDK) + *Azospirillum*. The lowest yield (30.13 t/ha) was recorded with the treatment where soil application of FYM was done. Application of FYM + 75% RDN and RDP (P as RP + Phosphate solubilizing bacteria) + RDK + *Azospirillum* recorded the highest net income of Rs. 78 565/ha and benefit:cost ratio of 2.72. The lowest net income of Rs. 37 684/ha and benefit:cost ratio of 1.67 was recorded upon treatment with FYM alone.

Prasad *et al*. (2002) conducted a field experiment during September 2000 to February 2001, in Allahabad, Uttar Pradesh, India, to study the effect of biofertilizers *Vesicular Arbuscular Mycorrhiza* (VAM) and *Azospirillum spp*. alone or in combination with various chemical fertilizers (N and P) on the growth, yield and quality of tomato (*Lycopersicon esculentum)* cv. Ches/KP/89-1. Combination of VAM and *Azospirillum* was superior over the single

application of VAM or *Azospirillum*. Mixed biofertilizer (VAM + *Azospirillum*) with 75% of recommended chemical fertilizer was found to be superior over all levels of biofertilizer and chemical fertilizer for growth and yield of this crop.

Sengupta *et al.* (2002) found that inoculation of tomato plants with *Azotobacter* and *Azospirillium* resulted in improved growth and yield with significant increase in TSS and ascorbic acid content as compared to untreated control. Terry *et al*. (2002) evaluated the effect of simple and mixed inoculation of *Azotobacter chroococcum* and *Arbuscular Mycorrhizal Fungi* on the growth, development and yield of tomato, lettuce, garden beans and radish. The results showed a positive effect of microorganism inoculation on the parameters measured, the most effective being those obtained by mixed inoculation of *Glomus clarum* and *Azotobacter chroococcum*, which proved that they acted in a synergistic form when added simultaneously.

Amer *et al*. (2003) studied the effects of biofertilizers (*Azotobacter, Azospirillum and Bacillus megaterium*) and mineral fertilizers (25%, 50%, 75% and full recommended NPK rate) on the growth, fruit yield and quality of tomato cv. GS12. They observed that increasing mineral fertilizer rates from 25 to 100% of the recommended rates significantly increased plant height, number of branches and leaves, dry weight of roots, shoots and leaves per plant, total fruit yield and crop quality. Biofertilizer application significantly improved the vegetative growth, total fruit yield, flesh thickness, total soluble solid and vitamin C contents of the crop. Mixed biofertilizer application gave better results than dual or single biofertilizer application. The combined application of mineral fertilizers and biofertilizers significantly increased the vegetative growth, total fruit yield and fruit quality. The application of the full-recommended mineral fertilizer rate in combination with biofertilizers resulted in the highest vegetative growth, fruit quality and fruit yield. The same results were obtained with the application of 75% of the recommended mineral fertilizer rate combined with biofertilizer. The application of *Azotobacter, Azospirillum* and phosphorein in tomato in newly reclaimed sandy soils reduced the required amount of mineral fertilizer without reducing the productivity or quality of tomatoes, thus reducing the high cost of chemical fertilizers and pollution of the agriculture environment.

Gajbhiye *et al.* (2003) in a study on effects of biofertilizers on the growth and yield of tomato showed that *Azotobacter* was more effective than phosphobacteria in the improvement of plant height, number of primary branches per plant, number of fruits per plant, fruit size and yield.

Raut *et al*. (2003) conducted studies with tomato in Jabalpur, Madhya Pradesh, India, during 1998/99 involving 12 treatments. They observed that maximum plant height (45.67 cm), number of branches (12.52), number of flowers per cluster (5.56), number of flower cluster per plant (32.88), fruit weight per plant (591g) and fruit yield (196.43 q/ha) were recorded with T_1(100:50:50 kg NPK+20 tonnes FYM). The maximum number of fruits per plant (20.96) was recorded with T_9 (20 tonnes PM+5 kg *Azospirillum*+5 kg phosphate solubilizing bacteria). Ascorbic acid content in fruits was highest (16.5 mg/100 g) with T_8 (30 tonnes FYM+5 kg *Azospirillum*) which enhanced storage life. The maximum net return of Rs 33 408.00 was obtained with T_1, with benefit:cost ratio of 2.30.

Bhat and Prasad (2004) studied the effect of different levels of boron (50, 75 and 100%) and biofertilizers on the growth and yield of tomato (*Lycopersicon esculentum* Mill). The experiment included 12 treatments. It was concluded that mixed application of biofertilizers, *Vesicular Arbuscular Mycorrhizae* + *Azospirillum*+ 75% boron (B_3F_2) was found to be superior over all levels of biofertilizers and boron for growth and yield of tomato. The yield was found maximum (15.24 t/ha) with B_3F_2 in comparison with B_0F_3 which recorded a minimum yield of (7.81 t/ha).

Hernandez and Chailloux (2004) obtained significant results regarding plant height, stem diameter, root length and yield through the inoculation of *Mycorrhiza* in tomato plants.

Singh *et al.* (2004) studied the effect of integrated nutrient management on crop nutrient uptake and yield under okra-pea-tomato cropping system and it was found that integrated use of organic and inorganic sources of nutrients and biofertilizers increased the N, P and K concentrations in the plants including

fruits of okra, pea and tomato and shoot dry matter yield of okra and tomato were increased.

Abou (2005) observed the impact of using of *Saccharomyces cerevisiae* either as foliar spray with extract of activated cells or as seedlings inoculation on growth characters and yield of tomato plants (*Lycopersicon esculentum)* cv. Super Strain B in the presence of inoculation with nitrogen fixer (*Azospirillum lipoferum*) and phosphate-solubilizing bacteria (*Bacillus megaterium* var. *phosphaticum*). Generally, the results revealed that inoculation with any biofertilizer enhanced the activities of dehydrogenase and nitrogenase. Also, several plant parameters were stimulated significantly as a result of inoculation with *Azospirillum* alone or with phosphate dissolver referring to control. Moreover, application of yeast either as foliar spray or seedling inoculum enhanced the tested strains of N_2-fixer and P-solubilizer, which led to increased growth parameters, mineral content as well as carbohydrate concentration of tomato plant, fruit yield, total soluble solids (T.S.S.) and vitamin C in the fruits.

Alfonso *et al*. (2005) revealed that one of the main problems regarding the efficient use and management of biofertilizers in agriculture lies in the unknown species present in agro-ecosystems and crop rhizospheres. From the ecological point of view, it is important to know the members of the bacterial population allowing them to be applied as inoculants and enable a positive agro-biological effect on agricultural crops. This investigation was aimed at evaluating the agro-biological effectiveness of *Azospirillum spp*. on tomato growth, development and yield. The predominating microbial genus in the crop rhizosphere was thus selected and the effect of inoculating it was then evaluated by judging the crop's response. Results showed that *Pseudomonas, Azospirillum, Azotobacter, Bacillus* and *Streptomyces* belonged to the microbial population of the tomato rhizosphere and *Azospirillum* was the most prominent genus. Artificial inoculation of this rhizobacteria caused a positive effect on seedling growth as well as on plant nutritional stage, the agricultural yield was higher by 11% as compared to control plants. A high microbial population level was recorded in the rhizosphere of the inoculated plants.

Bhadoria *et al.* (2005) studied the effect of *Azotobacter* inoculation with nitrogen levels on quality characters of tomato and revealed that *Azotobacter* along with N helped in increasing fresh weight, total soluble solids, ascorbic acid contents and reduced fruit cracking as compared to control.

Terry *et al*. (2005) conducted a field experiment in Cuba on a typical lixiviated Red Ferralitic soil during 2000 and 2001 to study the effects of beneficial microorganisms and bioactive products on the growth, yield and quality of tomato. The treatments consisted of inoculation of *Glomus clarum* and *Azospirillum brasilense*, spraying of Biostan to foliage at different stages of plant development and combination of both treatments, with or without 90 kg N/ha. The inoculation of *G.clarum* and *A.brasilense* combined with spraying of Biostan significantly enhanced the nutrient status, yield and fruit quality relative to the control (150 kg N/ha). This treatment resulted in a yield of 35.0 t/ha, which was higher by 17% than that recorded for the control.

Kumar and Sharma (2006a) undertook an investigation using *Azotobacter*, *Azospirillum*, *Pseudomonas* and VAM to study their role on various aspects of tomato seed production. The study revealed that *Azotobacter* when applied to nursery, seedling and field soil resulted in maximum values of number of fruits per plant (19.23), fruit yield per plant (1109 g) and per hectare (356.9 q), 1000-seed weight (3.63 g), seed yield per plant (4.58 g) and per hectare (152.70 kg) and benefit: cost ratio (1.45:1).

Kumar and Sharma (2006b) inoculated tomato cv. Solan Vajr plants with *Azotobacter, Azospirillum* and *Pseudomonas* alone or in combination with 75 or 100% NPK and 25 tonnes FYM/ha in a field experiment. Inoculation with *Azotobacter* in combination with 100% NPK and FYM resulted in the highest mean number of fruits per plant (21.84), seed yield per plant (6.80 g) and per hectare (226.51 kg), 1000-seed weight (3.71 g) and benefit: cost ratio (2.38: 1). Seed vigour index was highest (1242) with inoculation of *Azospirillum* in combination with 75% NPK and FYM.

Terry *et al*. (2006) determined the effect of biofertilizers (*Glomus clarum* + *Azospirillum brasilense*) and bioactive compounds (Biostan and Biobras-16) on the development, yield and quality of tomato. Crop yield increased by 12-19% (26-29 t/ha), as well as the bromatological quality of fruits increased with the combined application of the biofertilizers and the bioproducts.

Carlos *et al.* (2007) described the beneficial effects of plant growth promoting microorganisms (PGPM's) inoculation on vegetables growing either under normal or stressful conditions, with an emphasis on the use of *Azospirillum*. He also focused on the recent advances on *Azospirillum* plant interactions and the bacterial mechanisms of plant growth promotion.

Kadlag *et al.* (2007) conducted a field experiment during *Kharif* season of 2002-2003 at MPKV, Rahuri and revealed that recommended dose of fertilizer + phosphate solubilising bacteria produced the highest fruit yield (35.85 tonnes/ha). The combined use of recommended dose and biofertilizers were beneficial for nutrient uptake of tomato. Fruit quality of tomato was improved by recommended dose + *Azospirillum* and phosphate solubilising bacteria.

Kumar *et al*. (2007) carried out an experiment during the 2003 and 2004 summer seasons in Uttar Pradesh, to study the effect of biofertilizers on the growth, yield and quality of tomato cv. Pusa Hybrid 2. Among the different biofertilizer treatments, *Azospirillum* followed by *Azotobacter* gave maximum plant growth, number of primary branches, days taken to first flowering, number of fruits per plant, average fruit weight, total soluble solids and ascorbic acid content.

Narayan *et al*. (2007) revealed that the application of biofertilizers has been found to have a beneficial effect on the growth, yield and quality of tomato. Their integrated use with chemical fertilizers had more pronounced effect on yield and yield attributing traits as compared to the application of chemical fertilizers alone. In the present study it has been observed that application of *Azotobacter*+75% N and 100% PK (NPK applied through chemical fertilizers)

significantly increased yield of tomato. The maximum net income and cost benefit ratio was recorded from same treatment.

Padma and Reddy (2007) conducted a field trial on tomato variety Marutham and concluded that the vegetative characters and yield contributing characters *viz.* plant height, number of branches, number of flower clusters and number of fruits per plant, average fruit weight and yield were found best with biovita in comparison with biozyme, cytozyme and check treatment.

Kamal *et al*. (2008) carried out a field experiment to assess the efficacy of biofertilizers along with chemical fertilizers on flowering, quality and yield of tomato. Significant difference was obtained for fruit diameter, fruit weight, specific gravity, total soluble solids, ascorbic acid, juice content and yield per plant whereas, days to 50% flowering, days to full bloom and acidity were not found to differ significantly. Maximum days to 50% flowering (27.67), days taken to full bloom (43.00) and fruit weight (65.87 g) was obtained with treatment T_3 having *Azospirillum*+RDF, whereas fruit diameter (54.28 mm) was maximum with treatment T_1 having recommended dose of fertilizers (RDF). Highest specific gravity (1.07) and juice content (91.21%) were found with treatment T_9 (VAM+RDF); total soluble solid (5.20 degrees B) with treatment T_6 (PSB+75% N+recommended dose of P and K); ascorbic acid (26.19 mg/100 g fruit) and acidity (0.57) with treatment T_7 (PSB+RDF). Maximum fruit yield per plant (2.68 kg) was obtained with treatment T_5 (*Azotobacter*+RDF). However, highest cost benefit ratio (1:2.02) was found with the due to application of *Azotobacter* and *Azospirillum* with recommended dose of NPK.

Singh *et al.* (2008) reported in tomato that the quality and fruit yield of hybrid tomato was affected by biofertilizer (*Azotobacter*) and nitrogen fertilizer. The highest yield was obtained with *Azotobacter* combined with the recommended rate of nitrogen.

Singh *et al*. (2008) conducted an experiment to examine the quality and fruit yield of hybrid tomato cv. ARTH-210 as influenced by biofertilizer (*Azotobacter spp*.) and levels of nitrogen in the Horticultural Department of

Allahabad Agricultural Institute, Allahabad, Uttar Pradesh, India, during the winter season of 1998-99. The treatments were 4 levels of nitrogen (0, 50, 75 and 100% of recommended N dose) and biofertilizer (*Azotobacter spp*.) with or without the control. Under Allahabad agroclimatic conditions, yield was highest in tomatoes applied with *Azotobacter spp*.+100% of recommended N dose. The yield obtained in control was quite high as compared to treatment where biofertilizer without nitrogen dose was applied. This reduction in yield was due to some harmful effect of *Azotobacter spp*. but biofertilizer and different levels of nitrogen did not affect the quality of tomato fruit.

Mahato *et al.* (2009) carried out an experiment to evaluate the response of bio-fertilizer and inorganic fertilizer on germination and growth of tomato plant. *Azotobactor* as biofertilizer reported better than inorganic fertilizer in relation to seed germination and all plant growth parameters.

Shukla *et al*. (2009) studied the effect of N fertilizer (100 kg/ha), P_2O_5 (75 kg/ha), K_2O (55 kg/ha), *Azotobacter* and PSB on the performance of tomato hybrid Naveen 2000. The earliest flowering was recorded for NPK + PSB and NPK + *Azotobacter*. The application of N only resulted in the earliest maturity (60 days), followed by N and PSB (62 days each). P + *Azotobacter* delayed maturity to 82 days. The number of fruits per cluster were markedly increased by the application of K + *Azotobacter*. Fruit weight was greatest for NPK + *Azotobacter* + PSB, followed by N, K and NPK + PSB. The highest yield was obtained with NPK + *Azotobacter* + PSB, followed by NPK + PSB.

Unlu and Padem (2009) study was carried out an experiment at Suleyman Demirel University Agricultural Research and Experimental Station to compare the effects of conventional and organic production systems on yield, quality and plant characteristics of Joker F_1 determinate tomato cultivar. First, four different doses (0-70-140-210 m3/ha) of the manure applications in both conventional and organic production were compared. Then, two plant activators (Crop-Set and ISR 2000), two microbial fertilizers (Bionem and Natural Bioplasma) and all possible combinations of these two were compared in organic production only. At the end

of the experiments, it was observed that yield ranged from 48.7 to 72.3 tons/ha and early yield ranged from 26.5 to 47.2 tons/ha. The average fruit weight was between 143.26-167.02g. At the end of the experiment, the applications resulted considerable variations in vitamin C (15.91-23.70 mg/100 g), soluble solid content (3.52-4.18%), firmness (1.46-1.87 kg/cm2) and titratable acidity (% 0.232-0.428).

Yadav and Tripathi (2009) in a field experiment revealed that maximum yield of tomato and its growth and development characteristics along with yield components and quality attributes were obtained in that plot which was treated with phosphorus as SSP @ 450 kg/ha^{-1} + PSB + FYM @30 t ha^{-1}. Combined application of all three treatments was more beneficial than that of its alone application. Seed of tomato treated with PSB showed significant increase in yield and yield attributing characteristics.

Bhardwaj *et al.* (2010) studied the effect of various combinations of crop residue, FYM, biofertilizers and chemical fertilizer levels on tomato under mid-hill conditions of Himachal Pradesh. 100% NPK and in-situ incorporation of crop residue produced the highest yield of 70.84 and 91.67 q ha^{-1}, TSS 5.3% and 4.8% and ascorbic acid 37.2, 35.5 mg per 100 g fruit, respectively. The per cent increase in yield under this treatment over 100% NPK alone was 13 % and 9.3% during the years 2002 and 2003, respectively.

Gajbhiye *et al.* (2010) carried out an experiment to study the effect of biofertilizers *viz. Azotobacter* and *Phosphobacterium* on the fruit quality of 10 tomato cultivars and revealed that application of *Azotobacter* registered highest locule number per fruit, lycopene and vitamin-C content while, *Phosphobacterium* treatment recorded maximum pericarp thickness, total soluble solids and specific gravity.

Gosavi *et al.* (2010) carried out the investigations to study the effect of organic manures with biofertilizer on fruit characters of tomato hybrid RTH-2. The important fruit quality parameter such as pericarp thickness, TSS, acidity, ascorbic acid and lycopene were found to be better in the treatment with organic fertilizers in combination with biofertilizer.

Kumar *et al*. (2010) carried out a study at the Research Farm of C.S.S.S. (P.G.) College Machhra, Meerut during 2006-2007 and 2007-08 to find out the response of integrated nutrient management (INM) on growth, yield and quality of tomato (*Lycopersicon esculentum* Mill.). Three levels of each of organic manure (FYM 15 t/ha, vermicompost 10 t/ha and poultry manure 3q/ha), inorganic fertilizer (2/3 dose of RDF of NPK, 90:60:60, 1/2 dose of RDF of NPK 60:40:40 and 1/4 dose of RDF of NPK 30:20:20) and biofertilizers (VAM 2 kg/ha, PSB 2 kg/ha and *Azospirillum* @2 kg/ha) were applied alone and in combination. Thus, there were 27 treatment combination and a control. The maximum height of plant, number of fruits per plant, fruit size, fruit yield per hectare and TSS content were recorded with the application of 2/3 dose of NPK while inoculation of VAM recorded maximum number of seeds/plant, highest seed yield (kg/ha), ascorbic acid content (%) and acidity content (%). Number of branches/plant and seed test weight were highest in plants treated with vermicompost.

Malik and Kumar (2010) conducted field experiments were conducted during 2006 and 2007 in Meerut, Uttar Pradesh, India to evaluate the growth and yield of tomato grown under integrated nutrient management (INM). The treatments included organic manures (farmyard manure at 15 t/ha, vermicompost at 10 t/ha and poultry manure at 3 q/ha), inorganic fertilizers (2/3 of the recommended NPK (90:60:60), 1/2 dose of NPK (60:40:40) and 1/4 dose of NPK (30:20:20)) and biofertilizers (*Vesicular Arbuscular Mycorrhiza*, *Phosphate Solubilizing Bacteria* (PSB) and Azospirillum @ 2 kg/ha). Maximum fruit yield per plot was obtained with the application of PSB (6.78 and 6.86 kg), followed by 2/3 dose of NPK (6.80 and 6.81 kg) and vermicompost (6.72 and 6.80 kg) in both years. Maximum fruit yield per hectare was obtained with 2/3 dose of NPK (214.92 and 214.85 q/ha), followed by vermicompost (210.17 q/ha) and PSB (209.64 q/ha) in the first year and VAM (214.80 q/ha) and vermicompost (206.34 q/ha) in the second year.

Patil *et al.* (2010) studied the effect of different biofertilizers and inorganic fertilizers on tomato and revealed that plant height and number of

branches were significantly influenced by different biofertilizers. However, the increase in yield attributes like number of fruits, average weight of fruit and yield per hectare due to inorganic fertilizers were more or less similar with that produced by biofertilizers.

Pathan *et al*. (2010) conducted a study at Marathwada Agricultural University Prabhani. Treatment of Bio-K (1ml/l) of water + RDF of NP and 50 % of K gave best result in terms of shape index of fruit, juice percentage, peel percentage, seed weight per fruit, total soluble solid and ascorbic acid content of fruit as compared to control and rest of treatments.

Sharma *et al. (*2010) conducted an experiment to study the effect of integrated nutrient management on growth, yield and quality of tomato. Combined application of seedling dip with *Azotobactor* @ 2 kg/ha+75% N + full dose of PK + full dose of FYM treatment combination significantly increased growth, yield and quality characters over recommended dose of fertilizers or organic manures.

Thakur *et al.* (2010) studied the effect of organic manures and biofertilizers on different growth parameters and fruit yield of tomato and observed that maximum yield and longest harvest duration was observed with NPK application while, maximum plant height was obtained through *Azotobacter* application.

Thakur *et al.* (2010) conducted field experiments to assess the effect of different organic manures and biofertilizers on tomato and revealed that amongst all the treatments, combined application of vermicompost and biofertilizers increased the growth and yield in comparison to untreated control.

Zheng *et al*. (2010) cultivated tomato seedlings on substrate to study the effect of bio-phosphorus fertilizer on the seedling growth. The results showed that compared with the control, application of biophosphorus fertilizer significantly improved all the morphological indexes of the seedlings, the contents of soluble sugar and soluble protein in the seedling leaves and the root

activity of the seedlings and when the volumetric ratio of bio-phosphorus fertilizer application to substrate was 1:100, the effect of bio-phosphorus fertilizer was the best. It was concluded that application of bio-phosphorus fertilizer could promote the growth of tomato seedlings and improve the physiological activity of the seedlings.

Singh *et al*. (2012a) laid out an experiment in Randomized Complete Block Design (RCBD) comprising of ten treatment combinations of organic manures and biofertilizers. Among all the treatments, T_7 (Vermicompost +Biofertilizers) performed best for all seed yield characters, whereas treatment T_9 (Biovita + Biofertilizers) was found best for tomato seed quality characteristics.

Singh *et al*. (2012b) laid out an experiment in Randomized Complete Block Design (RCBD) comprising of ten treatment combinations of organic manures and biofertilizers viz. T_1-FYM@20t/ha, T_2-Vermicompost@5t/ha, T_3-Neem Cake@2t/ha, T_4-Biovita Granules@50kg/ha, T_5-Biofertilizer (*Azotobacter* + PSB + KSB) each @5kg/ha, T_6- T_1 + Biofertilizer, T_7-T_2+Biofertilizer, T_8-T_3+Biofertilizer, T_9-T_4+Biofertilizer and T_{10}-Absolute control. Among all the treatments, T_7 (Vermicompost +Biofertilizers) performed best for all plant growth and fruit yield characters except average fruit weight, whereas treatment T_9 (Biovita + Biofertilizers) was found best for fruit quality characteristics i.e., shelf life of fruits, TSS and ascorbic acid content.

Thakur *et al.* (2012) carried out an experiment to evaluate the effect of biofertilizers and organic manures on fruit and seed yield of tomato cv. Solan Vajr under mid-hill conditions as compared to recommended dose of NPK and control. Amongst the organic amendments application of vermicompost recorded the highest fruit and seed yield followed by *Azotobacter.*

2.2 EFFECT OF MULCHES ON GROWTH, FRUIT YIELD AND QUALITY OF TOMATO

Mulch is well known for modifying energy and water balance at surface of soil and creating more favourable conditions for plant growth. Micro climate

factors strongly affect soil temperature and soil moisture in root zone which in turn may influence plant growth and productivity.

Singh *et al*. (1976) conducted an experiment to study the effect of various mulch materials on the growth and yield of bottle gourd, ridge gourd and sponge gourd under the rainfed condition of Dry Farming Research Centre, Haryana Agricultural University, Barwal during 1973 and 1974. Polythene mulch was found very effective in reducing the weed population and improving the yield from 48 to 95% over control in all the three crops during both years. Straw and sawdust mulches were also effective in increasing vine length and yield of crops.

Decoteau *et al*. (1988) revealed that the quality of radiation reflected from certain mulches may have direct effect on above ground plant growth in tomato. Korla *et al*. (1990) observed maximum yield with pine needles+FYM in ginger. Asiebu (1991) recorded maximum yield of tomato with the application of 80 kgN/ha+black polythene as mulch and there was no advantage of applying N fertilizer beyond 80 kg/ha.

Mulches conserve soil moisture by retarding evaporation but effect on soil temperature varies depending upon composition and optical properties of mulch (Ham *et al.,*1991). Firake *et al*. (1991) tried different mulch materials like transparent polyethylene, black polyethylene and sugarcane straw in tomato cultivar 'Pusa Ruby' and recorded 98.14 percent higher fruit yield with sugarcane straw mulch over the control.

Ram and Singh (1992) conducted an experiment to evaluate the potentiality, suitability and economy of certain mulching materials viz. white polythene, black polythene, dry grass/straw and the leaves and twigs of local bushes/trees (vegetational mulch) under low hill/valley condition of U.P. The vegetational mulch applied at the time of planting is beneficial and economical for obtaining better yield. It reduced the weed population, help in early emergence, better plant height, higher number of shoot/hill, number of tubers/plant than control.

Similar increase in the yield of cvs. of tomato 'Sunny' and 'Pik-Rite' tomatoes were observed by Abdul Baki *et al.* (1992) with black polyethylene mulch. Similarly, Quezada Martin *et al.* (1992) also recorded 30, 29, 28, 26, 24 and 5 per cent increase in tomato fruit yield over control by using white, black, red, yellow, green and blue coloured polyethylene mulch respectively.

Sharma *et al*. (1992) studied the effect of different mulches on yield and quality of grapes (*Vitis venifera* L.) and found that fruit yield per vine increased significantly under chilgoza pine needles and was followed by sawdust and hay mulch.

While comparing black and white polyethylene as mulch in tomato Gonzalez *et al.* (1993) observed that black polyethylene mulch was significantly superior in enhancing fruit development and fruit number. Mulching with black plastic not only increased yield but also increased compressive resistance of fruits over unmulched (control) in tomato (Elker *et al.*1993). Highest percentage of top quality fruits of apple cv. Rlstar grafted on M 27 when mulched with pine bark (Spring, 1993).

Chakraborty and Sadhu (1994) conducted an experiment during winter season of 1991-92 and 1992-93 to study the effect of different mulch types and colours on growth and yield of tomato (*Lycopersicon esculentum* Miller), weed growth, soil temperature, moisture and salinity. Polythene mulches, irrespective of colour were superior to rice straw or water hyacinth mulch in improving the growth and yield of tomato. Among the mulch colours, black and red polyethylene increased the plant height by 23.8 and 30.9 % respectively and the leaf number by 42 % as compared to control. Black colour advanced the flowering period by 10 days and red colour by 11 days. Early flowering, greater number of fruit/plant and large fruit size with red and black polyethylene resulted in 77% and 73.3 % higher yield respectively, compared with the control. Black polyethylene completely suppressed the weed growth and other colour also checked the weed growth (blue colour by 96.2% and white by 77.4%). Whereas, clear polyethylene and natural mulching material such as rice straw and water

hyacinth were markedly less efficient. Higher soil temperature (2-3^{0}C above the control), greater soil moisture conservation (31.5-67%) and lower salinity level (36.7-59.8%) were also observed with polyethylene mulches, but mulch colour had no appreciable effect on these parameters.

Elkner and Kaniszewski (1995) conducted an experiment to evaluate the effect of drip irrigation and mulching with black polyethylene plastic on the yield and fruit quality of two tomato cultivars. Irrigation evidently increased total yield by 16 % and marketable yield by about 28 % in comparison to plots without irrigation. Mulching with black plastic also increased total yield by about 20 % and marketable yield by 24 %. Interaction of irrigation, mulching and cultivar was evidently shown on the content of dietary fiber. Irrigation and mulching decreased content of soluble fiber in tomato fruits of both tested cultivars.

Apaydin *et al*. (1998) reported higher total and early yields in tomato crop, mulched with black polyethylene over conventional cultural methods. Mika *et al*. (1998) studied different types of mulches, herbicides and cultivation as orchard ground cover management system in young apple orchard and observed that trees mulched with pine bark, sawdust and polythene film showed best growth as compared to herbicides and hand weeding treatments.

Hundal *et al*. (2000) laid an experiment with three mulches (black, transparent polythene and rice straw) and two mulching techniques (full plot and half meter wide strip) applied alone or in combination with two herbicides (stomp 0.75 kg/ha and 0.12 kg/ha) in tomato during 1991-92 and 1992-93. Higher leaf N and P content was analysed under mulched plots, although leaf K content was unaffected by these treatments. Available soil, NH_4 and NO_3-N, P and K status of the soil after the harvest of tomato crop increased significantly under mulched treatment.

In a study conducted on quality parameters in tomato, Hedau *et al.* (2001) and Nair (1999) reported that mulch material have no significant effect on ascorbic acid, TSS and acidity. Ubaidullah Jan *et al***.** (2002) observed that application of black polyethylene resulted in maximum number of flower clusters

per plant (15.09), number of fruit per plant (12.53), fruit weight per plant (970.72 g) and fruit yield (15.33 t/ha). Mulching materials reduced the number of days to flowering (37.57).

Hedau *et al.* (2002) studied the effects of different mulches (black polyethylene, transparent polyethylene, silver black polyethylene, pea straw and no mulch) on the productivity of tomato hybrid Naveen 2000 and observed that fruit yield was highest with silver black polyethylene mulch (76.42 t/ha), followed by black polyethylene mulch (73.51 t/ha).

Sannigrahi and Borah (2002) evaluated the effectiveness of different organic mulches including black polyethylene under rainfed conditions in tomato and found that mulching increased the number of fruits per plant and higher fruit yield than the control where no mulch was applied.

Lal *et al*. (2003) conducted an experiment in Uttaranchal, India, during 1989 and 1990 to investigate the effect of organic (oak leaves, pine needles, hay and farmyard manure, FYM) and black polyethylene on moisture content, thermal control, tree vigour and yield of apples cv. Starking Delicious. The highest plant height (331.0 cm) and plant spread (101.5 cm) was observed under oak leaves. The highest mean yield was observed under black polyethylene (16.92 kg per plant) followed by oak leaves (14.17 kg per plant), hay (14.06 kg per plant), FYM (13.27 kg per plant) and pine needles (12.90 kg per plant) while the lowest was recorded in the control. Mulching with black polyethylene also recorded the highest soil temperature and moisture retention.

Sinha (2003) studied the effects of mulch (black polyethylene, local grass, pine needles at 12 t/ha or farmyard manure at 25 t/ha) and pre-emergence herbicide (pendimethalin at 2.0 litre/ha or oxyfluorfen at 0.5 litre/ha), singly or in combination, on weed density and performance of ginger cv. Himgiri in Solan, Himachal Pradesh, India, during 1997 and 1998. *Galinsoga parviflora*, *Cyperus sp*., *Euphorbia sp*. and *Setaria glauca* [*S. pumila*] were the major weeds in both years. All the treatments exhibited significant weed control. Black polyethylene was the most efficient, resulting in the lowest weed fresh (155.30 g/m^2) and dry

(50.55 g/m^2) weights. Treatment with grass mulch + farmyard manure, pine needles + farmyard manure + pendimethalin and pine needles + farmyard manure resulted in the greatest plant height (89.56, 88.95 and 86.83 cm), number of tillers per plant (11.58, 10.80 and 9.44), number of leaves per plant (95.38, 94.92 and 92.90), yield per plant (140.40, 137.50 and 113.20 g) and yield per hectare (183.10, 183.60 and 158.60 quintal). The highest cost benefit ratio (0.95) was obtained with grass + farmyard manure.

Yoltas *et al.* (2003) studied the effects of reflective and black mulches on the yield, quality and pest populations on tomato cv. DR-055. The total yields under reflective mulch, black mulch and no mulch treatments were 122.85, 104.99 and 95.68 t/ha, respectively. Earliness percentage was higher in mulch treatments.

Singh (2005) studied the effect of different mulches on growth and yield of tomato cv. Rupali. Polyethylene mulches were found superior to rice straw or sugarcane trash mulch in improving the growth and yield of tomato. Early flowering, higher number of fruits per plant and larger fruit size was observed with black and clear polyethylene mulch which resulted in 57.5 % and 40.7% higher yield compared to unmulched control. Singh *et al*. (2006) elucidated that the use of mulch in normal planting (plant spacing 60 x 45 cm) with 90% surface area covered with mulch resulted in maximum plant height (102.7 cm), higher number of branches per plant (6.4), more number of fruits per plant (91.9) and fruit yield (665.0 q/ha). The cost benefit ratio of 1:2.12 was noticed when tomato was planted at normal spacing along with 90% of its surface area covered with black polyethylene mulch.

Narayanama *et al.* (2005) carried out an investigation on twelve-year-old Royal Delicious apple grown on crab apple seedling rootstock. The experiment was laid out in randomized block design (RBD) with seven treatments viz., dry grass mulch, atrazine (4 kg ha-1)+grass mulch, pine needle mulch, black polythene mulch, glyphosate (0.8 l ha-1), clean cultivation and control (no mulch material) of water conservation techniques for combating water stress. Mulching

treatments, except pine needle mulch produced heavier crop in comparison to control, clean cultivation and glyphosate treatments. Black polythene mulch and atrazine+dry grass mulch were found to be most effective in conserving soil moisture, reducing fruit drop and produced larger fruits with higher anthocyanin, TSS, sugar content, and lower titratable acidity. Yield and yield efficiency also improved significantly with black polythene mulch and atrazine+dry grass mulch treatments.

Aruna *et al*. (2007) conducted an experiment with different mulches and fertigation on tomato Iicreased plant height (127.20 cm), earlier flowering (29.30 days), increased number of fruits per plant (32.7 no), single fruit weight (65.25 gm) and yield per plant (6.40 kg) was observed by mulching with black polythene mulch along with the application of 100% of recommended dose in the form of urea+phosphoric acid+potassium sulfate. The quality attributes was also high. Increased total soluble solids (3.60 degrees brix), acidity content (0.79%) and ascorbic acid content (64.20 mg/100 gm) were observed in the treatment M_1S_6 (mulching with black polythene mulch along with the application of 100% of recommended dose in the form of ammonium sulfate+super phosphate+potassium chloride).

Kataria and Chandel (2007) conducted a field experiment to study the influence of different moisture regimes on the growth and yield of potato (*Solanum tuberosum*) and explore the possibility of growing relay crops in spring potato. They observed that mulching with pine needles significantly increased tuber yield, growth and yield attributes

Kumar *et al.* (2007) conducted a polyhouse experiment to evaluate the effects of growing media, irrigation regime, integrated plant nutrient system (IPNS) and mulching on the productivity of tomato. Results revealed that Module 1 - soil:compost:sand (2:1:1) growing medium + 20 kpa irrigation regime + 50 kg NPK/ha as basal + fertigation with water soluble fertilizer polyfeed (19:19:19) at 25 kg/ha starting at the third week after transplanting + black polythene

[polyethylene] mulch - recorded the highest fruit yields of 9.20 and 11.40 kg/m^2 in 2003 and 2004 respectively.

Zhang *et al*. (2008) carried out a pot experiment in a greenhouse to evaluate the effects of three mulching types together with diluted seawater irrigation on evapotranspiration (ET), water use efficiency (WUE) of Swiss chard, soil water, soil temperature and salt accumulation. The effectiveness of different mulching types for saving water and improving crop yield under saline irrigation was studied. Pots were mulched in the form of gravel, pine needles and rice straw. The results showed that use of mulches significantly reduced ET of Swiss chard. Mulches also effectively reduced salt accumulation under high saline irrigation. Average soil temperature among mulches was in the order of gravel > rice straw > pine needles > no-mulch during winter season, regardless of soil depth. Mulching material improved plant biomass as well as WUE. Under high saline water, mulches differed for dry matter production and WUE in the order of gravel > pine needles > rice straw > no-mulch. The experiment indicated that mulching practice can be used favorably for crop production under saline irrigation.

Joolka *et al*. (2008) carried out an investigation on twelve-year-old Royal Delicious apple grown on crab apple seedling rootstock. The experiment was laid out in randomized block design (RBD) with seven treatments viz., dry grass mulch, atrazine (4 kg ha-1)+grass mulch, pine needle mulch, black polythene mulch, glyphosate (0.8 l ha-1), clean cultivation and control (no mulch material) of water conservation techniques for combating water stress. Mulching treatments, except pine needle mulch produced heavier crop in comparison to control, clean cultivation and glyphosate treatments. Black polythene mulch and atrazine+dry grass mulch were found to be most effective in conserving soil moisture, reducing fruit drop and produced larger fruits with higher anthocyanin, TSS, sugar conten, lower titratable acidity, yield and yield efficiency.

Singh *et al*. (2009) conducted a two year field study during 2001-2002 and 2002-2003 on sandy loam soil to investigate the effect of drip irrigation and

black polyethylene mulch compared with surface irrigation, on growth, yield, water use efficiency and economics of tomato (*Lycopersicon esculentum* Miller). Use of black polyethylene mulch plus drip irrigation raised the fruit yield to 57.87 tonnes/ha. Plant height, leaf area index, dry matter production, fruit weight and yield increased significantly with the use of drip irrigation alone and in conjunction with polyethylene mulch compared to surface irrigation alone or with mulch.

Sharma and Kathiravan (2009) conducted a field study with different mulches, viz. transparent polythene (TP), black polythene (BP), bicoloured polythene (BIP), field grass (GM), pine needles (PN) and unmulched control (UM) to ascertain their effects on soil hydrothermal regimes and growth of 16-year-old plum trees (cv. Santa Rosa) during December to June, 2004-05 and 2005-06 (two seasons). Results revealed that all mulches maintained comparatively higher soil moisture contents over unmulched control and in situ moisture conservation was more in upper 0-7.5 cm layer. Among mulches, BP closely followed by BIP conserved highest moisture being 31.8-52.8 and 9.3-20.9% higher over UM in 0-30 cm soil depth during 2004-05 and 2005-06, respectively. Other mulches also conserved higher moisture over UM and followed the order: BP > BIP > TP > PN > GM > UM. Mulches considerably influenced soil temperature and TP recorded higher temperature both at 7.5 and 15 cm depths and effectiveness of mulches in moderating temperature followed the order: TP > BP > BIP > GM > PN > UM at 07.30 h and TP > BP > BIP > UM > GM > PN at 14.30 h. Weed infestation was effectively checked and minimum weed growth was observed under BP and BIP. Plant growth expressed as annual shoot growth and fruit yield was significantly influenced by mulches and BP gave higher yield (80.62 q ha-1). Both GM and PN were equally effective in increasing the yield over UM. The seasonal income under BP, BIP, TP, GM and PN was 1.16, 1.20, 1.58, 1.09 and 1.12 times higher, respectively compared to control.

Headu *et al.* (2010) studied the effect of bio-fertilization on the nursery of tomato (cv. Manisha) and effect of fertilization in combination with mulching on

fruit yield and quality of tomato were studied during 2005 and 2006. Early and maximum seed germination was observed consistently for two years with the treatments, where seeds were inoculated with *Azospirillum* and *Azotobactor* in combination with Microphos. Maximum fruit yield with good quality fruits (Vitamin C and Total soluble solids) were produced with the application of recommended dose of NPK. However, they were at par with the treatments having inoculated tomato seedlings with *Azospirillum* and *Azotobactor*. Significantly increase in fruit yield and number of fruits per plot was observed when mulching was done with black polyethylene. The control (recommended NPK) and all fertilizer treatments with black polythene mulch showed increase in fruit yield and number of fruits per plot. The maximum fruit yield (151.5 q/ha in 2005 and 135 q/ha in 2006) was recorded with the treatment having recommended NPK and black polyethylene mulch which was at par with the treatment having *Azospirillum* and black polyethylene mulch.

Uddain *et al*. (2010) also studied the effect of different mulches and found that black polyethylene mulch was most suitable for getting higher number of fruits per plant and yield per plant. Mulching also significantly increased fruit yield, fruit diameter and firmness over the no-mulched treatment. Fruits from plants mulched with polyethylene were very firm (Samaila *et al*. 2011).

Samila *et al.* (2011) conducted an experiment to evaluate the effect of mulching, nitrogen and irrigation interval on the nutritional quality of tomato (*Lycopersicon esculentum* Mill) at Shika, Nigeria. Treatments consisted of three mulching (no mulch, rice-straw mulch and black polythene mulch) four nitrogen rates (0, 45, 90 and 135 kg N ha-1) and three irrigation intervals (5, 10 and 15 days). Mulching significantly increased the dry matter, protein and carbohydrate contents in fruits, but decreased the crude fiber content. In most cases rice-straw mulch appeared a better mulching material. N rate of 45 kg ha^{-1} had more dry matter content over control, but higher values for protein and carbohydrate contents were with 90 kg ha^{-1}. The 135 kg N ha^{-1} rate depressed carbohydrate content. Irrigation interval of 10 days recorded more dry matter and crude fiber while highest fruit carbohydrate contents was attained at 15 day irrigation interval

over the 5-day interval. Delaying irrigation significantly depressed fruit protein content. Rice-straw mulch+90 kg N ha^{-1} or polythene mulch in combination with 45 kg N ha^{-1} had more carbohydrate in fruits.

Singh and Kamal (2012) studied the effect of black plastic mulch on tomato yield and reported that black plastic mulch significantly increased the tomato yield. The yield increased with black plastic mulch was 29.8% as compared to bare soil.

2.3 EFFECT OF BIOFERTILIZERS AND MULCHES ON SOIL PROPERTIES

Harikrishna *et al*. (2002) conducted a field experiment to study the effect of integrated nutrient management on yield and nutrient uptake of tomato cv. Megha, as well as on availability of nutrients in the soil. The application of 25 t FYM/ha + 75% N + 100% P + 100% K + *Azotobacter brasilense* resulted in the highest available N (299.9 kg/ha), P_2O_5 (44.2 kg/ha) and K_2O (321.9 kg/ha), although differences in K availability between this and other treatments were non-significant and in the highest fruit yield (54.32 t/ha) and N, P and K uptake at harvest. None of the treatments significantly influenced the K content in the plant.

Choudhary *et al.* (2005) studied the effect of inorganic fertilizers coupled with farmyard manure (FYM) and biofertilizer on organic carbon, available N, P_2O_5 and K_2O in soil in tomato crop and revealed that the incorporation of *Azotobacter*, PSB, and FYM with inorganic fertilizers significantly improved the organic carbon content and available N, P_2O_5 and K_2O status of the soil.

Verma *et al*. (2005) conducted an experiment on the response of different mulching materials and methods of P and K fertilizers application in apple cv. Red Delicious There was conspicuous and significant effect on apple production and soil health. Soil organic carbon and available N, P and K content were recorded maximum under Grass mulched+band application of P and K fertilizers treatment, whereas minimum values of soil carbon and available N,P and K

contents were recorded with unmulched+broadcasting and mixing of P and K fertilizers during 2001 and 2002.

Gopinath *et al.* (2009) found that both composted farmyard manure (FYMC) and (FYMC+ Poultry Manure + Vermicompost + Biofertlizers) enhanced soil pH (7.1) and oxidizable organic carbon (1.2-1.3%) compared with (FYMC+NPK) and unamended control after a two-year transition period.

Ojha *et al.* (2009) conducted a field experiment in sandy loam soil having pH 7.57, EC 0.36 (dSm^{-1}) and OC 0.47 and indicated that the chemical properties of soil and availability of nitrogen, phosphorus and potassium were significantly influenced by application of inorganic, organic and biofertilizer. The value of soil pH and EC were recorded with marginal difference, which was non-significant in all treatment level either alone or in combination levels.

Nedunchezhiyan (2009) conducted an experiment for three years at Dumduma, Bhubaneshwar under rainfed conditions. Mulching along with 120-39.3-100 kg N-P-K/ha recorded the highest N,P and K uptake and post harvest soil nutrients status followed by mulching along with 100-32.7-83.3 kg N-P-K/ha.

Bhardwaj *et al.* (2010) studied the effect of various combinations of crop residue, FYM, biofertilizers and chemical fertilizer levels in tomato under mid-hill conditions of Himachal Pradesh. It was indicated that integrated use of chemical fertilizers and organics increased the organic carbon, available NPK contents of the soil over their soil applications. Integrated use of any one of the organics and/or biofertilizer with 75% recommended NPK produced high yield, quality (except FYM) and available NPK built up in soils. Moreover, conjoint application of crop residue + FYM + dual inoculation of *Azotobacter*/*Rhizobium* + VAM produced yield, quality and in general organic carbon, available NPK built up in the soils equal to alone 75% of recommended NPK dose in tomato.

Reddy *et al*. (2010) conducted studies on integrated use of organic manures and inorganic fertilizers, based on tomato-onion cropping system.

Application of organic manures with inorganic fertilizers significantly improved the availability of N, P, and K in soil. Based on the results of this study it was concluded that the combined use of organic manures and inorganic fertilizers is suitable for sustaining yield and maintaining soil health.

Singh (2012) reported the maximum retention of soil fertility year after year and getting high fruit yield with application of vermicompost and biofertilizers.

2.4 EFFECT OF BIOFERTILIZERS AND MULCHES ON DISEASES INCIDENCE/SEVERITY

Mulch is most widely used due to its excellent properties and low cost. Effective control of tomato fruit rot has been reported by Krutzer and Brayant (1944) and Welch (1949) through application of straw mulch in combination with fungicide spray. Temperature achieved at the upper soil layers by mulching in the range of those found to be lethal to the pathogens (Nelson and Wilhelm 1958). Mulching has also been reported to reduce hazards of phyototoxity occurring at high temperatures (Dawson *et al*., 1965). Ten variety of tomato were found to be resistant against buckeye rot (Sharma *et al*., 1974 and Rattan and Saini, 1979).

Sumehgy (1975) noticed moderate field tolerance in cultivar 'College Abundant' and 'College Red' to septoria leaf spot. Madalgeri *et al*. (1988) screened 58 tomato genotypes for combined resistance to *Stemphilium solani*, *Alternaria solani* and *Septoria lycopersici* reported field resistance to *Solanum lycopersici* in 23 genotypes out of 58 received from India, USA, Taiwan and Netherlands.

Mulching with black plastic not only increased yield but also increased compressive resistance of fruits over unmulched (control) in tomato (Elker *et al.,* 1993). Dodan *et al.* (1994) found that highest yield was obtained with a combination of fungicide (mancozeb) sprays, clipping lower leaves, weeding, applying a polyethylene mulch to obstruct dispersal of soilborne inoculum of *Phytophthora nicotianae var. parasitica* and removal of affected fruits.

Bhardwaj and Masand (1995) reported that mulched and unmulched treatments during 1990 both incidence and fruit yield affected with buckeye-rot were less than during 1990 and 1992, perhaps owing to low seasonal rainfall. Chen and Lal (1999) also observed that by preventing fruits from touching the soil, rotting and incidence of soil borne disease can be reduced in tomato. On contrary, Bernhardt and Gorgan (1982) and Sohi (1984) indicated that mulching increased the disease incidence and affected the tomato fruit yield.

Gomez *et al*. (1997) observed that the use of mulch facilitied for weed control, decreased damage from bacterial infection of the fruit (*Xanthomonas campestris* pv. *vesicatoria*) and increased the commercial yield.

Lyimo *et al.* (1998) 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% and increased fruit yield more than two fold compared to unmulched and unstaked control. The apparent rate of infection of the two pathogen was also significantly lower in mulched and staked tomato. Mulching was more effective than staking in suppressing early and late blight diseases in tomato.

Mills *et al*. (2002) conducted a field study to evaluated foliar disease in fresh market tomato grown using combinations of four bed strategies and three fungicide programmes. Bed strategies included uncovered beds with or without a composted dairy manure amendment or beds covered with black polythene or hairy vetch mulch. It was observed that in plots with hairy vetch covered beds, early blight caused by *Aternaria solani*, *Septoria* leaf spot caused by *Septoria lycopersiceae* and defoliation were lower verses uncovered beds each year. Early blight and defoliation were lower beds covered with vetch verse polythene mulch.

Mills *et al*. (2002) conducted a field experiment to monitor foliar disease in tomato grown in beds with bare soil, black polythene, composted dairy manure and hairy vetch. Early blight was reduced in plots with polythene verses compost

and bare soil in one and two years respectively. *Septoria* leaf spot was reduced in plots with vetch verses other bed strategies in 1998 and bare soil or compost in 1999. Soil coverage of tomato leaflets and soil particle dispersal were reduced in plots with polythene or vetch verse bare soil or compost in both years that these variables were assessed. These findings suggested that foliar disease reduction in mulch was associated with reduced splash dispersal and reduced leaf wetness.

Chandel *et al*. (2005) an experiment was conducted to determine the efficacy of different cultural methods (mulching and defoliation) in controlling Septoria leaf spot caused by Septoria obese in chrysanthemum. Six different mulches, i.e. polythene sheet, sawdust, wheat straw, eucalyptus leaves, pine needles and grasses, while 5 different plant heights were selected for defoliation to determine their effect on disease development and spread. Polythene mulch gave maximum (64.28 %) disease control with minimum disease severity (18.33 %) compared to 51.33% disease severity in the untreated control. Strawberry can be protected from grey mould, the most common and serious fruit rot disease, by covering the crops with plastic tunnels from the beginning of blooming onwards (Genggotti *et al.,* 2005).

Fruit rot (*Phytophthora nicotianae* var *nicotianae*) is an important disease of bell paper in mid hills of Himachal Pradesh which causes huge losses to the farmers by premature defoliation. The incidence of this disease can be kept in check if the field floor is mulched with pine needles before the onset of monsoon rains as the infection of the disease takes place with rain splashed zoospores (Gupta and Jarial, 2008).

Mehta *et al*. (2010) reported that the maximum plant height, harvest duration, fruit weight and minimum incidence of tomato fruit rot was observed with application of mulching and staking plots. Bala (2012) observed that the black polyethylene mulch proved to be most effective to lowest incidence of buckeye rot and minimum *Alternaria* blight severity

Chapter-3

MATERIALS AND METHODS

The present investigations entitled "Response of tomato genotypes to different mulches and biofertilizers" were conducted at the Experimental Research Farm of Horticulture Research Station, Kandaghat, Dr Y S Parmar U H F, Solan, Himachal Pradesh during 2011 and 2012.

EXPERIMENTAL SITE

Location

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. The experimental site is falls in the mid hill zone of Himachal Pradesh and located at Kandaghat, which is 15 km away from Solan city on Kalka-Shimla national highway having an altitude of 1435 metres above mean sea level.

Climate

Climate of the area is generally sub-temperate and semi-humid characterized by cold winters. The average annual precipitation of the area is 1120 mm, which is received in the monsoon season (June-September). During the crop season, mean temperature varies from 18.6^{o}C to 26.0^{o}C while the relative humidity from 46-80 %. The important meteorological observations recorded during the period of investigation have been presented in Appendix-I and illustrated graphically in Figure 3.1.

EXPERIMENTAL DETAILS

Genotypes

Plant material for present investigation consisted of three tomato genotypes viz. Naveen 2000^{+}, Sun-7711 and Solan Lalima. The varietal

characteristics of these genotypes and their sources of availability are given in table (3.1).

Table 3.1: Salient characteristics and sources of availability of three tomato genotypes

Sr. No.	Name of genotypes	Source	Characteristics
1	Naveen 2000^{+}	M/S Indo-American Hybrid Seed Bangalore Presently changed to Indian Seeds	An early, indeterminate, fresh market F_1hybrid which produces medium size (about 80g) fruits. Plants are resistant to fusarium and verticillium wilt. It is widely adopted hybrid. It gives on an average 550-650 q/ha fruit yield.
2	Sun-7711	Nunhems seed company	An indeterminate F_1hybrid having roundish-red fruits of average size of 85 g. Plants are resistant to fusarium and verticillium wilt. It gives an average yield of 650-750q/ha.
3	Solan Lalima	UHF, Nauni Solan	An indeterminate open pollinated variety. Fruits are medium sized of deep red colour having TSS 4-5 ^{0}Brix with an average yield of 750-850q/ha.

Experimental layout

The experiment was laid out in Split-Split Plot Design (SSPD) comprising of 27 treatments including combinations of varieties, biofertilizers and mulches (Table 3.2), with three replications. Plants were transplanted on 2 April, 2011 and 4 April, 2012 at a spacing of 90 cm x 30 cm in a plot having size 2.7 m x 1.8 m, accommodating 18 plants per plot.

TECHNICAL PROGRAMME:

Crop : Tomato

a) Genotypes : Three

V_1 = Naveen 2000^{+}

V_2 = Sun-7711

V_3 = Solan Lalima

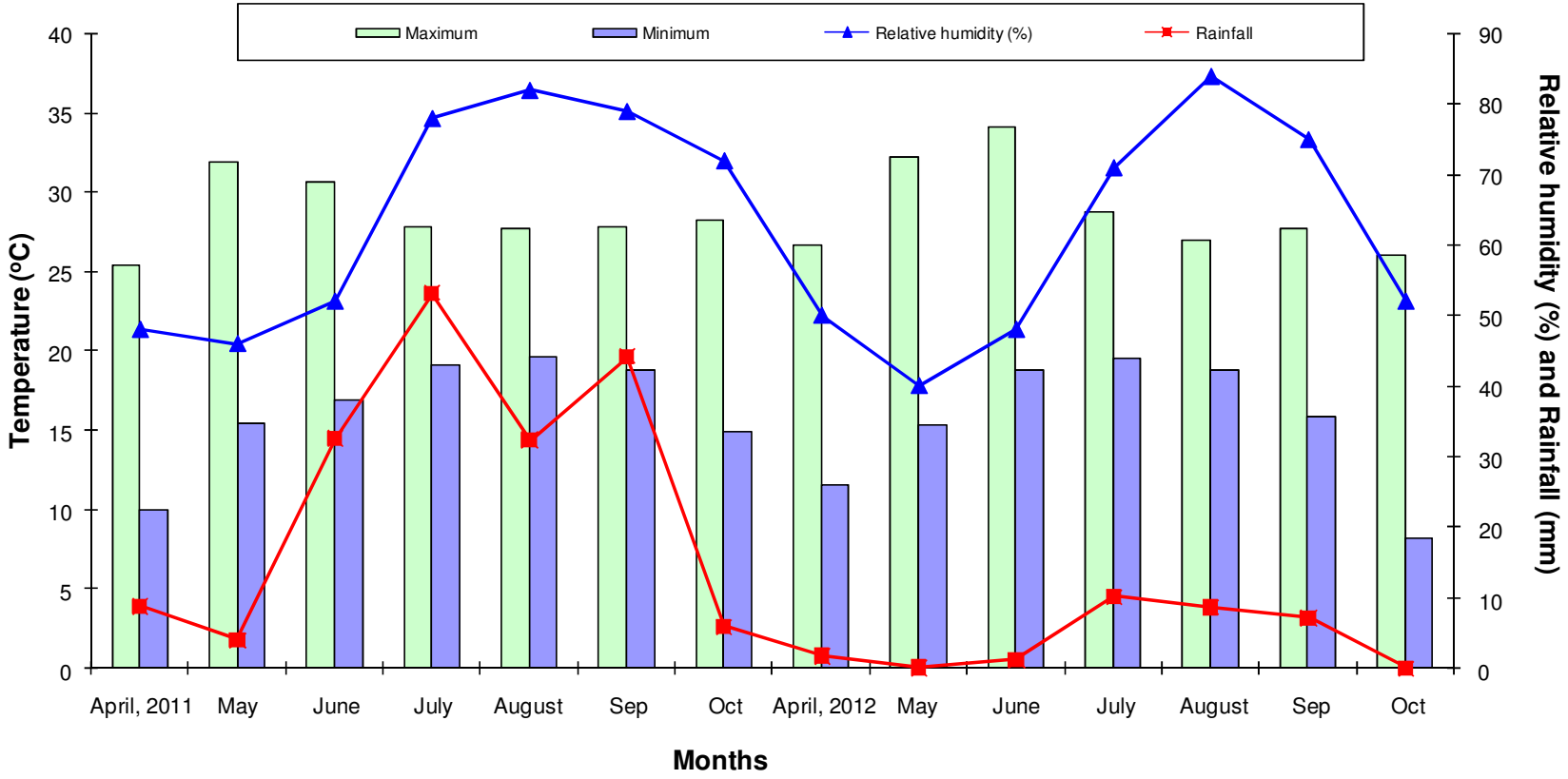

Fig. 3.1 Meteorological data observed during the year 2011and 2012

b) Biofertilizers : Three levels

$\mathbf{B_0}$ = NPK recommended (150:120:60 kg/ha)

$\mathbf{B_1}$ = NPK recommended (150:120:60 kg/ha) + *Azotobacter* (1g/plant) + PSB (1g/plant)

$\mathbf{B_2}$ = NPK 75% + *Azotobacter* (1g/plant) + PSB (1g/plant)

c) Mulch : Three levels

$\mathbf{M_0}$ = No mulch

$\mathbf{M_1}$ = Pine needle

$\mathbf{M_2}$ = Black Polythene

Statistical Design : Split- Split-Plot Design

Main plot treatments : Genotypes

Sub plot treatments : Biofertilizers

Sub-Sub-Plot treatments : Mulch materials

Total treatments : 27

Replications : 3

Plot size : 2.7 m x1.8 m

Table 3.2 Details of treatment combinations:

Modules	Treatment	Details
1	$\mathbf{V_1 B_0 M_0}$	Naveen 2000$^+$ + No mulch + NPK recommended (150:120:60 kg/ha.)
2	$\mathbf{V_1 B_0 M_1}$	Naveen 2000$^+$ + Pine Needle + NPK recommended (150:120:60 kg/ha.)
3	$\mathbf{V_1 B_0 M_2}$	Naveen 2000$^+$ + Black Polythene + NPK recommended (150:120:60 kg/ha.)
4	$\mathbf{V_1 B_1 M_0}$	Naveen 2000$^+$ + No mulch + NPK recommended (150:120:60 kg/ha.) + *Azotobacter* (1g/plant) + PSB (1g/plant)
5	$\mathbf{V_1 B_1 M_1}$	Naveen 2000$^+$ + Pine Needle + NPK recommended (150:120:60 kg/ha.) + *Azotobacter* (1g/plant) + PSB (1g/plant)
6	$\mathbf{V_1 B_1 M_2}$	Naveen 2000$^+$ +Black Polythene + NPK recommended (150:120:60 kg/ha.) + *Azotobacter* (1g/plant) + PSB (1g/plant)
7	$\mathbf{V_1 B_2 M_0}$	Naveen 2000$^+$ + No mulch + NPK 75% + *Azotobacter* (1g/plant) + PSB (1g/plant)
8	$\mathbf{V_1 B_2 M_1}$	Naveen 2000$^+$ + Pine Needle + NPK 75% + *Azotobacter* (1g/plant) + PSB (1g/plant)

9	$\mathbf{V_1 B_2 M_2}$	Naveen 2000$^+$ + Black Polythene + NPK 75% + *Azotobacter* (1g/plant) + PSB (1g/plant)
10	$\mathbf{V_2 B_0 M_0}$	Sun 7711 + No mulch + NPK recommended (150:120:60 kg/ha.)
11	$\mathbf{V_2 B_0 M_1}$	Sun 7711 + Pine Needle + NPK recommended (150:120:60 kg/ha.)
12	$\mathbf{V_2 B_0 M_2}$	Sun 7711 + Black Polythene + NPK recommended (150:120:60 kg/ha.)
13	$\mathbf{V_2 B_0 M_0}$	Sun 7711 + No mulch + NPK recommended (150:120:60 kg/ha.) + *Azotobacter* (1g/plant) + PSB (1g/plant)
14	$\mathbf{V_2 B_1 M_1}$	Sun 7711 + Pine Needle + NPK recommended (150:120:60 kg/ha.) + *Azotobacter* (1g/plant) + PSB (1g/plant)
15	$\mathbf{V_2 B_1 M_2}$	Sun 7711+ Black Polythene + NPK recommended (150:120:60 kg/ha.) + *Azotobacter* (1g/plant) + PSB (1g/plant)
16	$\mathbf{V_2 B_2 M_0}$	Sun 7711+ No mulch + NPK 75% + *Azotobacter* (1g/plant) + PSB (1g/plant)
17	$\mathbf{V_2 B_2 M_1}$	Sun 7711 + Pine Needle + NPK 75% + *Azotobacter* (1g/plant) + PSB (1g/plant)
18	$\mathbf{V_2 B_2 M_2}$	Sun 7711 + Black Polythene + NPK 75% + *Azotobacter* (1g/plant) + PSB (1g/plant)
19	$\mathbf{V_3 B_0 M_0}$	Solan Lalima + No mulch + NPK recommended (150:120:60 kg/ha.)
20	$\mathbf{V_3 B_0 M_1}$	Solan Lalima + Pine Needle + NPK recommended (150:120:60 kg/ha.)
21	$\mathbf{V_3 B_0 M_2}$	Solan Lalima + Black Polythene + NPK recommended (150:120:60 kg/ha.)
22	$\mathbf{V_3 B_1 M_0}$	Solan Lalima + No mulch + NPK recommended (150:120:60 kg/ha.) + *Azotobacter* (1g/plant) + PSB (1g/plant)
23	$\mathbf{V_3 B_1 M_1}$	Solan Lalima + Pine Needle + NPK recommended (150:120:60 kg/ha.) + *Azotobacter* (1g/plant) + PSB (1g/plant)
24	$\mathbf{V_3 B_2 M_2}$	Solan Lalima + Black Polythene + NPK recommended (150:120:60 kg/ha.) + *Azotobacter* (1g/plant) + PSB (1g/plant)
25	$\mathbf{V_3 B_2 M_0}$	Solan Lalima + No mulch + NPK 75% + *Azotobacter* (1g/plant) + PSB (1g/plant)
26	$\mathbf{V_3 B_2 M_1}$	Solan Lalima + Pine Needle + NPK 75% + *Azotobacter* (1g/plant) + PSB (1g/plant)
27	$\mathbf{V_3 B_2 M_2}$	Solan Lalima + Black Polythene + NPK 75% + *Azotobacter* (1g/plant) + PSB (1g/plant)

Preparation of nursery beds and sowing of seeds

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 and thereafter covered with a mixture of sand + FYM and finally the beds were covered with a layer of dried grass and watered with the help of rose-can. Regular watering was done of the manured bed to maintain proper moisture for the growing of seedling after complete germination of seeds,

dry grass was removed to expose the tender seedling to sunlight for better growth. Nurseries were kept weed free by way of hand weeding and to prevent the attack of damping off. One drenching of Diathane M-45@ 0.25 % + Bavistin @ 0.1% was given when the plants were 15 days old.

Field preparation

The experimental field was thoroughly ploughed with the help of tractor followed by planking 15 days prior to actual date of transplanting. Stones, pebbles and residues of previous crop were removed manually. Field was levelled and sufficient provision for drainage was made.

Fertilizers application

FYM

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.

NPK

The complete dose of phosphorus and potassium and 1/3 dose of nitrogen was applied at the time of field preparation as basal dose and the rest of nitrogen was applied in two equal doses viz. one month after transplanting and again two month after transplanting. These were applied through NPK grade complex (12:32:16) at the rate of 500kg/ha and remaining quantity of nitrogen were given by calcium ammonium nitrate.

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.

Application of biofertilizers

Biofertilizers (*Azotobacter* and Phosphorus Solubilizing Bacteria - PSB) for conducting the experiment were procured from National Fertilizers Limited, New Delhi. 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.

Mulch materials

Black polyethylene mulch of 50µ (200 gauge thickness) and dry pine needle mulch were applied in plots according to the treatment combinations.

Training

After the transplants had fully established, the lateral shoots were pinched out to keep two main shoots. Regular pinching of side shoots was done throughout the growing season.

Aftercare of crop

Three hand weedings were done at different intervals during the crop growth period to keep the crop free from weeds. Irrigations were given as per the crop requirement. Crop was sprayed with Ridomil, Diathane M-45 (0.25%) and Blitox@ 0.3% before the onset of monsoon and then 2 or 3 sprays were applied at 15 days interval for managing *Phytophthora* blight and fruit rot. Yellow sticky traps were installed at the top of the crop canopy and simultaneously spray of Nemacide (0.02%) was done from time to time for the control of fruit fly attack. All other cultural practices as recommended in Package of Practice for Vegetable Crops (Annonymous, 2009) were followed to ensure a good crop stand.

OBSERVATIONS RECORDED

The data were recorded on ten randomly selected plants for all the characters except quality attributes for which a composite sample of ten fruits in

Black polythene mulch

Pine needles mulch

No mulch

Plate 1. Different mulch treatments given to the tomato plants

each plots at second harvest was used. The observations were recorded for following parameters:-

Days to first flowering

This observation was recorded by visiting the experimental field everyday and number of days were counted from the date of transplanting to the day when first flower appeared.

Days to first harvest

The data on which the first harvest of fruits was recorded. From this, the days taken to first harvest of fruits from the date of transplanting were calculated.

Harvest duration (days)

Harvest duration constituted the number of days from first fruit picking to last fruit picking.

Plant height (cm)

Plant height of 10 randomly selected plants in each treatment was measured from the ground level to the highest tip of the plant at the end of the crop season and mean was worked out.

Number of fruits per plant

The marketable fruits harvested from selected plants were counted at each harvest and averaged to obtain the number of fruits per plant.

Fruit yield per plant (kg)

The pickings were made at half ripe stage and rounded up for computing fruit yield per plant. Fruit yield was recorded at every picking in kilogram and later added up to get the total yield per plant.

Fruit yield per plot (kg)

Yield per plot was recorded in kg by summing up the yield of all the selected plants accommodated in each plot under each treatment.

Fruit yield per ha (q)

Yield per hectare was recorded in quintals and determined by average number of yield per plant into total number plants in per hectare.

Fruit length (cm)

Ten fruits were taken randomly at the second harvest and their polar length measured in centimeters with the help of vernier calliper. The mean of ten such readings formed the basis to record fruit length (cm).

Fruit width (cm)

Ten fruits were taken randomly and width was measured in centimeters with the help of vernier caliper. Mean of ten readings constituted the basis for width in centimeters

Average fruit weight (g)

The average fruit weight was obtained by dividing the total fruit yield by total number of fruits of selected plants.

Pericarp thickness (mm)

Pericarp thickness of ten randomly picked fruits were measured after cutting the fruits transversely. The measurement was done with digital vernier calliper in millimeters and mean values for pericarp thickness were worked out.

Total soluble solids (°Brix)

The randomly taken ten ripe tomato fruits at second harvest were crushed and their juice was passed through a double layer of fine mesh cheese cloth. A drop of juice was placed on plate of Erma Hand Refrectometer (0 to 32 ranges) and the reading was recorded. The mean of ten readings was averaged for individual treatment.

Titratable acidity (%)

25 ml of fruit juice was thoroughly mixed with distilled water in a waring blender, volume made up to 250 ml and filtered through whatman No.1 filter to obtain a clear solution. 25 ml of this solution was titrated against N/10 NaOH equivalent to 0.064 g of anhydrous citric acid by using phenolphthalein as an indicator. The value were expressed in percentage of titratable acidity in juice.

Ascorbic acid content (mg per 100 g)

The ascorbic acid content were determined by 2,6- dichlorophenol indophenol visual titration method as described by Ranganna (1986). Aliquotes prepared by macerating freshly harvested fully ripe tomato fruits in the presence of 3% metaphosphoric acid and titrated against 2,6- dichlorophenol indophenol dye to pink end point persisting at least for 15 seconds. The ascorbic acid content calculated by means of the following formula:

$$\text{mg of ascorbic acid per 100 gm of fresh tissue} = \frac{\text{Titre} \times \text{Dye factor}}{\text{Aliquot of extract taken for estimation}} \times \frac{\text{Volume made up}}{\text{Volume of sample taken for estimation}} \times 100$$

Lycopene content (mg per 100g)

Lycopene content of ripe tomato fruits was determined according to method described by Rangana (1986) and was expressed as mg per 100g of fruit weight. Tomato pulp was repeatedly extracted with acetone using pestle and mortar until the residue was colourless. The acetone extracts were transferred to a separating funnel containing about 20 ml of 5 % sodium sulphate solution, then two layers appeared. These layer were separated and petroleum ether extracts were kept in brown bottle containing about 10 g anhydrous sodium sulphate. Petroleum ether extracts were then decanted into 100 ml volumetric flask and absorbance was measured in Spectrophotometer at 503 nm using petroleum ether as blank.

Fruit firmness (g per 0.503cm^2)

An objective value fruit firmness was obtained by use of fruit pressure tester model FT011 manufactured by EFFEGI48011, Afonsine, Italy was used to measure this trait. Vine ripe fruits at full pink stage were randomly picked and pressure was applied with plunger after peeling a bit of outer skin and recorded in g/0.503cm^2 surface area. Average of ten fruits were taken/treatments.

Shelf life (days)

The ten ripe fruits of each treatment were kept at room temperature (28±2^{o}C) and their firmness was recorded at harvest and subsequently after a gap

of two days till when the firmness dropped below 500g per 0.503 cm^2. The rest of the fruits rendered unmarketable were discarded. The number of days were recorded and expressed as shelf life (days) till the fruits remained in marketable condition.

DISEASES PARAMETERS

Incidence of Buckeye rot (%)

Buckeye rot is a serious disease during rainy season. The incidence of buckeye rot in the percentage was recorded on per plant basis by using the following formula:

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

Severity of Bacterial leaf spot (%)

The bacterial leaf spot severity in different treatments was recorded as per the scale (Table 3.3) given by Shekhawat & Chakarvarti (1974):

Table 3.3. Severity of bacterial leaf spot were recorded as per the scale

Grade	Infected leaf area (%)	Category	Symptoms
0	0.00	Highly resistant	Apparently healthy foliage
1	<1	Resistant	Very few minute spots on leaves and fruits completely free
2	1-10	Moderately resistant	Few spots on leaves, upto 10% of leaf area necrotic. Fruits showing 1 to 2 spots
3	10.1-25	Moderately susceptible	Spots covering upto 25% of leaf and 10% of fruit area
4	25.1-50	Susceptible	Pronounced spots, covering upto 50 and 25% of leaf and fruit areas, respectively
5	>50	Highly susceptible	More than 50% of leaf and fruit areas covered under lesions. Lesions on stem, branches and petioles, defoliation starts to occuure.

The per cent severity of bacterial leaf spot was calculated according to the formula given by Mc Kinney (1923):

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

Severity of Early blight (%)

The Early blight severity in different treatments was recorded as per the scale given by Shekhawat & Chakarvarti (1974):

Table 3.4. Severity of Early blight were recorded as per the scale

Grade	Plant area infected (%)	Category
0	0.00	Highly resistant
1	0.1-15.0	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 per cent severity of early blight was calculated according to the formula given by McKinney (1923):

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

Severity of *Septoria* blight (%)

Septoria blight disease of tomato was identified on the basis of symptoms described by Strider (1985) and Horst (1997). A 0-5 scale as evolved by McKinney (1923) was used for recording the disease severity of *Septoria* blight.

Table 3.5 Severity of *Septoria* blight were recorded as per the scale

Grade	Infected leaf area (%)	Category	Symptoms
0	0.0	Highly resistant	Leaves apparently healthy with no sign of disease
1	0.1-0.5	Resistant	Leaves show slight infection on upper leaf surface
2	0.6-15.0	Moderately resistant	Small, circular, bronze or reddish purple lesion covering 15 per cent leaf area
3	16-30	Moderately susceptible	Spots coalesce together to form large area covering 30 leaf area
4	31-45	Susceptible	Leaves turn black and spots covering more than 45 per cent leaf area
5	>46.0	Highly susceptible	Leaves severely infected and spots covering more than 46 percent leaf area with formation of fruiting bodies on infected spots

The per cent severity of disease was calculated by using following formula.

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

ANALYSIS OF SOIL CHARACTERISTICS

Soil characteristics

In order to judge the fertility status of the soil, random soil samples were collected at a depth range of 0-15 cm from different spots before experimental layout from an unmanured field. Then composite sample was prepared, which was analyzed for various soil characteristics in order to get information about the physico-chemical properties of the soil. The methods employed and results obtained for important physico-chemical characteristics of the soil of the experimental area have been summarized in Table (3.6).

Table 3.6 : Physico-chemical properties of soil before planting

Particulars	Values obtained	Method Employed
A. Mechanical analysis (%)		
1. Sand	41.43	International Pipette method (Piper, 1966)
2. Silt	31.26	
3. Clay	27.31	
4. Texture	Sandy Loam	
B. Chemical analysis		
1. Soil pH	7.29	Digital pH meter
2. EC (dSm^{-1})	0.32	Conductivity meter
3. Organic carbon (%)	1.42	Walkley and Black, 1934
4. Available N (kg ha^{-1})	253.40	Alkaline Potassium Permanganate Method (Subbiah and Asija, 1956)
5. Available P (kg ha^{-1})	35.30	Olsen Method (Olsen *et al*., 1954)
6. Available K (kg ha^{-1})	346.43	Normal Neutral Ammonium Acetate Method (Merwin and Peech, 1951)

Inference: The experimental studies exhibited that soil was sandy loam in texture, rich in organic matter and having pH, EC and OC values of 7.29, 0.32 dSm^{-1} and 1.42 % respectively. The available N, P and K content was noted to be 253.40, 35.30 and 346.43 kg ha^{-1} respectively.

Available NPK

Soil sample from 10-15 cm depth was collected from the field, passed through 2 mm sieve and stored in cloth bags for chemical analysis. Available

nitrogen was determined by alkaline potassium permanganate method (Subbiah & Asija, 1956) and available phosphorus was determined by Olsen's methods (Olsen *et al*., 1954) using spectrophotometer. Available potassium was determined by ammonium acetate method using flame photometer (Jackson, 1973).

Soil pH

Soil pH was determined using 1:2.5 soil water suspension by electronic digital pH meter.

Electrical conductivity (dSm^{-1})

Electrical conductivity was determined by using electrical conductivity meter and expressed as dSm^{-1}.

Organic carbon (%)

Organic carbon was estimated using wet combustion method given by Walkely and Black (1934).

ECONOMICS OF CULTIVATION

After taking into consideration the variables as well as fixed inputs and corresponding price, the cost incurred on each treatment was worked out. Similarly, gross returns were calculated for each treatment based on market price of the produce. Net returns was then computed by deducting the cost incurred from the gross returns for each treatment. The cost benefit ratio was calculated by dividing the net returns with total cost of production.

STATISTICAL ANALYSIS

All the data pertaining to growth, yield and quality attributes were statistically analyzed as per design of experiment (Split-Split Plot Design) suggested by Gomez and Gomez (1983). The treatments mean was tested at 5 % level of significance.

Analysis of Variance

Sources of variation	Df	Mean sum of squares	Variance ratio (F value)
Replicate	r-1	Mr	Mr/Me(a)
A	α-1	Ma	Ma/ Me(a)
error(a)	(α-1)(r-1)	Me(a)	
Total	rα-1		
B	β-1	Mb	Mb/ Me(b)
AB	(α-1)(β-1)	Mab	Mab/ Me(b)
error(b)	α(β-1)(r-1)	Me(ab)	
total(b)	Rαβ		
C	λ-1	Mc	Mc/ Me(c)
AC	(α-1) (λ-1)	Mac	Mac/ Me(c)
BC	(β-1) (λ-1)	Mbc	Mbc/ Me(c)
ABC	(α-1) (β-1) (λ-1)	Mabc	Mabc/ Me(c)
error(c)	αβ(λ-1)(r-1)	Me(abc)	
Total	rαβλ-1		

Chapter-4

EXPERIMENTAL RESULTS

The present investigations entitled **"Response of tomato genotypes to different mulches and biofertilizers"** were conducted at the Experimental Farm of Horticulture Research Station, Kandaghat, Dr Y S Parmar U H F, Solan, Himachal Pradesh, during 2011 and 2012. The observations were recorded on different characters and results obtained during both the years and pooled data have been described below.

4.1 NUMBER OF DAYS TO FIRST FLOWERING

The observation recorded on number of days to first flowering has been presented in Table (4.1a, 4.1b & 4.1c). The perusal of data revealed that significant individual effect of varieties, biofertilizers and mulches during both the years and in pooled data.

Table 4.1a: Response of tomato genotypes to different mulches and biofertilizers with respect to number of days to first flowering and days to first harvest

Treatment combination	Number of days to first flowering			Number of days to first harvest		
	2011	2012	Pooled	2011	2012	Pooled
Varieties (V)						
V_1 (Naveen 2000$^+$)	43.81	43.37	43.59	73.56	63.52	68.54
V_2 (Sun-7711)	41.37	41.11	41.24	70.81	61.59	66.20
V_3 (Solan Lalima)	45.77	45.33	45.56	76.11	71.41	73.76
$CD_{0.05}$	**0.83**	**0.74**	**0.78**	**2.49**	**0.97**	**1.42**
Biofertilizers						
B_0 (NPK recommended)	44.48	43.55	44.02	74.52	66.37	70.44
B_1 (100% NPK + *Azotobacter* (1g/plant) + PSB (1g/plant)	42.85	42.63	42.74	72.03	64.59	68.31
B_2 (75% NPK+*Azotobacter* (1g/plant)+PSB(1g/plant)	43.63	43.63	43.63	73.93	65.55	69.74
$CD_{0.05}$	**0.73**	**0.42**	**0.44**	**0.54**	**0.41**	**0.32**
Mulches (M)						
M_0 (No Mulch)	44.88	44.55	44.72	75.29	67.37	71.33
M_1 (Pine needle)	43.33	43.07	43.20	73.11	65.04	69.07
M_2 (Black polyethylene)	42.74	42.18	42.46	72.07	64.11	68.09
$CD_{0.05}$	**0.78**	**0.42**	**0.48**	**0.87**	**0.67**	**0.48**

In the individual effect, pooled analysis showed that the variety V_2 (Sun-7711) exhibited minimum number of days to first flowering (41.24) while the variety V_3 (Solan Lalima) exhibited maximum number of days to first flowering (45.56). Among the biofertilizers, minimum number of days to first flowering (42.74) were taken by B_1, while B_0 took maximum number of days (44.02) to first flowering.

The pooled data of various mulches used revealed that M_2 (Black polythene) recorded minimum number of days to first flowering (42.46) and M_0 (No mulch) took maximum number of days to first flowering (44.72). The first order as well as second order interaction did not show any significant differences during both the years of study.

Table 4.1b: Effect of different interactions V x B, B x M and V x M number of days to first flowering and days to first harvest

Treatment combination	Number of days to first flowering			Number of days to first harvest		
	2011	2012	Pooled	2011	2012	Pooled
$V_1 B_0$	44.55	43.88	44.22	74.22	64.78	69.50
$V_1 B_1$	42.77	42.66	42.72	72.44	62.44	67.44
$V_1 B_2$	44.11	43.55	43.83	74.00	63.33	68.67
$V_2 B_0$	41.88	40.889	41.39	71.56	62.00	66.78
$V_2 B_1$	40.77	40.44	40.61	69.22	61.00	65.11
$V_2 B_2$	41.44	42.00	41.72	71.67	61.77	66.72
$V_3 B_0$	47.00	45.89	46.44	77.78	72.33	75.06
$V_3 B_1$	45.00	44.77	44.89	74.44	70.33	72.39
$V_3 B_2$	45.33	45.33	45.33	76.11	71.56	73.83
$CD_{0.05}$	NS	NS	NS	NS	NS	NS
$B_0 M_0$	46.11	45.00	45.56	76.67	68.44	72.56
$B_0 M_1$	44.11	43.33	43.72	73.89	66.00	69.94
$B_0 M_2$	43.22	42.33	42.78	73.00	64.67	68.83
$B_1 M_0$	43.88	44.00	43.94	73.89	66.22	70.06
$B_1 M_1$	42.66	42.44	42.56	71.77	64.00	67.89
$B_1 M_2$	42.00	41.44	41.72	70.44	63.56	67.00
$B_2 M_0$	44.66	44.67	44.67	75.33	67.44	71.39
$B_2 M_1$	43.22	43.44	43.33	73.67	65.11	69.39
$B_2 M_2$	43.00	42.77	42.89	72.78	64.11	68.44
$CD_{0.05}$	NS	NS	NS	NS	NS	NS
$V_1 M_0$	45.44	44.78	45.11	75.78	66.33	71.06
$V_1 M_1$	43.33	43.33	43.33	72.88	62.22	67.56
$V_1 M_2$	42.66	42.00	42.33	72.00	62.00	67.00
$V_2 M_0$	42.66	42.11	42.39	71.78	62.44	67.11
$V_2 M_1$	41.22	41.00	41.11	70.44	61.56	66.00
$V_2 M_2$	40.22	40.22	40.22	70.22	60.77	65.50
$V_3 M_0$	46.55	46.78	46.67	78.33	73.33	75.83
$V_3 M_1$	45.44	44.89	45.17	76.00	71.33	73.67
$V_3 M_2$	45.33	44.33	44.83	74.00	69.56	71.78
$CD_{0.05}$	NS	NS	NS	NS	NS	NS

4.2 NUMBER OF DAYS TO FIRST HARVEST

The results obtained on number of days to first harvest has been presented in Table (4.1a, 4.1b & 4.1c) which show significant individual effects of varieties, biofertilizers and mulches. The first and second order of interactions were found to be non-significant.

In the individual effect, pooled analysis showed that the minimum number (66.20) of days to first harvest were recorded with V_2 (Sun-7711). On the contrary maximum number of days (73.76) to first harvest were recorded with V_3 (Solan Lalima). Among different biofertilizers, B_1 took minimum days (68.31) while B_0 took maximum days (70.44) to first harvest. Further, the pooled data of various mulches showed that M_2 (Black polythene) took minimum (68.09) while M_0 (No mulch) took maximum number (71.33) of days to first harvest.

Table 4.1c: Effect of V x B x M interaction number of days to first flowering and days to first harvest

Treatment combination	Number of days to first flowering			Number of days to first Harvest		
	2011	2012	Pooled	2011	2012	Pooled
$V_1B_0M_0$	46.33	45.67	46.00	77.67	67.67	72.67
$V_1B_0M_1$	44.00	43.67	43.83	73.33	63.67	68.50
$V_1B_0M_2$	43.33	42.33	42.83	71.67	63.00	67.33
$V_1B_1M_0$	44.33	44.00	44.17	74.33	65.00	69.67
$V_1B_1M_1$	42.33	42.67	42.50	72.00	61.00	66.50
$V_1B_1M_2$	41.67	41.33	41.50	71.00	61.33	66.17
$V_1B_2M_0$	45.67	44.67	45.17	75.33	66.33	70.83
$V_1B_2M_1$	43.67	43.67	43.67	73.33	62.00	67.67
$V_1B_2M_2$	43.00	42.33	42.67	73.33	61.67	67.50
$V_2B_0M_0$	43.33	42.00	42.67	72.33	63.00	67.67
$V_2B_0M_1$	42.00	41.00	41.50	71.00	62.00	66.50
$V_2B_0M_2$	40.33	39.67	40.00	71.33	61.00	66.17
$V_2B_1M_0$	42.00	41.67	41.83	70.33	61.67	66.00
$V_2B_1M_1$	40.33	40.33	40.33	69.00	61.00	65.00
$V_2B_1M_2$	40.00	39.33	39.67	68.33	60.33	64.33
$V_2B_2M_0$	42.67	42.67	42.67	72.67	62.67	67.67
$V_2B_2M_1$	41.33	41.67	41.50	71.33	61.67	66.50
$V_2B_2M_2$	40.33	41.67	41.00	71.00	61.00	66.00
$V_3B_0M_0$	48.67	47.33	48.00	80.00	74.67	77.33
$V_3B_0M_1$	46.33	45.33	45.83	77.33	72.33	74.83
$V_3B_0M_2$	46.00	45.00	45.50	76.00	70.00	73.00
$V_3B_1M_0$	45.33	46.33	45.83	77.00	72.00	74.50
$V_3B_1M_1$	45.33	44.33	44.83	74.33	70.00	72.17
$V_3B_1M_2$	44.33	43.67	44.00	72.00	69.00	70.50
$V_3B_2M_0$	45.67	46.67	46.17	78.00	73.33	75.67
$V_3B_2M_1$	44.67	45.00	44.83	76.33	71.67	74.00
$V_3B_2M_2$	45.67	44.33	45.00	74.00	69.67	71.83
$CD_{0.05}$	NS	NS	NS	NS	NS	NS

4.3 HARVEST DURATION (days)

The results obtained on harvest duration, presented in Table (4.2a) a show significant individual effect of varieties, biofertilizers and mulches. The first order interactions V×B, B×M and V×M were also found significant for this character and results have been presented in Table 4.2b. The second order interaction between V×B×M has also recorded significant effect and hvee been presented in Table 4.2c.

In the individual effect, poled data analysis showed that the variety V_2 (Sun-7711) exhibited maximum harvest duration (61.74 days) while the variety V_1 (Naveen2000$^+$) recorded minimum harvest duration (45.57 days). Among different biofertilizers, B_1 recorded maximum harvest duration (55.46 days) and B_0 was noticed minimum harvest duration (52.63 days). Further, the pooled data analysis of different mulches revealed that maximum harvest duration (55.37 days) was obtained with M_2 (Black polythene) while M_0 (No mulch) recorded minimum harvest duration (52.72 days).

Table 4.2a: Response of tomato genotypes to different mulches and biofertilizers with respect to harvest duration and fruit weight

Treatment combination	Harvest duration (Days)			Plant height (m)		
	2011	2012	Pooled	2011	2012	Pooled
Varieties (V)						
V_1 (Naveen 2000$^+$)	68.34	71.69	70.02	2.00	1.95	1.98
V_2 (Sun-7711)	81.10	82.55	81.83	2.27	2.13	2.20
V_3 (Solan Lalima)	74.22	75.37	74.80	2.32	2.20	2.26
$CD_{0.05}$	**1.81**	**0.36**	**0.99**	**0.01**	**0.01**	**0.01**
Biofertilizers						
B_0(NPK recommended)	73.57	74.65	74.11	2.13	2.05	2.09
B_1 (100% NPK+*Azotobacter* (1g/plant)+PSB(1g/plant)	75.80	78.16	76.98	2.20	2.10	2.12
B_2 (75% NPK+*Azotobacter* (1g/plant)+PSB(1g/plant)	74.30	76.80	75.55	2.24	2.13	2.17
$CD_{0.05}$	**0.52**	**0.73**	**0.51**	**0.01**	**0.01**	**0.01**
Mulches (M)						
M_0 (No Mulch)	73.33	75.18	74.25	2.04	1.96	2.00
M_1 (Pine needle)	74.54	76.65	75.59	2.16	2.07	2.12
M_2 (Black polyethylene)	75.80	77.79	76.79	2.38	2.25	2.32
$CD_{0.05}$	**0.34**	**0.45**	**0.31**	**0.01**	**0.01**	**0.01**

In V×B interaction, treatment combination V_2B_1 registered maximum (82.63) days for harvest duration (60.74 kg/ha) whereas minimum (68.66) in

V_1B_0. The interaction effect between biofertilizers and mulches on this trait was found to be significant the maximum harvest duration (77.91days) was obtained with B_1M_2 and minimum (72.79days) harvest duration was recorded in B_0M_0. Further with regard to V×M, V_2M_2 exhibited maximum (82.86) days for harvest duration while V_1M_0 recorded minimum (68.39) days for this trait.

Table 4.2b: Effect of different interactions V x B, B x M and V x M harvest duration and fruit weight in tomato

Treatment combination	Harvest duration (Days)			Plant height (m)		
	2011	2012	Pooled	2011	2012	Pooled
$V_1 B_0$	67.41	69.90	68.66	1.91	1.88	1.89
$V_1 B_1$	69.16	73.51	71.34	2.12	2.06	2.09
$V_1 B_2$	68.44	71.66	70.05	1.96	1.91	1.94
$V_2 B_0$	80.83	81.37	81.10	2.19	2.10	2.15
$V_2 B_1$	82.00	83.26	82.63	2.16	2.07	2.11
$V_2 B_2$	80.49	83.02	81.76	2.45	2.22	2.34
$V_3 B_0$	72.45	72.68	72.57	2.30	2.15	2.23
$V_3 B_1$	76.23	77.71	76.97	2.33	2.27	2.30
$V_3 B_2$	73.98	75.73	74.85	2.32	2.16	2.24
$CD_{0.05}$	**0.90**	**1.26**	**0.89**	**0.02**	**0.01**	**0.01**
$B_0 M_0$	71.83	73.76	72.79	2.00	1.93	1.97
$B_0 M_1$	73.75	74.68	74.22	2.09	1.99	2.04
$B_0 M_2$	75.12	75.52	75.32	2.31	2.22	2.27
$B_1 M_0$	75.24	76.68	75.96	2.01	1.93	1.97
$B_1 M_1$	75.63	78.49	77.06	2.18	2.13	2.15
$B_1 M_2$	76.51	79.30	77.91	2.43	2.33	2.38
$B_2 M_0$	72.91	75.08	73.99	2.10	2.01	2.05
$B_2 M_1$	74.23	76.78	75.51	2.22	2.09	2.16
$B_2 M_2$	75.76	78.55	77.16	2.41	2.20	2.30
$CD_{0.05}$	**0.60**	**0.76**	**0.54**	**0.01**	**0.01**	**0.01**
$V_1 M_0$	66.72	70.07	68.39	1.89	1.84	1.87
$V_1 M_1$	68.57	71.81	70.19	1.94	1.88	1.91
$V_1 M_2$	69.73	73.19	71.46	2.16	2.13	2.15
$V_2 M_0$	80.07	81.98	81.03	2.11	2.01	2.06
$V_2 M_1$	80.71	82.48	81.59	2.30	2.14	2.22
$V_2 M_2$	82.53	83.19	82.86	2.40	2.24	2.32
$V_3 M_0$	73.19	73.47	73.33	2.11	2.02	2.07
$V_3 M_1$	74.34	75.65	75.00	2.25	2.19	2.22
$V_3 M_2$	75.13	76.99	76.06	2.58	2.38	2.48
$CD_{0.05}$	**0.60**	**0.76**	**0.54**	**0.01**	**0.01**	**0.01**

Data in Table 4.2c clearly indicated the significant effect of V×B×M interaction on harvest duration of tomato fruit. Maximum harvest duration (83.31days) was observed with treatment combination $V_2B_1M_2$. However minimum harvest duration (67.46 days) was recorded with treatment combination $V_1B_0M_0$.

4.4 PLANT HEIGHT (m)

The results obtained on plant height has been presented in Table (4.3a) which shows significant individual effect of varieties, biofertilizers and mulching. The first order as well as second order interaction for this trait recorded non-significant differences between treatments in Table (4.3b & 4.3c).

Table 4.2c: Effect of V x B x M interaction harvest duration and fruit weight in tomato

Treatment combination	Harvest duration (Days)			Plant height (m)		
	2011	2012	Pooled	2011	2012	Pooled
$V_1B_0M_0$	65.61	69.31	67.46	1.79	1.82	1.81
$V_1B_0M_1$	67.49	69.43	68.46	1.75	1.78	1.76
$V_1B_0M_2$	69.15	70.96	70.05	2.10	2.12	2.11
$V_1B_1M_0$	67.95	70.61	69.28	1.95	2.02	1.99
$V_1B_1M_1$	70.01	74.24	72.13	2.01	2.12	2.06
$V_1B_1M_2$	69.53	75.67	72.60	2.22	2.22	2.22
$V_1B_2M_0$	66.60	70.28	68.44	1.79	1.81	1.80
$V_1B_2M_1$	68.22	71.76	69.99	1.87	1.91	1.89
$V_1B_2M_2$	70.50	72.93	71.72	2.08	2.15	2.12
$V_2B_0M_0$	79.11	81.07	80.09	2.00	2.03	2.01
$V_2B_0M_1$	80.97	81.20	81.09	2.10	2.23	2.17
$V_2B_0M_2$	82.40	81.85	82.13	2.20	2.32	2.26
$V_2B_1M_0$	81.29	83.50	82.40	1.79	1.94	1.87
$V_2B_1M_1$	81.45	82.92	82.18	2.14	2.21	2.17
$V_2B_1M_2$	83.26	83.35	83.31	2.28	2.32	2.30
$V_2B_2M_0$	79.82	81.39	80.60	2.24	2.36	2.30
$V_2B_2M_1$	79.71	83.31	81.51	2.19	2.45	2.32
$V_2B_2M_2$	81.94	84.38	83.16	2.22	2.55	2.39
$V_3B_0M_0$	70.76	70.91	70.83	2.01	2.15	2.08
$V_3B_0M_1$	72.80	73.40	73.10	2.11	2.25	2.18
$V_3B_0M_2$	73.81	73.74	73.78	2.35	2.49	2.42
$V_3B_1M_0$	76.50	75.94	76.22	2.06	2.06	2.06
$V_3B_1M_1$	75.44	78.30	76.87	2.25	2.20	2.23
$V_3B_1M_2$	76.74	78.88	77.81	2.50	2.73	2.61
$V_3B_2M_0$	72.32	73.57	72.95	1.99	2.13	2.06
$V_3B_2M_1$	74.78	75.26	75.02	2.21	2.30	2.25
$V_3B_2M_2$	74.84	78.35	76.60	2.29	2.52	2.40
$CD_{0.05}$	**1.03**	**1.36**	**0.93**	**0.02**	**0.02**	**0.02**

Individual effects, pooled data of both the years show that the variety V_3 (Solan Lalima) had maximum plant height (2.11m) while V_1 (Naveen 2000^+) recorded minimum height of 1.88m. Among different biofertilizers, B_2 exhibited maximum plant height (2.17m) and B_0 was observed minimum (2.09m) plant height. Similarly plant height was significantly affected by various mulching treatments. The maximum plant height (2.19m) was observed with black polythene mulch while M_0 (No mulch) gave minimum plant height (1.88m).

The data in Table 4.3b revealed that in the interaction between variety and biofertilizers, treatment combination V_2B_2 recorded maximum plant height (2.34m) which was statistically superior to all other treatments. Minimum value (1.89m) was observed with V_1B_0. Further treatment combination B_1M_2 recorded maximum plant height (2.38m), whereas minimum (1.97m) was found with B_0M_0. In the interaction between variety and mulch treatment combination V_3M_2 recorded maximum plant height (2.48m) and was found statistically superior to all other treatments.V_1M_o recorded minimum value (1.87m) for this trait.

The second order interaction between different varieties, biofertilizers and mulch materials had also significant differences for plant height. The pooled analysis of data in the experiment of both the year revealed that maximum plant height (2.61m) was obtained with treatment combination $V_3B_1M_2$. Minimum plant height (1.81m) was recorded by treatment combination $V_1B_0M_0$.

4.5 NUMBER OF FRUITS/PLANT

The results obtained on number of fruits/plant have been presented in Table (4.3a) which shows significant individual effects of varieties, biofertilizers and mulch. Among first order interaction V×B, V×M and B×M showed significant effect on number of fruits/plant during both the year and pooled data of study (Table 4.3b). The second order V×B×M for this trait also recorded significant differences between treatments (Table 4.3c).

In individual effects, pooled data of both the years show that the variety V_3 (Solan Lalima) recorded maximum number of fruits/plant (38.00) while

minimum (29.85) was recorded with V_1 (Naveen 2000$^+$). Similarly number of fruits/plant was significantly affected by biofertilizers. The maximum number of fruits/plant (38.01) was observed with B_1, while B_0 recorded minimum number of fruits/plant (29.99). With regard to mulches, M_2 (Black polythene) recorded maximum number of fruits/plant (36.16) while minimum (32.67) was observed with M_0 (No mulch).

Table 4.3a: Response of tomato genotypes to different mulches and biofertilizers with respect to number of fruit/plant and yield (kg/plant)

Treatment combination	Number of fruit/plant			Yield (kg/plant)		
	2011	2012	Pooled	2011	2012	Pooled
Varieties (V)						
V_1 (Naveen 2000$^+$)	29.70	29.99	29.85	2.28	2.39	2.34
V_2 (Sun-7711)	36.91	34.40	35.66	3.07	2.94	3.00
V_3 (Solan Lalima)	33.81	42.18	38.00	2.21	2.81	2.51
$CD_{0.05}$	**0.08**	**0.14**	**0.10**	**0.02**	**0.01**	**0.01**
Biofertilizers						
B_0 (NPK recommended)	28.38	31.59	29.99	2.09	2.36	2.22
B_1 (100% NPK+*Azotobacter* (1g/plant)+PSB(1g/plant)	32.16	38.85	35.50	2.47	3.04	2.76
B_2 (75% NPK+*Azotobacter* (1g/plant)+PSB(1g/plant)	39.89	36.13	38.01	3.00	2.74	2.87
$CD_{0.05}$	**0.07**	**0.20**	**0.11**	**0.01**	**0.02**	**0.01**
Mulches (M)						
M_0 (No Mulch)	31.65	33.68	32.67	2.30	2.47	2.39
M_1 (Pine needle)	33.58	35.75	34.67	2.54	2.74	2.64
M_2 (Black polyethylene)	35.19	37.13	36.16	2.73	2.93	2.83
$CD_{0.05}$	**0.09**	**0.26**	**0.13**	**0.01**	**0.02**	**0.01**

In V×B interaction, V_3B_2 gave the maximum number of fruits/plant (41.43) which was followed by V_2B_2 and V_3B_1 recording 39.14 and 39.12 number of fruits/plant. Biofertilizers and mulch interaction were also found significant for this traits. The maximum number of fruits/plant (39.80) was recorded with $B_2 M_2$ which was followed by B_2M_1 and B_1M_2 recording 38.39 and 37.28 number of fruits/plant respectively. 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) while the interaction V_1M_0 recorded minimum number of fruits/plant (28.30).

The second order interactions, i.e. V×B×M, the maximum number of fruits/plant (34.34) was recorded with $V_3B_1M_2$ while the minimum number of fruits/plant (24.04) was recorded with $V_1B_0M_0$.

4.6 YIELD (kg/plant)

The results obtained on fruit yield has been presented in Table (4.3a) which shows significant individual effect of varieties, biofertilizers and mulches. The first order interactions V×B, B×M and V×M were found significant and results have been presented in Table (4.3b). The second order interactions V × B × M has also significant effect of the fruit yield kg/plant (Table 4.3c).

Table 4.3b: Effect of different interactions V x B, B x M and V x M number of fruit/plant and yield (kg/plant) in tomato

Treatment combination	Number of fruit/plant			Yield (kg/plant)		
	2011	2012	Pooled	2011	2012	Pooled
$V_1 B_0$	24.51	25.71	25.11	1.86	1.98	1.92
$V_1 B_1$	28.95	32.99	30.97	2.26	2.72	2.49
$V_1 B_2$	35.65	31.28	33.46	2.72	2.48	2.60
$V_2 B_0$	31.53	31.30	31.41	2.57	2.63	2.60
$V_2 B_1$	35.32	37.51	36.41	2.99	3.27	3.13
$V_2 B_2$	43.90	34.38	39.14	3.65	2.92	3.28
$V_3 B_0$	29.10	37.77	33.44	1.85	2.46	2.15
$V_3 B_1$	32.21	46.04	39.12	2.17	3.13	2.65
$V_3 B_2$	40.11	42.74	41.43	2.63	2.84	2.73
$CD_{0.05}$	**0.13**	**0.35**	**0.18**	**0.01**	**0.02**	**0.01**
$B_0 M_0$	26.80	30.26	28.53	1.92	2.19	2.05
$B_0 M_1$	28.27	31.77	30.02	2.09	2.36	2.23
$B_0 M_2$	30.07	32.74	31.41	2.27	2.52	2.39
$B_1 M_0$	30.54	36.73	33.63	2.25	2.74	2.50
$B_1 M_1$	32.30	38.88	35.59	2.49	3.05	2.77
$B_1 M_2$	33.64	40.93	37.28	2.68	3.33	3.00
$B_2 M_0$	37.61	34.05	35.83	2.73	2.49	2.61
$B_2 M_1$	40.18	36.61	38.39	3.03	2.79	2.91
$B_2 M_2$	41.87	37.73	39.80	3.25	2.95	3.10
$CD_{0.05}$	**0.15**	**0.45**	**0.22**	**0.01**	**0.03**	**0.02**
$V_1 M_0$	28.40	28.19	28.30	2.10	2.15	2.13
$V_1 M_1$	29.64	30.10	29.87	2.29	2.41	2.35
$V_1 M_2$	31.06	31.68	31.38	2.46	2.61	2.54
$V_2 M_0$	35.05	33.02	34.04	2.84	2.74	2.79
$V_2 M_1$	36.67	34.59	35.63	3.06	2.96	3.01
$V_2 M_2$	39.02	35.57	37.30	3.32	3.12	3.22
$V_3 M_0$	31.50	39.83	35.66	1.95	2.52	2.24
$V_3 M_1$	34.43	42.56	38.50	2.27	2.83	2.55
$V_3 M_2$	35.49	44.14	39.82	2.42	3.06	2.74
$CD_{0.05}$	**0.15**	**0.45**	**0.22**	**0.01**	**0.03**	**0.02**

Highest fruit yield (3.00 kg/plant) was observed with V_2 (Sun-7711) while lowest yield (2.34 kg/plant) was recorded with V_1 (Naveen 2000^+). Biofertilizers affected the fruit yield significantly B_2 recorded the highest yield (2.87 kg/plant) while the lowest yield (2.22 kg/plant) was observed with B_0. Among various mulches, M_2 (Black polythene) showed the highest yield (2.83 kg/plant) while least yield (2.39 kg/plant) was observed with M_0 (No mulch).

Table 4.3c: Effect of V x B x M interaction number number of fruit/plant and yield (kg/plant) in tomato

Treatment combination	Number of fruit/plant			Yield (kg/plant)		
	2011	2012	Pooled	2011	2012	Pooled
$V_1B_0M_0$	23.63	24.45	24.04	1.74	1.82	1.78
$V_1B_0M_1$	24.45	26.14	25.30	1.86	1.99	1.93
$V_1B_0M_2$	25.46	26.54	26.00	1.99	2.12	2.05
$V_1B_1M_0$	27.24	31.28	29.26	2.05	2.43	2.24
$V_1B_1M_1$	29.11	32.50	30.81	2.29	2.71	2.50
$V_1B_1M_2$	30.49	35.20	32.85	2.45	3.03	2.74
$V_1B_2M_0$	34.34	28.84	31.59	2.52	2.21	2.36
$V_1B_2M_1$	35.37	31.67	33.52	2.71	2.53	2.62
$V_1B_2M_2$	37.24	33.32	35.28	2.93	2.69	2.81
$V_2B_0M_0$	29.83	29.67	29.75	2.36	2.44	2.40
$V_2B_0M_1$	31.19	31.52	31.35	2.56	2.65	2.61
$V_2B_0M_2$	33.56	32.71	33.13	2.79	2.81	2.80
$V_2B_1M_0$	33.80	36.16	34.98	2.79	3.05	2.92
$V_2B_1M_1$	35.02	37.56	36.29	2.96	3.27	3.12
$V_2B_1M_2$	37.14	38.81	37.98	3.22	3.47	3.35
$V_2B_2M_0$	41.53	33.25	37.39	3.36	2.73	3.04
$V_2B_2M_1$	43.80	34.69	39.25	3.65	2.96	3.30
$V_2B_2M_2$	46.37	35.20	40.78	3.94	3.06	3.50
$V_3B_0M_0$	26.94	36.68	31.81	1.65	2.30	1.98
$V_3B_0M_1$	29.17	37.64	33.41	1.86	2.44	2.15
$V_3B_0M_2$	31.19	38.99	35.09	2.03	2.62	2.33
$V_3B_1M_0$	30.58	42.74	36.66	1.91	2.74	2.33
$V_3B_1M_1$	32.76	46.60	39.68	2.24	3.17	2.70
$V_3B_1M_2$	33.28	48.77	41.03	2.36	3.48	2.92
$V_3B_2M_0$	36.97	40.07	38.52	2.29	2.53	2.41
$V_3B_2M_1$	41.37	43.46	42.42	2.72	2.89	2.81
$V_3B_2M_2$	42.00	44.67	43.34	2.87	3.10	2.98
$CD_{0.05}$	**0.26**	**0.77**	**0.38**	**0.02**	**0.03**	**0.03**

In V×B interactions, V_2B_2 recorded highest yield (3.28 kg/plant) which was followed by V_2B_1 recording (3.13 kg/plant) and least yield (1.92 kg/plant) was noticed with V_1B_0. Among B×M interactions, B_2M_2 noticed highest fruit yield (3.10 kg/plant) while lowest yield (2.05 kg/plant) was recorded with B_0M_0. Further in the V×M interactions, V_2M_2 showed highest fruit yield (3.22 kg/plant) while V_1M_0 recorded least yield (2.13 kg/plant).

The second order interaction between different varieties, biofertilizers and mulch materials has also significant differences for yield (kg/plant). The pooled analysis of data in the experiment of both the year revealed that maximum yield (3.50 kg/plant) was obtained with treatment combination $V_2B_2M_2$. Minimum yield (1.78 kg/plant) was recorded by treatment combination $V_1B_0M_0$.

4.7 YIELD (kg/plot)

The observation recorded on yield (kg/plot) has been presented in Table 4.4a. The perusal of data revealed significant individual effect of varieties, biofertilizers and mulches during both the years and in pooled data. The first order interactions V×B, B×M and V×M were also found significant for this character and results have been presented in Table 4.4b. The second interaction between V×B×M has also recorded significant effect of yield (kg/plot) presented in Table 4.4c.

In the individual effect, pooled analysis showed that the variety V_2 (Sun-7711) recorded the maximum yield (54.08 kg/plot) while the variety V_1 (Naveen 2000^+) recorded minimum yield (42.07 kg/plot). Among different biofertilizers, B_2 exhibited maximum yield (51.69 kg/plot) and B_0 observed minimum yield (40.04 kg/plot). With regard to different mulches, M_2 (Black polythene) gave the maximum yield (50.96 kg/plot) while M_0 (No mulch) exhibited minimum yield of 42.93 kg/plot.

In V×B interactions, V_2B_2 gave the maximum yield (59.08 kg/plot) which was followed by V_2 B_1 (56.29 kg/plot). V_1B_0 treatment combination registered minimum yield (34.56 kg/plot). With regard to B×M interactions, B_2M_2 gave

maximum yield (55.78 kg/plot). Minimum yield (36.94 kg/plot) was registered with B_0M_0. Further, the treatment combination V_2M_2 recorded maximum yield (57.90 kg/plot), whereas, minimum yield (38.30 kg/plot) was found with V_1M_0.

Table 4.4a: Response of tomato genotypes to different mulches and biofertilizers with respect to yield (kg/plot) and yield (q/ha)

Treatment combination	Yield (kg/plot)			Yield (q/ha)		
	2011	2012	Pooled	2011	2012	Pooled
Varieties (V)						
V_1 (Naveen 2000$^+$)	41.07	43.06	42.07	676.07	708.87	692.47
V_2 (Sun-7711)	55.28	52.87	54.08	909.90	870.35	890.13
V_3 (Solan Lalima)	39.86	50.53	45.20	656.19	831.85	744.02
$CD_{0.05}$	**0.15**	**0.16**	**0.10**	**2.10**	**2.85**	**1.61**
Biofertilizers						
B_0 (NPK recommended)	37.70	42.39	40.04	620.56	697.73	659.14
B_1 (100% NPK+*Azotobacter* (1g/plant)+PSB(1g/plant)	44.52	54.69	49.61	732.91	900.30	816.61
B_2 (75% NPK+*Azotobacter* (1g/plant)+PSB(1g/plant)	53.99	49.39	51.69	888.68	813.04	850.86
$CD_{0.05}$	**0.12**	**0.28**	**0.15**	**1.93**	**4.63**	**2.53**
Mulches (M)						
M_0 (No Mulch)	41.37	44.49	42.93	680.89	732.33	706.61
M_1 (Pine needle)	45.69	49.22	47.45	752.03	810.18	781.10
M_2 (Black polyethylene)	49.16	52.77	50.96	809.24	868.57	838.90
$CD_{0.05}$	**0.11**	**0.33**	**0.17**	**1.81**	**5.49**	**2.75**

In second order interaction, the treatment combination $V_2B_2M_2$ recorded maximum yield (63.02 kg/plot) which was followed by combination $V_2B_1M_2$ (60.26 kg/plot). The minimum yield was found in $V_1B_0M_0$ (32.03 kg/plot).

The results obtained on yield (q/ha), presented in Table 4.4a, show significant individual effects of varieties, biofertilizers and mulches. The first order interactions V×B, B×M and V×M were also found significant for this character and results have been presented in Table 4.4b. The second order interactions V×B×M for this trait was also recorded significant differences between treatments (Table 4.4c). Maximum yield (890.13 q/ha) was obtained with V_2 (Sun-7711). However V_1 (Naveen 2000$^+$) showed minimum value (692.47 q/ha) for this trait. Among various biofertilizers, B_2 registered maximum yield (850.86 q/ha) while B_0 exhibited minimum value of yield (659.14 q/ha). Mulches affected yield parameter significantly. M_2 (Black polythene) showed maximum yield (838.90 q/ha) whereas minimum yield (706.61 q/ha) was registered with M_0 (No mulch).

Table 4.4b: Effect of different interactions V x B, B x M and V x M yield (kg/plot) and yield (q/ha) in tomato

Treatment combination	Yield (kg/plot)			Yield (q/ha)		
	2011	2012	Pooled	2011	2012	Pooled
$V_1 B_0$	33.54	35.59	34.56	552.06	585.87	568.96
$V_1 B_1$	40.70	49.00	44.85	669.90	806.56	738.23
$V_1 B_2$	48.98	44.60	46.79	806.25	734.17	770.21
$V_2 B_0$	46.31	47.40	46.85	762.27	780.19	771.23
$V_2 B_1$	53.83	58.75	56.29	886.16	967.08	926.63
$V_2 B_2$	65.69	52.47	59.08	1081.26	863.78	972.52
$V_3 B_0$	33.25	44.17	38.71	547.35	727.13	637.24
$V_3 B_1$	39.04	56.33	47.69	642.67	927.26	784.96
$V_3 B_2$	47.30	51.10	49.20	778.54	841.15	809.85
$CD_{0.05}$	**0.20**	**0.48**	**0.27**	**3.35**	**8.02**	**4.38**
$B_0 M_0$	34.54	39.34	36.94	568.52	647.56	608.04
$B_0 M_1$	37.70	42.51	40.10	620.57	699.76	660.16
$B_0 M_2$	40.86	45.31	43.09	672.60	745.86	709.23
$B_1 M_0$	40.51	49.34	44.92	666.74	812.12	739.43
$B_1 M_1$	44.88	54.88	49.88	738.85	903.32	821.09
$B_1 M_2$	48.18	59.87	54.02	793.13	985.47	889.30
$B_2 M_0$	49.05	44.79	46.92	807.40	737.29	772.35
$B_2 M_1$	54.47	50.27	52.37	896.68	827.44	862.06
$B_2 M_2$	58.44	53.12	55.78	961.97	874.38	918.18
$CD_{0.05}$	**0.19**	**0.58**	**0.29**	**3.13**	**9.50**	**4.76**
$V_1 M_0$	37.84	38.75	38.30	622.91	637.93	630.42
$V_1 M_1$	41.14	43.40	42.27	677.23	714.36	695.80
$V_1 M_2$	44.23	47.04	45.63	728.07	774.31	751.19
$V_2 M_0$	51.09	49.27	50.18	840.91	811.03	825.97
$V_2 M_1$	55.01	53.28	54.15	905.55	877.10	891.32
$V_2 M_2$	59.73	56.07	57.90	983.24	922.93	953.09
$V_3 M_0$	35.17	45.44	40.30	578.84	748.01	663.43
$V_3 M_1$	40.90	50.97	45.94	673.33	839.06	756.20
$V_3 M_2$	43.52	55.19	49.35	716.39	908.46	812.43
$CD_{0.05}$	**0.19**	**0.58**	**0.29**	**3.13**	**9.50**	**4.76**

4.8 YIELD (q/ha)

The data in Table 4.4b revealed that in the interaction between variety and biofertilizers, treatment combination V_2B_2 recorded maximum yield (972.52 q/ha) which is statistically superior to all other treatments. Minimum yield (568.96 q/ha) was recorded by V_1B_0. Further, the treatment combination B_2M_2 recorded maximum value (918.18 q/ha) for this trait while B_0M_0 exhibited minimum yield (608.04 q/ha). In this interaction between variety and mulches

treatment combination V_2M_2 recorded maximum yield (953.09 q/ha) whereas minimum yield (630.42 q/ha) was observed with V_1M_0.

In second order interaction, the treatment combination $V_2B_2M_2$ recorded maximum yield (1037.33 q/ha) which was followed by combination $V_2B_2M_1$ (978.22 q/ha) and minimum yield in $V_1B_0M_0$ (527.27 q/ha).

Table 4.4c: Effect of V x B x M interaction yield (kg/plot) and yield (q/ha) in tomato

Treatment combination	Yield (kg/plot)			Yield (q/ha)		
	2011	2012	Pooled	2011	2012	Pooled
$V_1B_0M_0$	31.28	32.78	32.03	514.96	539.57	527.27
$V_1B_0M_1$	33.52	35.88	34.70	551.69	590.54	571.12
$V_1B_0M_2$	35.81	38.12	36.97	589.52	627.50	608.51
$V_1B_1M_0$	36.85	43.79	40.32	606.62	720.78	663.70
$V_1B_1M_1$	41.14	48.69	44.92	677.27	801.54	739.41
$V_1B_1M_2$	44.09	54.51	49.30	725.80	897.36	811.58
$V_1B_2M_0$	45.39	39.70	42.54	747.13	653.44	700.29
$V_1B_2M_1$	48.77	45.62	47.19	802.73	751.00	776.86
$V_1B_2M_2$	52.79	48.48	50.63	868.90	798.08	833.49
$V_2B_0M_0$	42.54	43.87	43.20	700.26	722.11	711.18
$V_2B_0M_1$	46.15	47.73	46.94	759.59	785.60	772.59
$V_2B_0M_2$	50.24	50.60	50.42	826.98	832.86	829.92
$V_2B_1M_0$	50.21	54.85	52.53	826.58	902.81	864.69
$V_2B_1M_1$	53.27	58.90	56.08	876.82	969.53	923.17
$V_2B_1M_2$	58.02	62.51	60.26	955.10	1028.92	992.01
$V_2B_2M_0$	60.50	49.10	54.80	995.90	808.17	902.03
$V_2B_2M_1$	65.62	53.23	59.43	1080.23	876.18	978.20
$V_2B_2M_2$	70.93	55.10	63.02	1167.65	907.01	1037.33
$V_3B_0M_0$	29.79	41.37	35.58	490.33	681.01	585.67
$V_3B_0M_1$	33.44	43.93	38.68	550.42	723.15	636.78
$V_3B_0M_2$	36.53	47.22	41.87	601.30	777.22	689.26
$V_3B_1M_0$	34.45	49.37	41.91	567.03	812.75	689.89
$V_3B_1M_1$	40.25	57.04	48.64	662.48	938.89	800.69
$V_3B_1M_2$	42.43	62.58	52.51	698.51	1030.12	864.32
$V_3B_2M_0$	41.26	45.58	43.42	679.17	750.28	714.72
$V_3B_2M_1$	49.03	51.95	50.49	807.08	855.14	831.11
$V_3B_2M_2$	51.60	55.77	53.68	849.36	918.04	883.70
$CD_{0.05}$	**0.33**	**0.58**	**0.50**	**5.41**	**19.46**	**8.26**

4.9 FRUIT LENGTH (cm)

The results obtained on fruit length has been presented in Table 4.5a which shows significant individual effects of varieties, biofertilizers and mulches.

All the first order and second order interactions involving varieties, biofertilizers and mulches showed significant effect for this trait as presented in Table 4.5b and 4.5c respectively.

In individual effects, pooled data of both the years show that V_3 (Solan Lalima) maximum fruit length (5.50 cm) while minimum value (5.19 cm) was recorded with V_1 (Naveen 2000^+). Similarly fruit length was significantly affected by biofertilizers. The maximum fruit length (5.79 cm) in experiment was observed with B_2. However, minimum fruit length (4.62 cm) was recorded with B_0. With regard to different mulches, M_2 (Black polythene) exhibited maximum fruit length (5.65 cm) while minimum value (5.08 cm) was recorded with M_0 (No mulch).

Table 4.5a: Response of tomato genotypes to different mulches and biofertilizers with respect to fruit length and fruit breadth

Treatment combination	Fruit length (cm)			Fruit breadth (cm)		
	2011	2012	Pooled	2011	2012	Pooled
Varieties (V)						
V_1 (Naveen 2000^+)	5.17	5.21	5.19	5.44	5.48	5.36
V_2 (Sun-7711)	5.36	5.42	5.39	5.34	5.38	5.62
V_3 (Solan Lalima)	5.47	5.52	5.50	5.59	5.63	5.47
$CD_{0.05}$	**0.04**	**0.01**	**0.02**	**0.01**	**0.02**	**0.01**
Biofertilizers						
B_0 (NPK recommended)	4.59	4.63	4.62	5.55	5.59	5.02
B_1 (100% NPK+*Azotobacter* (1g/plant)+PSB(1g/plant)	5.66	5.71	5.69	5.00	5.04	5.58
B_2 (75% NPK+*Azotobacter* (1g/plant)+PSB(1g/plant)	5.75	5.80	5.79	5.82	5.87	5.85
$CD_{0.05}$	**0.03**	**0.02**	**0.01**	**0.01**	**0.01**	**0.02**
Mulches (M)						
M_0 (No Mulch)	5.06	5.10	5.08	5.24	5.28	5.27
M_1 (Pine needle)	5.33	5.38	5.36	5.46	5.50	5.48
M_2 (Black polyethylene)	5.62	5.66	5.65	5.67	5.72	5.70
$CD_{0.05}$	**0.03**	**0.01**	**0.02**	**0.02**	**0.02**	**0.01**

In V×B interaction, V_3B_2 gave the maximum fruit length (6.12 cm). V_1B_0 treatment combination registered minimum fruit length (4.63 cm). Among interaction between biofertilizers and mulches, B_2M_2 recorded maximum fruit length (6.16 cm) while B_0M_0 gave minimum value (4.49 cm) for this trait. With

regard to V×M treatment combination, V_3M_2 resulted in maximum fruit length (5.66 cm) while V_1M_0 recorded minimum fruit length (4.75 cm).

The second order interactions, i.e. V×B×M, the maximum fruit length (6.29 cm) was recorded with $V_2B_2M_2$ while the minimum fruit length (4.54 cm) was recorded with $V_1B_0M_0$.

4.10 FRUIT BREADTH (cm)

The observation recorded on fruit breadth has been presented in Table 4.5a. The perusal of data revealed significant individual effect of varieties, biofertilizers and mulch during both the years and in pooled data. The first order interactions, V×B, B×M and V×M were also found significant for this character and results have been presented in Table 4.5b. The second order interaction between V×B×M has also recorded significant effect and has been presented in Table 4.5c.

In the individual effect, pooled analysis showed that the variety V_2 (Sun-7711) recorded maximum fruit breadth (5.62 cm) while minimum fruit breadth (5.36 cm) was observed with V_1 (Naveen 2000^+). Further, pooled analysis of different biofertilizers used revealed that maximum fruit breadth (5.85 cm) was obtained with B_2 while B_0 exhibited minimum fruit breadth (5.02 cm). Among different mulch material used, M_2 (Black polythene) recorded maximum fruit breadth (5.70 cm) while minimum (5.27 cm) was recorded with M_0 (No mulch).

The data in Table 4.5b revealed that in the interaction between variety and biofertilizers, treatment combination V_2B_2 recorded maximum fruit breadth (6.01 cm). Minimum value (4.77 cm) was recorded by V_1B_0. Further, the treatment combination B_2M_2 recorded maximum average fruit breadth (6.09 cm), whereas, minimum fruit breadth (4.86 cm) was found with B_1M_0. In the interaction between variety and mulch treatment combination V_2M_2 recoded maximum fruit breadth (5.86 cm) and minimum (5.08 cm) fruit breadth in V_1M_0.

Table 4.5b: Effect of different interactions V x B, B x M and V x M fruit length and fruit breadth in tomato

Treatment combination	Fruit length (cm)			Fruit breadth (cm)		
	2011	2012	Pooled	2011	2012	Pooled
$V_1 B_0$	4.60	4.64	4.63	5.29	5.33	4.77
$V_1 B_1$	5.68	5.71	5.69	5.05	5.10	5.08
$V_1 B_2$	5.22	5.27	5.25	5.98	6.02	5.66
$V_2 B_0$	4.59	4.63	4.62	5.64	5.68	5.67
$V_2 B_1$	5.55	5.63	5.59	4.75	4.79	5.31
$V_2 B_2$	5.95	6.00	5.98	5.63	5.67	6.01
$V_3 B_0$	4.58	4.62	4.61	5.73	5.77	5.76
$V_3 B_1$	5.75	5.79	5.77	5.19	5.22	5.21
$V_3 B_2$	6.09	6.14	6.12	5.86	5.91	5.89
$CD_{0.05}$	**0.04**	**0.01**	**0.02**	**0.02**	**0.01**	**0.01**
$B_0 M_0$	4.46	4.50	4.49	5.37	5.41	5.39
$B_0 M_1$	4.61	4.65	4.64	5.51	5.54	5.53
$B_0 M_2$	4.70	4.74	4.73	5.78	5.83	5.81
$B_1 M_0$	5.32	5.35	5.34	4.83	4.88	4.86
$B_1 M_1$	5.62	5.71	5.67	4.97	5.01	4.99
$B_1 M_2$	6.03	6.07	6.06	5.18	5.22	5.21
$B_2 M_0$	5.39	5.44	5.42	5.52	5.56	5.55
$B_2 M_1$	5.75	5.79	5.78	5.88	5.93	5.91
$B_2 M_2$	6.13	6.18	6.16	6.06	6.11	6.09
$CD_{0.05}$	**0.05**	**0.01**	**0.03**	**0.01**	**0.02**	**0.01**
$V_1 M_0$	4.72	4.76	4.75	5.05	5.10	5.08
$V_1 M_1$	5.17	5.20	5.19	5.43	5.48	5.46
$V_1 M_2$	5.61	5.65	5.64	5.83	5.88	5.51
$V_2 M_0$	5.13	5.17	5.16	5.17	5.20	5.19
$V_2 M_1$	5.34	5.43	5.39	5.37	5.41	5.39
$V_2 M_2$	5.62	5.66	5.64	5.48	5.53	5.86
$V_3 M_0$	5.32	5.36	5.35	5.51	5.55	5.54
$V_3 M_1$	5.47	5.52	5.49	5.56	5.60	5.59
$V_3 M_2$	5.64	5.67	5.66	5.71	5.75	5.74
$CD_{0.05}$	**0.05**	**0.01**	**0.03**	**0.01**	**0.02**	**0.01**

The second order interaction between different varieties, biofertilizers and mulch had also recorded significant differences for fruit breadth. The pooled analysis of the data in the experiment of both the year revealed that maximum fruit breadth (6.38 cm) was obtained with treatment combination $V_2B_2M_2$. However, minimum fruit breadth (4.58 cm) was recorded by treatment combination $V_2B_0M_0$.

Table 4. 5c: Effect of V x B x M interaction fruit length and fruit breadth in tomato

Treatment combination	Fruit length (cm)			Fruit breadth (cm)		
	2011	2012	Pooled	2011	2012	Pooled
$V_1B_0M_0$	4.52	4.56	4.54	4.94	4.98	4.96
$V_1B_0M_1$	4.62	4.65	4.64	5.22	5.26	5.24
$V_1B_0M_2$	4.68	4.72	4.70	5.71	5.76	5.74
$V_1B_1M_0$	5.13	5.16	5.15	4.80	4.86	4.83
$V_1B_1M_1$	5.65	5.69	5.67	4.92	4.97	4.95
$V_1B_1M_2$	6.26	6.29	6.28	5.43	5.49	5.46
$V_1B_2M_0$	4.53	4.57	4.55	5.42	5.47	5.45
$V_1B_2M_1$	5.24	5.28	5.26	6.17	6.21	6.19
$V_1B_2M_2$	5.91	5.96	5.94	6.36	6.40	5.90
$V_2B_0M_0$	4.42	4.46	4.44	5.56	5.59	4.58
$V_2B_0M_1$	4.64	4.68	4.66	5.66	5.71	5.68
$V_2B_0M_2$	4.73	4.76	4.75	5.71	5.76	5.74
$V_2B_1M_0$	5.26	5.28	5.27	4.56	4.59	5.58
$V_2B_1M_1$	5.48	5.66	5.57	4.84	4.87	4.85
$V_2B_1M_2$	5.92	5.95	5.94	4.87	4.91	4.89
$V_2B_2M_0$	5.73	5.77	5.75	5.39	5.42	5.41
$V_2B_2M_1$	5.92	5.96	5.94	5.63	5.68	5.66
$V_2B_2M_2$	6.21	6.28	6.29	5.88	5.92	6.38
$V_3B_0M_0$	4.46	4.49	4.48	5.62	5.67	5.65
$V_3B_0M_1$	4.59	4.63	4.61	5.66	5.68	5.67
$V_3B_0M_2$	4.71	4.75	4.73	5.92	5.97	5.95
$V_3B_1M_0$	5.59	5.63	5.61	5.15	5.19	5.17
$V_3B_1M_1$	5.74	5.78	5.76	5.17	5.20	5.19
$V_3B_1M_2$	5.93	5.97	5.95	5.26	5.29	5.28
$V_3B_2M_0$	5.91	5.98	5.95	5.76	5.81	5.79
$V_3B_2M_1$	6.09	6.15	6.12	5.86	5.92	5.89
$V_3B_2M_2$	6.28	6.30	6.25	5.96	6.01	5.99
$CD_{0.05}$	**0.09**	**0.02**	**0.04**	**0.02**	**0.03**	**0.02**

4.11 FRUIT WEIGHT (g)

The results obtained on fruit weight, presented in Table (4.6a) show significant individual effect of varieties, biofertilizers and mulches. All the first order and second order interactions involving varieties, biofertilizers and mulches showed significant effect for this trait as presented in Table 4.6b and 4.6c respectively.

Among different varieties, V_2 (Sun-7711) gave the maximum (84.18 g) fruit weight, whereas minimum fruit weight (65.92 g) was obtained with V_3 (Solan Lalima). Among different biofertilizers, B_1 gave maximum fruit weight

(77.86 g) while B_0 recorded minimum fruit weight (74.46 g). Further, the pooled data analysis of different mulches revealed that maximum fruit weight (78.51 g) was obtained with M_2 (Black polythene) whereas, minimum fruit weight (73.27 g) was observed with M_0 (No mulch).

Table 4.6a: Response of tomato genotypes to different mulches and biofertilizers with respect to fruit weight and pericarp thickness

Treatment combination	Fruit weight (g)			Pericarp thickness (mm)		
	2011	2012	Pooled	2011	2012	Pooled
Varieties (V)						
V_1 (Naveen 2000$^+$)	76.70	79.43	78.08	2.79	2.82	2.81
V_2 (Sun-7711)	83.12	85.26	84.18	3.72	3.76	3.75
V_3 (Solan Lalima)	65.31	66.36	65.92	2.54	2.56	2.56
$CD_{0.05}$	**0.11**	**0.13**	**0.08**	**0.01**	**0.02**	**0.01**
Biofertilizers						
B_0 (NPK recommended)	73.61	75.28	74.46	2.97	3.00	2.99
B_1 (100% NPK+*Azotobacter* (1g/plant)+PSB(1g/plant)	76.64	79.04	77.86	3.03	3.06	3.05
B_2 (75% NPK+*Azotobacter* (1g/plant)+PSB(1g/plant)	74.92	76.73	65.84	3.05	3.08	3.07
$CD_{0.05}$	**0.07**	**0.06**	**0.08**	**0.02**	**0.01**	**0.02**
Mulches (M)						
M_0 (No Mulch)	72.32	74.13	73.27	2.98	3.01	3.00
M_1 (Pine needle)	75.41	77.25	76.35	3.01	3.05	3.04
M_2 (Black polyethylene)	77.42	79.66	78.51	3.05	3.09	3.08
$CD_{0.05}$	**0.07**	**0.05**	**0.04**	**0.01**	**0.02**	**0.01**

In V×B interactions, V_2B_1 gave the maximum fruit weight (85.79g) which was followed by V_2B_2 (83.90g). V_1B_0 treatment combination registered minimum fruit weight (76.40g). With regard to B×M interactions, B_1M_2 gave maximum fruit weight (80.80g) and minimum fruit weight (72.25g) was registered with B_0M_0. Further, the treatment combination V_2M_2 recorded maximum fruit weight (86.22g) whereas, minimum (62.67g) in V_3M_0.

The second order interaction between different varieties, biofertilizers and mulch materials had also significant differences for fruit weight. The pooled analysis of data in the experiment of both the year revealed that maximum fruit weight (88.14g) was obtained with treatment combination $V_2B_1M_2$. Minimum fruit weight (62.04g) was recorded by treatment combination $V_3B_0M_0$.

Table 4.6b: Effect of different interactions V x B, B x M and V x M harvest duration and fruit weight in tomato

Treatment combination	Fruit weight (g)			Pericarp thickness (mm)		
	2011	2012	Pooled	2011	2012	Pooled
$V_1 B_0$	75.95	76.84	76.40	2.75	2.77	2.77
$V_1 B_1$	78.00	82.35	80.18	2.80	2.83	2.82
$V_1 B_2$	76.27	79.11	77.69	2.83	2.85	2.85
$V_2 B_0$	81.54	84.07	82.80	3.65	3.69	3.67
$V_2 B_1$	84.62	86.95	85.79	3.75	3.78	3.77
$V_2 B_2$	83.05	84.75	83.90	3.77	3.81	3.79
$V_3 B_0$	63.39	64.93	64.16	2.51	2.54	2.53
$V_3 B_1$	67.22	67.82	67.52	2.54	2.56	2.56
$V_3 B_2$	65.36	66.32	65.84	2.55	2.59	2.58
$CD_{0.05}$	**0.12**	**0.11**	**0.02**	**0.01**	**0.01**	**0.01**
$B_0 M_0$	71.40	73.10	72.25	2.94	2.97	2.96
$B_0 M_1$	74.01	75.07	74.54	2.97	3.00	2.99
$B_0 M_2$	75.46	77.67	76.57	3.00	3.03	3.02
$B_1 M_0$	73.43	75.40	74.42	2.99	3.02	3.01
$B_1 M_1$	77.09	79.46	78.27	3.03	3.05	3.05
$B_1 M_2$	79.32	82.26	80.80	3.07	3.10	3.09
$B_2 M_0$	72.13	73.90	73.01	3.01	3.04	3.03
$B_2 M_1$	75.23	77.23	76.23	3.05	3.08	3.07
$B_2 M_2$	77.33	79.06	78.19	3.09	3.13	3.11
$CD_{0.05}$	**0.11**	**0.08**	**0.07**	**0.01**	**0.01**	**0.01**
$V_1 M_0$	74.05	76.24	75.15	2.76	2.78	2.78
$V_1 M_1$	77.09	79.83	78.46	2.79	2.82	2.81
$V_1 M_2$	79.08	82.23	80.65	2.83	2.85	2.85
$V_2 M_0$	80.91	82.82	81.86	3.68	3.71	3.70
$V_2 M_1$	83.31	85.50	84.40	3.72	3.76	3.74
$V_2 M_2$	84.98	87.46	86.22	3.77	3.81	3.79
$V_3 M_0$	62.00	63.34	62.67	2.51	2.54	2.53
$V_3 M_1$	65.92	66.42	66.17	2.53	2.56	2.56
$V_3 M_2$	68.05	69.30	68.68	2.56	2.59	2.58
$CD_{0.05}$	**0.11**	**0.08**	**0.07**	**0.01**	**0.01**	**0.01**

4.12 PERICARP THICKNESS (mm)

The results obtained on pericarp thickness presented in Table 4.6a, show significant individual effects of varieties, biofertilizers and mulches. The first order interaction V×B, B×M and V×M were also found significant for this trait and results have been presented in Table 4.6b. The second order interaction V×B×M has also recorded significant effect and has been presented in Table 4.6c.

Table 4.6c: Effect of V x B x M interaction harvest duration and fruit weight in tomato

Treatment combination	Fruit weight (g)			Pericarp thickness (mm)		
	2011	2012	Pooled	2011	2012	Pooled
$V_1B_0M_0$	73.55	74.49	74.02	2.73	2.75	2.74
$V_1B_0M_1$	76.15	76.23	76.19	2.75	2.78	2.77
$V_1B_0M_2$	78.15	79.80	78.98	2.78	2.81	2.80
$V_1B_1M_0$	75.16	77.77	76.47	2.77	2.79	2.78
$V_1B_1M_1$	78.51	83.24	80.88	2.81	2.83	2.82
$V_1B_1M_2$	80.34	86.04	83.19	2.84	2.87	2.86
$V_1B_2M_0$	73.44	76.46	74.95	2.79	2.81	2.80
$V_1B_2M_1$	76.60	80.03	78.32	2.83	2.86	2.85
$V_1B_2M_2$	78.75	80.84	79.80	2.87	2.90	2.89
$V_2B_0M_0$	79.24	82.15	80.70	3.62	3.65	3.64
$V_2B_0M_1$	82.19	84.13	83.16	3.65	3.69	3.67
$V_2B_0M_2$	83.17	85.94	84.56	3.68	3.73	3.71
$V_2B_1M_0$	82.54	84.27	83.41	3.71	3.74	3.73
$V_2B_1M_1$	84.51	87.12	85.82	3.75	3.78	3.76
$V_2B_1M_2$	86.80	89.47	88.14	3.81	3.84	3.83
$V_2B_2M_0$	80.94	82.04	81.49	3.72	3.76	3.74
$V_2B_2M_1$	83.23	85.24	84.24	3.77	3.81	3.79
$V_2B_2M_2$	84.99	86.97	85.98	3.83	3.87	3.85
$V_3B_0M_0$	61.42	62.67	62.04	2.49	2.51	2.50
$V_3B_0M_1$	63.68	64.85	64.26	2.52	2.55	2.53
$V_3B_0M_2$	65.07	67.28	66.17	2.55	2.58	2.56
$V_3B_1M_0$	62.58	64.18	63.38	2.52	2.54	2.53
$V_3B_1M_1$	68.24	68.01	68.13	2.54	2.56	2.55
$V_3B_1M_2$	70.83	71.29	71.06	2.57	2.59	2.58
$V_3B_2M_0$	62.01	63.19	62.60	2.54	2.57	2.56
$V_3B_2M_1$	65.84	66.41	66.13	2.56	2.59	2.58
$V_3B_2M_2$	68.25	69.36	68.80	2.58	2.62	2.60
$CD_{0.05}$	**0.20**	**0.14**	**0.12**	**0.02**	**0.01**	**0.01**

Among different varieties, V_2 (Sun-7711) recorded highest pericarp thickness (3.75 mm) while lowest value (2.56 mm) was observed with V_3 (Solan Lalima). Among biofertilizers, B_2 exhibited highest pericarp thickness (3.07 mm) whereas B_0 exhibited lowest pericarp thickness (2.99 mm). Mulches also significantly affected the pericarp thickness of tomato M_2 (black polythene) mulch showed highest pericarp thickness (3.08 mm). However M_0 (No mulch) registered lowest value (3.00 mm) for this trait.

Among V×B interaction, treatment combination V_2B_2 registered highest (3.79 mm) pericarp thickness, whereas V_3B_0 gave lowest pericarp thickness (2.53 mm). The interaction effect between biofertilizers and mulches on this character

was found to be significant and the highest (3.11 mm) value was recorded with B_2M_2 while B_0M_0 recorded lowest pericarp thickness (2.96 mm). Among V×M treatment combination, V_2M_2 exhibited highest pericarp thickness (3.79 mm) while lowest value (2.53 mm) for this trait was recorded with V_3M_0.

Data in the table 4.6c clearly indicate significant effect of V×B×M interaction on pericarp thickness. Highest (3.85 mm) pericarp thickness was observed with $V_2B_2M_2$. However lowest pericarp thickness (2.50 mm) was recorded with the treatment combination $V_3B_0M_0$.

4.13 FRUIT FIRMNESS (g/0.503 cm^2)

The observations recorded on fruit firmness has been presented in Table (4.7a, 4.7b & 4.7c). The perusal of data revealed that significant individual effect of varieties, biofertilizers and mulches during both the years and in pooled data whereas, all the first and second order interaction involving varieties, biofertilizers and mulches did not show any significant differences during both the years of study.

Table 4.7a: Response of tomato genotypes to different mulches and biofertilizers with respect to fruit firmness and shelf life

Treatment combination	Fruit firmness (g/0.503cm^2)			Shelf life (days)		
	2011	2012	Pooled	2011	2012	Pooled
Varieties (V)						
V_1 (Naveen 2000$^+$)	777.12	791.15	784.14	11.66	11.96	11.81
V_2 (Sun-7711)	934.67	957.27	945.98	15.33	16.07	15.70
V_3 (Solan Lalima)	643.01	663.91	653.46	10.41	10.11	10.26
$CD_{0.05}$	**16.53**	**22.63**	**18.78**	**2.35**	**1.04**	**1.44**
Biofertilizers						
B_0 (NPK recommended)	770.29	783.44	776.87	12.40	12.25	12.33
B_1(100% NPK+*Azotobacter* (1g/plant)+PSB(1g/plant)	801.72	824.40	813.06	13.07	13.59	13.33
B_2 (75% NPK+*Azotobacter* (1g/plant)+PSB(1g/plant)	782.80	804.49	793.65	11.92	12.29	12.11
$CD_{0.05}$	**5.98**	**7.96**	**6.07**	**0.25**	**0.41**	**0.36**
Mulches (M)						
M_0 (No Mulch)	757.47	774.71	766.09	11.07	11.44	11.26
M_1 (Pine needle)	787.27	805.57	796.43	12.25	12.96	12.61
M_2 (Black polyethylene)	810.06	832.05	821.06	14.07	13.74	13.91
$CD_{0.05}$	**11.59**	**10.60**	**10.68**	**2.05**	**0.49**	**1.05**

Solan Lalima

Naveen 2000+

Sun 7711

Plate 2. Keeping quality of different genotypes

In the individual effect, pooled analysis showed that the variety V_2 (Sun-7711) had the highest fruit firmness (945.98g/0.503 cm^2) while the lowest firmness (653.46g/0.503 cm^2) was recorded with V_3 (Solan Lalima). Among the biofertilizers, B_1 treatment recorded highest firmness (813.06g/0.503 cm^2) while lowest fruit firmness (776.87g/0.503 cm^2) was recorded with B_0. Further, the pooled analysis of different mulches revealed that M_2 (Black polythene) was best showing highest fruit firmness (821.06g/0.503 cm^2) while M_0 (No mulch) showed that least fruit firmness (766.09g/0.503 cm^2).

Table 4.7b: Effect of different interactions V x B, B x M and V x M fruit firmness and shelf life in tomato

Treatment combination	Fruit firmness (g/0.503cm^2)			Shelf life (days)		
	2011	2012	Pooled	2011	2012	Pooled
$V_1 B_0$	765.81	778.58	772.20	10.77	11.55	11.17
$V_1 B_1$	790.16	805.67	797.92	12.66	12.77	12.72
$V_1 B_2$	775.40	789.21	782.31	11.55	11.55	11.56
$V_2 B_0$	912.63	925.08	918.86	14.66	15.77	15.22
$V_2 B_1$	957.23	988.20	972.72	16.44	17.00	16.72
$V_2 B_2$	934.15	958.53	946.34	14.88	15.44	15.17
$V_3 B_0$	632.44	646.65	639.55	11.77	9.44	10.61
$V_3 B_1$	657.76	679.32	668.54	10.11	11.00	10.56
$V_3 B_2$	638.85	665.74	652.30	9.33	9.88	9.61
$CD_{0.05}$	NS	NS	NS	NS	NS	NS
$B_0 M_0$	746.84	760.70	753.78	10.55	10.88	10.72
$B_0 M_1$	773.81	786.29	780.05	11.44	12.55	12.00
$B_0 M_2$	790.23	803.33	796.79	15.22	13.33	14.28
$B_1 M_0$	768.06	789.97	779.02	11.66	12.22	11.94
$B_1 M_1$	802.15	824.97	813.56	13.11	13.88	13.50
$B_1 M_2$	834.94	858.26	846.61	14.44	14.66	14.55
$B_2 M_0$	757.51	773.47	765.49	11.00	11.22	11.11
$B_2 M_1$	785.87	805.45	795.66	12.22	12.44	12.33
$B_2 M_2$	805.02	834.56	819.79	12.55	13.22	12.89
$CD_{0.05}$	NS	NS	NS	NS	NS	NS
$V_1 M_0$	755.38	766.87	761.13	10.22	11.00	10.61
$V_1 M_1$	773.46	787.65	780.56	11.77	12.11	11.94
$V_1 M_2$	802.53	818.94	810.74	13.00	12.77	12.89
$V_2 M_0$	898.69	917.19	907.95	14.55	14.77	14.67
$V_2 M_1$	945.92	964.56	955.25	15.77	16.33	16.06
$V_2 M_2$	959.40	990.06	974.74	15.66	17.11	16.39
$V_3 M_0$	618.35	640.08	629.22	8.44	8.55	8.50
$V_3 M_1$	642.44	664.49	653.47	9.22	10.44	9.83
$V_3 M_2$	668.26	687.15	677.71	13.55	11.33	12.44
$CD_{0.05}$	NS	NS	NS	NS	NS	NS

4.14 SHELF LIFE (days)

The results obtained on shelf life has been presented in Table (4.7a) which shows significant individual effect of varieties and mulching whereas the effect of biofertilizers was non-significant. The first order interactions (V×B, B×M, V×M) as presented in Table (4.7b) as well as the second order interaction (V×B×M) were observed to have non-significant effect for this trait (Table 4.7c).

The maximum shelf life (15.70 days) was recorded with V_2 (Sun-7711) while V_3 (Solan Lalima) had the minimum shelf life (10.26 days). Mulches affected the shelf life significantly M_2 (Black polythene) mulch showed maximum shelf life (13.91 days) while M_0 (No mulch) registered minimum shelf life (11.26 days).

Table 4.7c: Effect of V x B x M interaction fruit firmness and shelf life in tomato

Treatment combination	Fruit firmness (g/0.503cm^2)			Shelf life (days)		
	2011	2012	Pooled	2011	2012	Pooled
$V_1B_0M_0$	750.54	762.72	756.63	10.00	10.67	10.33
$V_1B_0M_1$	768.25	782.54	775.39	11.00	11.67	11.33
$V_1B_0M_2$	778.65	790.51	784.58	11.33	12.33	11.83
$V_1B_1M_0$	761.23	774.38	767.81	11.00	11.67	11.33
$V_1B_1M_1$	778.36	797.27	787.81	12.67	13.00	12.83
$V_1B_1M_2$	830.89	845.37	838.13	14.33	13.67	14.00
$V_1B_2M_0$	754.37	763.53	758.95	9.67	10.67	10.17
$V_1B_2M_1$	773.79	783.16	778.48	11.67	11.67	11.67
$V_1B_2M_2$	798.05	820.95	809.50	13.33	12.33	12.83
$V_2B_0M_0$	878.30	890.93	884.62	14.00	14.33	14.17
$V_2B_0M_1$	921.77	933.25	927.51	14.67	16.33	15.50
$V_2B_0M_2$	937.84	951.09	944.47	15.33	16.67	16.00
$V_2B_1M_0$	915.45	946.00	930.72	15.00	15.33	15.17
$V_2B_1M_1$	970.82	994.43	982.62	16.67	17.33	17.00
$V_2B_1M_2$	985.44	1024.20	1004.82	17.67	18.33	18.00
$V_2B_2M_0$	902.33	914.66	908.49	14.67	14.67	14.67
$V_2B_2M_1$	945.19	966.03	955.61	16.00	15.33	15.67
$V_2B_2M_2$	954.94	994.91	974.92	14.00	16.33	15.17
$V_3B_0M_0$	611.70	628.47	620.09	7.67	7.65	7.66
$V_3B_0M_1$	631.41	643.09	637.25	8.67	9.67	9.17
$V_3B_0M_2$	654.21	668.40	661.31	19.00	11.00	15.00
$V_3B_1M_0$	627.51	649.54	638.52	9.00	9.67	9.33
$V_3B_1M_1$	657.28	683.23	670.26	10.00	11.33	10.67
$V_3B_1M_2$	688.50	705.22	696.86	11.33	12.00	11.67
$V_3B_2M_0$	615.84	642.24	629.04	8.67	8.33	8.50
$V_3B_2M_1$	638.64	667.16	652.90	9.00	10.33	9.67
$V_3B_2M_2$	662.07	687.84	674.96	10.33	11.00	10.67
$CD_{0.05}$	NS	NS	NS	NS	NS	NS

4.15 TOTAL SOLUBLE SOLIDS (^{0}brix)

The perusal of data given in Table (4.8a) reveal that there was significant influence of varieties, biofertilizers and mulches on the fruit TSS. While the first order interaction (V×B, B×M, V×M) as given in Table (4.8b) as well as the second order interaction (V×B×M) presented in Table (4.8c) had non-significant effect on fruit TSS.

Table 4.8a: Response of tomato genotypes to different mulches and biofertilizers with respect to TSS and titratable acidity

Treatment combination	TSS (^{0}Brix)			Titratable acidity (%)		
	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)
V_2 (Sun-7711)	4.41	4.57	4.49	0.47 (1.21)	0.45 (1.20)	0.46 (1.21)
V_3 (Solan Lalima)	4.98	5.05	5.02	0.40 (1.18)	0.39 (1.18)	0.39 (1.18)
$CD_{0.05}$	**0.22**	**0.21**	**0.20**	**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)
B_1(100%NPK+*Azotobacter* (1g/plant)+PSB(1g/plant)	4.74	4.86	4.79	0.44 (1.19)	0.41 (1.19)	0.43 (1.19)
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)
$CD_{0.05}$	**0.14**	**0.11**	**0.12**	**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)
M_1 (Pine needle)	4.52	4.63	4.58	0.47 (1.21)	0.45 (1.20)	0.46 (1.21)
M_2 (Black polyethylene)	4.73	4.83	4.78	0.44 (1.19)	0.41 (1.19)	0.42 (1.19)
$CD_{0.05}$	**0.08**	**0.09**	**0.08**	**0.01**	**0.02**	**0.01**

In individual effects, pooled data of both the years shows that V_3 (Solan Lalima) had maximum fruit TSS (5.02 ^{0}Brix) in contrary to V_1 (Naveen 2000$^+$) which recorded minimum fruit TSS (4.19 ^{0}Brix). Among biofertilizers, B_1 recorded maximum TSS (4.79 ^{0}Brix) while minimum fruit TSS (4.33 ^{0}Brix) was observed with B_0. With regards to different mulches, M_2 (Black polythene) showed maximum fruit TSS (4.78 ^{0}Brix) while M_0 (No mulch) noticed minimum fruit TSS of 4.34 ^{0}Brix.

4.16 TITRATABLE ACIDITY (%)

The observation recorded on titratable acidity has been presented in Table 4.8a. The perusal of data revealed significant individual effect of varieties, biofertilizers and mulch material during both the years and in pooled data. All the first order interaction showed significant effect on titratable acidity (Table 4.8b). The second order interaction V×B×M for this trait also recorded significant differences between treatments (Table 4.8c).

Table 4.8b: Effect of different interactions V x B, B x M and V x M TSS and titratable acidity in tomato

Treatment combination	TSS (^{0}Brix)			Titratable acidity (%)		
	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)
$V_1 B_1$	4.37	4.49	4.43	0.45 (1.21)	0.47 (1.21)	0.45 (1.21)
$V_1 B_2$	4.12	4.25	4.19	0.51 (1.23)	0.51 (1.23)	0.51 (1.23)
$V_2 B_0$	4.26	4.39	4.33	0.48 (1.20)	0.49 (1.22)	0.48 (1.20)
$V_2 B_1$	4.54	4.72	4.63	0.42 (1.19)	0.44 (1.20)	0.42 (1.19)
$V_2 B_2$	4.44	4.59	4.52	0.43 (1.19)	0.45 (1.20)	0.43 (1.19)
$V_3 B_0$	4.67	4.74	4.70	0.43 (1.19)	0.43 (1.19)	0.43 (1.19)
$V_3 B_1$	5.30	5.36	5.33	0.36 (1.17)	0.36 (1.17)	0.36 (1.17)
$V_3 B_2$	4.97	5.05	5.01	0.38 (1.17)	0.39 (1.18)	0.38 (1.17)
$CD_{0.05}$	**NS**	**NS**	**NS**	**0.02**	**0.01**	**0.02**
$B_0 M_0$	4.03	4.20	4.12	0.51 (1.23)	0.52 (1.23)	0.51 (1.23)
$B_0 M_1$	4.28	4.38	4.33	0.49 (1.22)	0.49 (1.22)	0.49 (1.22)
$B_0 M_2$	4.50	4.58	4.54	0.45 (1.21)	0.46 (1.21)	0.45 (1.21)
$B_1 M_0$	4.47	4.61	4.55	0.45 (1.20)	0.46 (1.20)	0.45 (1.20)
$B_1 M_1$	4.77	4.85	4.81	0.42 (1.19)	0.43 (1.19)	0.42 (1.19)
$B_1 M_2$	4.97	5.12	5.04	0.37 (1.17)	0.39 (1.17)	0.37 (1.17)
$B_2 M_0$	4.29	4.42	4.36	0.46 (1.21)	0.47 (1.21)	0.46 (1.21)
$B_2 M_1$	4.52	4.67	4.60	0.44 (1.20)	0.45 (1.20)	0.44 (1.20)
$B_2 M_2$	4.72	4.79	4.76	0.41 (1.19)	0.42 (1.19)	0.41 (1.19)
$CD_{0.05}$	**NS**	**NS**	**NS**	**0.01**	**0.02**	**0.01**
$V_1 M_0$	3.90	3.99	3.95	0.54 (1.24)	0.54 (1.23)	0.54 (1.24)
$V_1 M_1$	4.12	4.27	4.20	0.51 (1.23)	0.52 (1.24)	0.51 (1.23)
$V_1 M_2$	4.35	4.51	4.44	0.45 (1.20)	0.47 (1.21)	0.45 (1.20)
$V_2 M_0$	4.19	4.42	4.31	0.47 (1.21)	0.49 (1.22)	0.47 (1.21)
$V_2 M_1$	4.43	4.55	4.49	0.45 (1.20)	0.46 (1.21)	0.45 (1.20)
$V_2 M_2$	4.61	4.74	4.68	0.42 (1.19)	0.43 (1.19)	0.42 (1.19)
$V_3 M_0$	4.69	4.83	4.77	0.41 (1.19)	0.42 (1.19)	0.41 (1.19)
$V_3 M_1$	5.02	5.08	5.05	0.39 (1.18)	0.39 (1.18)	0.39 (1.18)
$V_3 M_2$	5.22	5.23	5.23	0.37 (1.17)	0.37 (1.17)	0.37 (1.17)
$CD_{0.05}$	**NS**	**NS**	**NS**	**0.01**	**0.02**	**0.01**

In individual effects, pooled data of both the years show that V_1 (Naveen 2000^+) recorded maximum titratable acidity (0.51%) while V_3 (Solan Lalima) exhibited minimum value (0.39 %) for this character. Biofertilizers also had significant influences on this trait. B_0 resulted in maximum (0.49%) titratable acidity and minimum titratable acidity (0.43%) was recorded with B_1. Among mulches, M_0 (No mulch) resulted in maximum (0.48%) acidity while M_2 (Black polythene) exhibited minimum titratable acidity (0.42%) of tomato.

Table 4.8c: Effect of V x B x M interaction TSS and titratable acidity in tomato

Treatment combination	TSS (^{0}Brix)			Titratable acidity (%)		
	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)
$V_1B_0M_1$	3.88	4.03	3.96	0.56 (1.25)	0.53 (1.24)	0.54 (1.241)
$V_1B_0M_2$	4.17	4.31	4.24	0.51 (1.23)	0.49 (1.22)	0.50 (1.225)
$V_1B_1M_0$	4.11	4.23	4.17	0.52 (1.23)	0.50 (1.22)	0.51 (1.229)
$V_1B_1M_1$	4.38	4.49	4.44	0.49 (1.23)	0.47 (1.21)	0.49 (1.221)
$V_1B_1M_2$	4.61	4.76	4.69	0.47 (1.21)	0.39 (1.18)	0.42 (1.194)
$V_1B_2M_0$	4.01	3.96	3.99	0.46 (1.23)	0.55 (1.24)	0.53 (1.238)
$V_1B_2M_1$	4.09	4.30	4.19	0.43 (1.24)	0.52 (1.23)	0.52 (1.236)
$V_1B_2M_2$	4.27	4.48	4.38	0.41 (1.23)	0.46 (1.21)	0.48 (1.215)
$V_2B_0M_0$	4.06	4.24	4.15	0.52 (1.24)	0.50 (1.22)	0.51 (1.229)
$V_2B_0M_1$	4.26	4.38	4.32	0.50 (1.22)	0.50 (1.23)	0.50 (1.225)
$V_2B_0M_2$	4.46	4.55	4.51	0.46 (1.21)	0.46 (1.21)	0.47 (1.211)
$V_2B_1M_0$	4.34	4.56	4.45	0.49 (1.23)	0.46 (1.21)	0.48 (1.217)
$V_2B_1M_1$	4.55	4.69	4.62	0.46 (1.21)	0.42 (1.19)	0.44 (1.200)
$V_2B_1M_2$	4.73	4.92	4.83	0.40 (1.18)	0.38 (1.18)	0.39 (1.179)
$V_2B_2M_0$	4.20	4.46	4.33	0.38 (1.23)	0.45 (1.20)	0.48 (1.215)
$V_2B_2M_1$	4.49	4.57	4.53	0.37 (1.21)	0.44 (1.19)	0.45 (1.203)
$V_2B_2M_2$	4.64	4.76	4.70	0.35 (1.20)	0.41 (1.19)	0.43 (1.194)
$V_3B_0M_0$	4.44	4.59	4.52	0.52 (1.21)	0.45 (1.20)	0.46 (1.207)
$V_3B_0M_1$	4.70	4.73	4.72	0.53 (1.19)	0.43 (1.19)	0.43 (1.196)
$V_3B_0M_2$	4.86	4.90	4.88	0.50 (1.19)	0.41 (1.18)	0.41 (1.187)
$V_3B_1M_0$	4.98	5.06	5.02	0.51 (1.17)	0.38 (1.17)	0.38 (1.175)
$V_3B_1M_1$	5.36	5.36	5.36	0.45 (1.16)	0.37 (1.17)	0.37 (1.169)
$V_3B_1M_2$	5.56	5.67	5.61	0.44 (1.16)	0.34 (1.16)	0.37 (1.169)
$V_3B_2M_0$	4.68	4.85	4.76	0.42 (1.19)	0.40 (1.18)	0.41 (1.187)
$V_3B_2M_1$	5.00	5.16	5.08	0.39 (1.18)	0.37 (1.17)	0.38 (1.175)
$V_3B_2M_2$	5.24	5.13	5.18	0.37 (1.17)	0.36(1.17)	0.35 (1.160)
$CD_{0.05}$	NS	NS	NS	0.02	0.01	0.02

In V×B interaction, V_1B_0 gave maximum acidity (0.53%). V_3B_1 treatment combination registered minimum titratable acidity (0.36%). With regard to B×M

interaction, B_0M_0 exhibited maximum (0.51%) titratable acidity while minimum (0.37%) was observed with B_1M_2. In V×M interaction effect, V_1M_0 resulted in maximum (0.54%) titratable acidity while V_3M_2 recorded minimum value (0.37%) for this parameters.

The second order interaction between varieties, biofertilizers and mulch had also recorded significant differences for titratable acidity. The pooled analysis of data in the experiment of both the year revealed that maximum titratable acidity (0.58%) was obtained with treatment combination $V_1B_0M_0$. Minimum titratable acidity (0.35%) was observed with $V_3B_2M_2$.

4.17 ASCORBIC ACID (mg/100 g)

The observation recorded on ascorbic acid content has been presented in Table 4.9a, 4.9b & 4.9c. The perusal of data revealed that significant individual effect of varieties, biofertilizers and mulches during both the years and in pooled data as presented in 4.9a. All the first order interactions showed significant effect on ascorbic acid (Table 4.9b). The second order interaction (V×B×M) as depicted in Table 4.9c, also recorded significant effect.

Table 4.9a: Response of tomato genotypes to different mulches and biofertilizers with respect to ascorbic acid and lycopene content in tomato

Treatment combination	Ascorbic acid (mg/100g)			Lycopene content (mg/100g)		
	2011	2012	Pooled	2011	2012	Pooled
Varieties (V)						
V_1 (Naveen 2000$^+$)	30.34	31.13	30.73	2.44	2.49	2.47
V_2 (Sun-7711)	30.95	31.74	31.35	2.20	2.27	2.23
V_3 (Solan Lalima)	32.22	33.01	32.61	2.64	2.71	2.67
$CD_{0.05}$	**0.07**	**0.06**	**0.01**	**0.01**	**0.02**	**0.01**
Biofertilizers						
B_0 (NPK recommended)	30.61	31.40	31.00	2.24	2.30	2.27
B_1(100% NPK+*Azotobacter* (1g/plant)+PSB(1g/plant)	31.67	32.46	32.07	2.60	2.69	2.65
B_2 (75% NPK+*Azotobacter* (1g/plant)+PSB(1g/plant)	31.23	32.02	31.63	2.43	2.47	2.45
$CD_{0.05}$	**0.02**	**0.03**	**0.02**	**0.02**	**0.01**	**0.01**
Mulches (M)						
M_0 (No Mulch)	29.68	30.47	30.07	2.22	2.29	2.23
M_1(Pine needle)	31.45	32.24	31.85	2.38	2.45	2. 47
M_2 (Black polyethylene)	32.38	33.17	32.77	2.67	2.72	2.67
$CD_{0.05}$	**0.03**	**0.03**	**0.02**	**0.01**	**0.02**	**0.01**

Lycopene content estimation

Ascorbic acid content estimation

Plate 3. Estimation of lycopene and ascorbic acid content of tomato

In the individual effect, pooled analysis showed that the variety V_3 (Solan Lalima) had highest ascorbic acid content (32.61 mg/100g) while lowest ascorbic acid (30.73 mg/100g) was observed with V_1 (Naveen 2000^+). Among different biofertilizers, B_1 recorded highest (32.07 mg/100g) while B_0 recorded lowest (31.00 mg/100g) ascorbic acid content. Mulches also had significant effect on this trait with highest value (32.77 mg/100g) being observed with M_2 (Black polythene) while lowest value (30.07 mg/100g) was recorded with M_0 (No mulch) for this trait.

The data in Table 4.9b revealed that in the interaction between variety and biofertilizers, treatment combination V_3B_1 recorded highest ascorbic acid content

Table 4.9b: Effect of different interactions V x B, B x M and V x M ascorbic acid and lycopene content in tomato

Treatment combination	Ascorbic acid (mg/100g)			Lycopene content (mg/100g)		
	2011	2012	Pooled	2011	2012	Pooled
$V_1 B_0$	29.74	30.53	30.14	2.20	2.26	2.23
$V_1 B_1$	30.89	31.68	31.29	2.67	2.73	2.70
$V_1 B_2$	30.38	31.17	30.78	2.44	2.48	2.46
$V_2 B_0$	30.44	31.23	30.83	2.04	2.10	2.07
$V_2 B_1$	31.41	32.20	31.80	2.33	2.42	2.38
$V_2 B_2$	31.01	31.80	31.41	2.21	2.28	2.24
$V_3 B_0$	31.65	32.44	32.05	2.48	2.54	2.51
$V_3 B_1$	32.71	33.50	33.10	2.79	2.92	2.86
$V_3 B_2$	32.29	33.08	32.69	2.64	2.66	2.65
$CD_{0.05}$	**0.04**	**0.05**	**0.03**	**0.01**	**0.02**	**0.01**
$B_0 M_0$	29.13	29.92	29.52	2.09	2.16	2.13
$B_0 M_1$	30.93	31.72	31.33	2.18	2.25	2.22
$B_0 M_2$	31.77	32.56	32.16	2.45	2.50	2.48
$B_1 M_0$	30.23	31.02	30.62	2.35	2.44	2.40
$B_1 M_1$	31.90	32.69	32.30	2.56	2.67	2.61
$B_1 M_2$	32.87	33.66	33.27	2.88	2.96	2.92
$B_2 M_0$	29.68	30.47	30.08	2.22	2.28	2.26
$B_2 M_1$	31.52	32.31	31.92	2.39	2.44	2.42
$B_2 M_2$	32.49	33.28	32.88	2.67	2.70	2.69
$CD_{0.05}$	**0.05**	**0.05**	**0.04**	**0.02**	**0.01**	**0.01**
$V_1 M_0$	28.55	29.34	28.94	2.25	2.29	2.28
$V_1 M_1$	30.80	31.59	31.20	2.38	2.45	2.42
$V_1 M_2$	31.66	32.45	32.06	2.67	2.73	2.70
$V_2 M_0$	28.91	29.70	29.30	2.04	2.15	2.09
$V_2 M_1$	31.39	32.18	31.79	2.13	2.19	2.16
$V_2 M_2$	32.56	33.35	32.95	2.41	2.46	2.44
$V_3 M_0$	31.58	32.37	31.98	2.38	2.44	2.41
$V_3 M_1$	32.16	32.95	32.56	2.62	2.71	2.67
$V_3 M_2$	32.91	33.70	33.31	2.91	2.97	2.94
$CD_{0.05}$	**0.05**	**0.05**	**0.04**	**0.01**	**0.02**	**0.01**

(33.10 mg/100g) which was statistically superior to all other treatments. Lowest value (30.14 mg/100g) was observed with V_1B_0. Further treatment combination B_1M_2 recorded maximum ascorbic acid content (33.27 mg/100g), whereas minimum (29.52 mg/100g) was found 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 was found statistically superior to all other treatments. V_1M_o recorded minimum value (28.94 mg/100g) for this trait.

The second order interaction between different varieties, biofertilizers and mulch materials had also significant differences for ascorbic acid. The pooled analysis of data in the experiment of both the year revealed that maximum ascorbic acid content (33.87 mg/100g) was obtained with treatment combination $V_3B_1M_2$. Minimum ascorbic acid content (28.53 mg/100g) was recorded by treatment combination $V_1B_0M_0$.

4.18 LYCOPENE CONTENT (mg/100g)

The results obtained on lycopene content of the fruit, presented in Table 4.9a, show significant individual effect of varieties, biofertilizers and mulches. The first order interaction V×B, B×M and V×M were found to be significant as presented in Table 4.9b. The second order interaction V×B×M also recorded significant effect for all treatment and has been presented in Table 4.9c.

In individual effect, pooled analysis showed that variety V_3 (Solan Lalima) recorded maximum (2.67 mg/100g) while V_2 (Sun-7711) recorded minimum (2.23 mg/100g) lycopene content. Among different biofertilizers, B_1 recorded maximum (2.65 mg/100g) while B_0 recorded minimum (2.27 mg/100g) lycopene content. Further, the pooled analysis of different mulches revealed that M_2 (Black polythene) exhibited maximum lycopene content (2.67 mg/100g) while minimum (2.23 mg/100g) was observed with M_0 (No mulch).

In V×B interaction, V_3B_1 gave the maximum lycopene content (2.86 mg/100g). V_2B_0 treatment combination registered minimum lycopene content (2.07 mg/100g). Among interaction between biofertilizers and mulches, B_1M_2

recorded maximum lycopene content (2.92 mg/100g) while B_0M_0 gave minimum value (2.13 mg/100g) for this trait. With regard to V×M treatment combination, V_3M_2 resulted in maximum lycopene content (2.94 mg/100g) while V_2M_0 recorded minimum lycopene content (2.09 mg/100g).

Table 4.9c: Effect of V x B x M interaction ascorbic acid and lycopene content in tomato

Treatment combination	Ascorbic acid (mg/100g)			Lycopene content (mg/100g)		
	2011	2012	Pooled	2011	2012	Pooled
$V_1B_0M_0$	28.14	28.93	28.53	2.09	2.16	2.13
$V_1B_0M_1$	30.11	30.90	30.51	2.13	2.22	2.18
$V_1B_0M_2$	30.97	31.76	31.37	2.37	2.41	2.39
$V_1B_1M_0$	29.01	29.80	29.41	2.45	2.47	2.46
$V_1B_1M_1$	31.39	32.18	31.79	2.61	2.67	2.64
$V_1B_1M_2$	32.27	33.06	32.67	2.95	3.05	3.00
$V_1B_2M_0$	28.49	29.28	28.89	2.21	2.25	2.23
$V_1B_2M_1$	30.91	31.70	31.31	2.40	2.45	2.43
$V_1B_2M_2$	31.74	32.53	32.14	2.70	2.74	2.72
$V_2B_0M_0$	28.17	28.96	28.56	1.93	1.99	1.96
$V_2B_0M_1$	31.03	31.82	31.43	2.00	2.07	2.03
$V_2B_0M_2$	32.11	32.90	32.51	2.20	2.25	2.23
$V_2B_1M_0$	29.62	30.41	30.02	2.13	2.27	2.20
$V_2B_1M_1$	31.72	32.51	32.12	2.25	2.32	2.28
$V_2B_1M_2$	32.88	33.67	33.27	2.61	2.66	2.64
$V_2B_2M_0$	28.93	29.72	29.33	2.05	2.17	2.11
$V_2B_2M_1$	31.42	32.21	31.82	2.15	2.20	2.17
$V_2B_2M_2$	32.68	33.47	33.08	2.42	2.46	2.44
$V_3B_0M_0$	31.08	31.87	31.48	2.27	2.32	2.30
$V_3B_0M_1$	31.64	32.43	32.04	2.40	2.46	2.43
$V_3B_0M_2$	32.22	33.01	32.62	2.78	2.83	2.81
$V_3B_1M_0$	32.05	32.84	32.45	2.47	2.58	2.53
$V_3B_1M_1$	32.60	33.39	33.00	2.82	3.01	2.92
$V_3B_1M_2$	33.47	34.26	33.87	3.07	3.18	3.13
$V_3B_2M_0$	31.61	32.40	32.01	2.41	2.42	2.42
$V_3B_2M_1$	32.24	33.03	32.63	2.63	2.66	2.64
$V_3B_2M_2$	33.04	33.83	33.43	2.89	2.90	2.89
$CD_{0.05}$	**0.09**	**0.08**	**0.08**	**0.02**	**0.02**	**0.01**

Data in Table 4.9c clearly indicated the significant effect of V×B×M interaction on lycopene content of tomato fruit. Maximum lycopene content (3.13

mg/100g) was recorded with $V_3B_1M_2$ and minimum (1.96 mg/100g) was observed with $V_2B_0M_0$.

DISEASES PARAMETERS

4.19 BUCKEYE ROT (%)

The results obtained on buckeye rot have been presented in Table 4.10a. The perusal of data revealed individual effect of varieties, biofertilizers and mulches during both the years and in pooled data. The first order interactions V×B, B×M and V×M were also found significant for this character and results have been presented in Table 4.10b. The second order interaction between V×B×M has also recorded significant effect as depicted in Table 4.10c.

Table 4.10a: Response of tomato genotypes to different mulches and biofertilizers with respect to incidence of buckeye rot and severity of bacterial leaf spot

Treatment combination	Buckeye rot (%)			Bacterial leaf spot (%)		
	2011	2012	Pooled	2011	2012	Pooled
Varieties (V)						
V_1 (Naveen 2000$^+$)	12.08 (3.62)	10.30 (3.36)	11.19 (3.49)	40.40 (39.45)	36.89 (37.38)	38.64 (38.42)
V_2 (Sun-7711)	9.47 (3.23)	7.88 (3.98)	8.67 (3.11)	32.85 (34.95)	30.93 (33.77)	31.89 (34.37)
V_3 (Solan Lalima)	10.80 (3.43)	8.62 (3.10)	9.71 (3.27)	21.84 (27.84)	15.80 (23.39)	18.82 (25.69)
$CD_{0.05}$	**0.03**	**0.02**	**0.02**	**0.06**	**0.09**	**0.07**
Biofertilizers						
B_0 (NPK recommended)	11.45 (3.52)	9.24 (3.19)	10.34 (3.36)	32.92 (34.87)	28.65 (32.08)	30.79 (33.49)
B_1(100% NPK+*Azotobacter* (1g/plant)+PSB(1g/plant)	10.71 (3.42)	8.92 (3.14)	9.68 (3.26)	30.71 (33.44)	26.95 (30.83)	28.83 (32.17)
B_2 (75% NPK+*Azotobacter* (1g/plant)+PSB(1g/plant)	10.19 (3.34)	8.64 (3.10)	9.56 (3.25)	31.45 (33.93)	28.02 (31.64)	29.74 (32.81)
$CD_{0.05}$	**0.01**	**0.02**	**0.01**	**0.05**	**0.06**	**0.04**
Mulches (M)						
M_0 (No Mulch)	11.66 (3.55)	9.91 (3.30)	10.79 (3.43)	32.41 (34.52)	28.96 (32.23)	30.69 (33.39)
M_1 (Pine needle)	10.61 (3.40)	8.87 (3.14)	9.74 (3.27)	31.79 (34.14)	27.76 (31.44)	29.78 (32.82)
M_2 (Black polyethylene)	10.09 (3.33)	8.02 (3.00)	9.05 (3.17)	30.89 (33.93)	26.90 (30.87)	28.90 (32.26)
$CD_{0.05}$	**0.02**	**0.01**	**0.02**	**0.06**	**0.04**	**0.03**

In the individual effect, pooled analysis showed that the variety V_1 (Naveen 2000$^+$) exhibited maximum incidence of buckeye rot (11.19%) while it

was minimum (8.67%) in V_2 (Sun-7711). Among biofertilizers, B_0 exhibited maximum incidence (10.34%) while B_2 observed minimum (9.56%) incidence. With regard to mulches, M_0 (No mulch) exhibited maximum buckeye rot incidence (10.79%) while M_2 (Black polythene mulch) exhibited minimum (9.05%) incidence.

Table 4.10b. Effect of different interactions V x B, B x M and V x M incidence of buckeye rot and severity of bacterial leaf spot in tomato

Treatment combination	Buckeye rot (%)			Bacterial leaf spot (%)		
	2011	2012	Pooled	2011	2012	Pooled
V_1B_0	12.89 (3.73)	10.66 (3.41)	11.78 (3.57)	41.20 (39.91)	37.34 (37.65)	39.27 (38.79)
V_1B_1	12.05 (3.61)	10.01 (3.32)	11.03 (3.47)	39.72 (39.05)	36.54 (37.18)	38.13 (38.12)
V_1B_2	11.31 (3.51)	10.22 (3.35)	10.77 (3.43)	40.27 (39.37)	36.79 (37.32)	38.53 (38.35)
V_2B_0	10.07 (3.32)	8.21 (3.03)	9.14 (3.18)	33.90 (35.59)	31.42 (34.08)	32.66 (34.84)
V_2B_1	9.24 (3.20)	7.53 (2.92)	8.38 (3.06)	32.07 (34.48)	30.46 (33.48)	31.27 (33.99)
V_2B_2	9.10 (3.18)	7.90 (2.98)	8.50 (3.08)	32.56 (34.78)	30.91 (33.76)	31.74 (34.28)
V_3B_0	11.38 (3.52)	8.84 (3.14)	10.11 (3.33)	23.66 (29.09)	17.19 (24.48)	20.43 (26.86)
V_3B_1	10.84 (3.44)	8.39 (3.06)	9.62 (3.26)	20.35 (26.80)	13.85 (21.83)	17.10 (24.41)
V_3B_2	10.17 (3.34)	8.64 (3.10)	9.41 (3.22)	21.53 (27.63)	16.36 (23.85)	18.95 (25.79)
$CD_{0.05}$	**0.02**	**0.03**	**0.01**	**0.08**	**0.10**	**0.08**
B_0M_0	12.26 (3.64)	10.31 (3.36)	11.29 (3.50)	34.01 (35.52)	29.76 (32.80)	31.89 (34.18)
B_0M_1	11.36 (3.51)	9.12 (3.18)	10.24 (3.35)	32.94 (34.89)	28.46 (31.94)	30.71 (33.45)
B_0M_2	10.73 (3.42)	8.28 (3.04)	9.50 (3.24)	31.80 (34.18)	27.72 (31.46)	29.76 (32.85)
B_1M_0	11.67 (3.56)	9.56 (3.25)	10.62 (3.41)	31.07 (33.67)	28.05 (31.57)	29.56 (32.65)
B_1M_1	10.54 (3.39)	8.59 (3.09)	9.57 (3.25)	30.91 (33.56)	26.89 (30.80)	28.90 (32.22)
B_1M_2	9.92 (3.30)	7.78 (2.96)	8.85 (3.13)	30.16 (33.10)	25.91 (30.13)	28.04 (31.66)
B_2M_0	11.04 (3.47)	9.86 (3.29)	10.45 (3.38)	32.15 (34.35)	29.07 (32.33)	30.61 (33.36)
B_2M_1	9.93 (3.30)	8.90 (3.14)	9.42 (3.22)	31.53 (33.98)	27.91 (31.57)	29.72 (32.80)
B_2M_2	9.62 (3.26)	8.00 (3.00)	8.81 (3.13)	30.69 (33.45)	27.08 (31.03)	28.89 (32.26)
$CD_{0.05}$	**0.03**	**0.02**	**0.01**	**0.10**	**0.07**	**0.06**
V_1M_0	12.90 (3.73)	11.27 (3.50)	12.09 (3.62)	41.52 (40.10)	37.94 (38.01)	39.74 (39.06)
V_1M_1	11.91 (3.59)	10.18 (3.34)	11.05 (3.48)	40.31 (39.40)	36.93 (37.41)	38.62 (38.41)
V_1M_2	11.44 (3.53)	9.44 (3.23)	10.44 (3.38)	39.36 (38.84)	35.79 (36.73)	37.57 (37.79)
V_2M_0	10.25 (3.35)	8.89 (3.14)	9.57 (3.25)	33.35 (35.26)	32.14 (34.52)	32.75 (34.89)
V_2M_1	9.34 (3.21)	7.80 (3.97)	8.57 (3.09)	33.12 (35.12)	30.67 (33.62)	31.90 (34.37)
V_2M_2	8.82 (3.13)	6.94 (3.82)	7.88 (2.98)	32.07 (34.48)	29.98 (33.19)	31.03 (33.84)
V_3M_0	11.82 (3.58)	9.57 (3.25)	10.70 (3.42)	22.35 (28.19)	16.80 (24.17)	19.58 (26.24)
V_3M_1	10.58 (3.40)	8.62 (3.10)	9.60 (3.26)	21.95 (27.91)	15.66 (23.29)	18.81 (25.68)
V_3M_2	10.00 (3.32)	7.68 (2.95)	8.84 (3.14)	21.23 (27.42)	14.93 (22.70)	18.09 (25.15)
$CD_{0.05}$	**0.03**	**0.01**	**0.02**	**0.10**	**0.07**	**0.06**

The data in Table 4.10b revealed that in the interaction between variety and biofertilizers, treatment combination V_1B_0 recorded maximum (11.78%) while V_2B_1 observed minimum (8.38%) buckeye rot incidence. Further treatment combinations B_0M_0 recorded maximum (11.29%) while B_2M_2 recorded minimum (8.81%) incidence of this disease. In the interaction between variety and mulch treatment combination V_1M_0 recorded maximum (12.09) whereas it was minimum (7.88%) in V_2M_2.

The second order interaction between different varieties, biofertilizers and mulch had also recorded significant differences for the occurrence of buckeye rot. The pooled analysis of the data in the experiment of the both year revealed that maximum (12.66%) occurrence of buckeye rot in $V_1B_0M_0$ and it was minimum (7.56%) in $V_2B_1M_2$

4.20 BACTERIAL LEAF SPOT (%)

The data on the severity of bacterial leaf spot disease has been presented in table 4.10a. The analysis of variance showed significant differences for severity of bacterial leaf spot. The observations recorded reflected the significant individual effects of varieties, biofertilizers and mulches during both the years and in pooled data. The first order interactions V×B, B×M and V×M were also found to be significant and results have been presented in Table 4.10b. The second order interaction V×B×M has also recorded significant effect (Table 4.10c).

A perusal of the data indicated that the variety V_1 (Naveen 2000^+) exhibited maximum bacterial leaf spot severity (38.64%) while it was minimum (18.82%) in V_3 (Solan Lalima). Among various biofertilizer levels, B_0 exhibited maximum (30.79%) while B_1 observed minimum (28.83%) values for diseases severity. The use of mulches tended to reduce the severity of bacterial leaf spot. The use of black polyethylene mulch (M_2) recorded the lowest (28.90%) severity of bacterial leaf spot. Whereas, it was maximum (30.69%) severity in unmulched plots.

Table 4.10c. Effect of V x B x M interaction for incidence of buckeye rot and severity of bacterial leaf spot in tomato

Treatment combination	Buckeye rot (%)			Bacterial leaf spot (%)		
	2011	2012	Pooled	2011	2012	Pooled
$V_1B_0M_0$	13.57 (3.81)	11.76 (3.57)	12.66 (3.70)	42.65 (40.76)	38.36 (38.25)	40.51 (39.51)
$V_1B_0M_1$	12.75 (3.71)	10.45 (3.38)	11.60 (3.55)	41.07 (39.84)	37.37 (37.67)	39.22 (38.76)
$V_1B_0M_2$	12.35 (3.65)	9.77 (3.28)	11.06 (3.47)	39.87 (39.14)	36.28 (37.02)	38.08 (38.09)
$V_1B_1M_0$	12.89 (3.73)	10.96 (3.46)	11.93 (3.60)	40.20 (39.34)	37.65 (37.84)	38.93 (38.59)
$V_1B_1M_1$	11.90 (3.59)	9.92 (3.30)	10.91 (3.45)	39.91 (39.17)	36.55 (37.18)	38.23 (38.18)
$V_1B_1M_2$	11.36 (3.52)	9.16 (3.19)	10.26 (3.36)	39.04 (38.66)	35.42 (36.51)	37.23 (37.59)
$V_1B_2M_0$	12.24 (3.64)	11.09 (3.48)	11.67 (3.56)	41.72 (40.22)	37.82 (37.94)	39.77 (39.08)
$V_1B_2M_1$	11.09 (3.48)	10.18 (3.34)	10.64 (3.41)	39.95 (39.19)	36.87 (37.37)	38.41 (38.28)
$V_1B_2M_2$	10.61 (3.41)	9.39 (3.22)	10.00 (3.32)	39.16 (38.72)	35.67 (36.66)	37.41 (37.70)
$V_2B_0M_0$	10.97 (3.46)	9.37 (3.22)	10.17 (3.34)	35.30 (36.44)	32.60 (34.80)	33.95 (35.63)
$V_2B_0M_1$	10.05 (3.33)	8.12 (3.02)	9.09 (3.18)	33.84 (35.56)	31.12 (33.89)	32.48 (34.73)
$V_2B_0M_2$	9.19 (3.19)	7.12 (2.85)	8.16 (3.03)	32.57 (34.79)	30.55 (33.54)	31.56 (34.17)
$V_2B_1M_0$	10.14 (3.34)	8.40 (3.07)	9.27 (3.21)	32.14 (34.52)	31.76 (34.29)	31.95 (34.41)
$V_2B_1M_1$	9.22 (3.20)	7.40 (2.90)	8.31 (3.05)	32.45 (34.71)	30.25 (33.36)	31.35 (34.04)
$V_2B_1M_2$	8.35 (3.06)	6.78 (2.79)	7.56 (2.93)	31.63 (34.21)	29.37 (32.81)	30.50 (33.51)
$V_2B_2M_0$	9.63 (3.26)	8.90 (3.15)	9.27 (3.20)	32.62 (34.82)	32.05 (34.47)	32.34 (34.64)
$V_2B_2M_1$	8.74 (3.12)	7.88 (2.98)	8.31 (3.05)	33.06 (35.08)	30.65 (33.60)	31.85 (34.35)
$V_2B_2M_2$	8.92 (3.15)	6.91 (2.81)	7.92 (2.99)	32.01 (34.44)	30.03 (33.22)	31.02 (33.84)
$V_3B_0M_0$	12.24 (3.64)	9.79 (3.29)	11.02 (3.47)	24.08 (29.38)	18.32 (25.33)	21.20 (27.41)
$V_3B_0M_1$	11.27 (3.50)	8.79 (3.13)	10.03 (3.32)	23.91 (29.26)	16.91 (24.27)	20.41 (26.85)
$V_3B_0M_2$	10.63 (3.41)	7.94 (2.99)	9.29 (3.21)	22.98 (28.63)	16.33 (23.83)	19.66 (26.31)
$V_3B_1M_0$	11.99 (3.60)	9.32 (3.21)	10.66 (3.41)	20.86 (27.16)	14.75 (22.58)	17.81 (24.95)
$V_3B_1M_1$	10.51 (3.39)	8.44 (3.07)	9.47 (3.24)	20.35 (26.81)	13.87 (21.86)	17.11 (24.43)
$V_3B_1M_2$	10.04 (3.32)	7.40 (2.90)	8.72 (3.12)	19.82 (26.43)	12.93 (21.06)	16.38 (23.86)
$V_3B_2M_0$	11.25 (3.50)	9.60 (3.26)	10.42 (3.38)	22.10 (28.03)	17.34 (24.60)	19.72 (26.35)
$V_3B_2M_1$	9.95 (3.31)	8.64 (3.11)	9.30 (3.21)	21.58 (27.67)	16.21 (23.74)	18.90 (25.76)
$V_3B_2M_2$	9.31 (3.21)	7.69 (2.95)	8.50 (3.08)	20.90 (27.20)	15.54 (23.21)	18.22 (25.26)
$CD_{0.05}$	**0.04**	**0.03**	**0.02**	**0.18**	**0.12**	**0.11**

In V x B interaction, V_3B_1 resulted in lowest (17.10 %) severity of bacterial leaf spot and the unmulched plots recorded highest disease severity (39.27%) in V_1B_0. Further treatment combination B_0M_0 recorded maximum (31.89%) while B_1M_2 recorded minimum (28.04%) severity of this disease.

Among V x M interaction, V_3M_2 exhibited minimum severity of bacterial leaf spot (18.09%) while it was highest (39.74%) in V_1M_0.

In second order interaction, the treatment combination $V_3B_1M_2$ recorded minimum severity (16.38%) which was followed by combinations $V_3B_1M_1$ (17.11 %) and $V_3B_1M_0$ (17.81 %).

4.21 EARLY BLIGHT (%)

The results obtained on severity of early blight have been presented in Table 4.11a. The perusal of data revealed individual effect of varieties, biofertilizers

Table 4.11a: Response of tomato genotypes to different mulches and biofertilizers with respect to severity of early blight and septoria blight

Treatment combination	Early blight (%)			Septoria blight (%)		
	2011	2012	Pooled	2011	2012	Pooled
Varieties (V)						
V_1 (Naveen 2000$^+$)	36.40 (37.10)	31.25 (33.97)	33.84 (35.53)	24.10 (5.01)	21.80 (4.77)	22.96 (4.89)
V_2 (Sun-7711)	30.46 (33.48)	23.82 (29.20)	27.14 (31.38)	23.71 (4.97)	20.00 (4.58)	21.84 (4.78)
V_3 (Solan Lalima)	22.79 (28.49)	18.67 (25.57)	20.73 (27.05)	21.72 (4.76)	18.54 (4.42)	20.11 (4.59)
$CD_{0.05}$	**0.07**	**0.08**	**0.06**	**0.02**	**0.03**	**0.01**
Biofertilizers						
B_0 (NPK recommended)	31.07 (33.79)	25.39 (30.15)	28.23 (32.00)	24.01 (5.00)	20.67 (4.65)	22.36 (4.83)
B_1 (100% NPK + *Azotobacter* (1g/plant) + PSB (1g/plant)	28.76 (32.28)	23.64 (28.91)	26.20 (30.63)	22.53 (4.85)	19.63 (4.54)	21.07 (4.70)
B_2 (75% NPK + *Azotobacter* (1g/plant) + PSB (1g/plant)	29.83 (33.00)	24.71 (29.68)	27.27 (31.37)	22.92 (4.89)	20.04 (4.58)	21.48 (4.74)
$CD_{0.05}$	**0.05**	**0.08**	**0.06**	**0.02**	**0.01**	**0.02**
Mulches (M)						
M_0 (No Mulch)	30.72 (33.54)	25.60 (30.26)	28.17 (31.93)	24.01 (4.98)	21.20 (4.71)	22.54 (4.85)
M_1 (Pine needle)	29.83 (32.99)	24.51 (29.54)	27.17 (31.29)	22.54 (4.92)	19.99 (4.58)	21.63 (4.76)
M_2 (Black polyethylene)	29.11 (32.53)	23.63 (28.94)	26.37 (30.77)	22.92 (4.83)	19.14 (4.49)	20.75 (4.66)
$CD_{0.05}$	**0.06**	**0.07**	**0.06**	**0.02**	**0.01**	**0.01**

Severity of early blight

Severity of bacterial leaf spot

Severity of septoria blight

Incidence of buckeye rot

Plate 4. Occurence of soil and foliar disease on tomato

and mulches during both the years and in pooled data. The first order interactions V×B, B×M and V×M were also found significant for this character and results have been presented in Table 4.11b. The second order interaction between V×B×M has also recorded significant effect as depicted in Table 4.11c.

Table 4.11b: Effect of different interactions V x B, B x M and V x M severity of early blight and septoria blight in tomato

Treatment combination	Early blight (%)			Septoria blight (%)		
	2011	2012	Pooled	2011	2012	Pooled
V_1B_0	37.22 (37.58)	31.69 (34.25)	34.46 (35.93)	24.92 (5.09)	22.25 (4.82)	23.59 (4.96)
V_1B_1	35.74 (36.70)	30.93 (33.77)	33.34 (35.25)	23.44 (4.94)	21.45 (4.74)	22.45 (4.84)
V_1B_2	36.29 (37.03)	31.13 (33.90)	33.71 (35.48)	23.99 (5.00)	21.70 (4.76)	22.85 (4.88)
V_2B_0	31.51 (34.13)	24.36 (29.56)	27.93 (31.89)	24.73 (5.07)	20.49 (4.64)	22.61 (4.86)
V_2B_1	29.68 (33.00)	23.31 (28.85)	26.50 (30.97)	22.90 (4.89)	19.53 (4.53)	21.22 (4.71)
V_2B_2	30.17 (33.31)	23.80 (29.18)	26.99 (31.28)	23.39 (4.94)	19.98 (4.58)	21.69 (4.77)
V_3B_0	24.49 (29.65)	20.13 (26.64)	22.31 (28.17)	22.49 (4.85)	19.26 (4.50)	20.88 (4.68)
V_3B_1	20.85 (27.15)	16.69 (24.10)	18.77 (25.66)	21.18 (4.71)	17.92 (4.35)	19.55 (4.53)
V_3B_2	23.03 (28.66)	19.19 (25.97)	21.11 (27.34)	21.36 (4.73)	18.43 (4.41)	19.90 (4.57)
$CD_{0.05}$	**0.08**	**0.10**	**0.11**	**0.02**	**0.03**	**0.01**
B_0M_0	32.39 (34.60)	26.41 (30.82)	29.40 (32.74)	25.14 (5.11)	21.78 (4.77)	23.46 (4.94)
B_0M_1	30.98 (33.73)	25.24 (33.04)	28.11 (31.92)	24.07 (5.01)	20.48 (4.63)	22.28 (4.82)
B_0M_2	29.85 (33.02)	24.53 (29.58)	27.19 (31.33)	22.93 (4.89)	19.74 (4.55)	21.34 (4.73)
B_1M_0	29.11 (32.52)	24.69 (29.62)	26.90 (31.09)	22.86 (4.88)	20.74 (4.66)	21.80 (4.77)
B_1M_1	28.95 (32.40)	23.62 (28.90)	26.29 (30.69)	22.70 (4.86)	19.57 (4.53)	21.14 (4.70)
B_1M_2	28.21 (31.93)	22.62 (28.21)	25.42 (30.11)	21.96 (4.79)	18.59 (4.42)	20.28 (4.61)
B_2M_0	30.67 (33.52)	25.71 (30.35)	28.19 (31.96)	23.61 (4.96)	21.09 (4.70)	22.35 (4.83)
B_2M_1	29.55 (32.83)	24.67 (29.66)	27.11 (31.29)	22.99 (4.90)	19.93 (4.57)	21.46 (4.74)
B_2M_2	29.27 (32.65)	23.74 (29.03)	26.51 (30.88)	22.15 (4.81)	19.10 (4.48)	20.63 (4.65)
$CD_{0.05}$	**0.10**	**0.12**	**0.11**	**0.03**	**0.02**	**0.01**
V_1M_0	37.54 (37.54)	32.31 (34.62)	34.93 (36.21)	25.24 (5.12)	22.85 (4.88)	24.05 (4.01)
V_1M_1	36.33 (36.33)	31.27 (33.99)	33.80 (35.53)	24.03 (5.00)	21.84 (4.78)	22.94 (4.89)
V_1M_2	35.38 (35.38)	30.18 (33.31)	32.78 (34.91)	23.08 (4.91)	20.70 (4.66)	21.89 (4.78)
V_2M_0	31.11 (31.11)	25.02 (30.00)	28.07 (31.96)	24.18 (5.02)	21.21 (4.71)	22.70 (4.87)
V_2M_1	30.38 (30.38)	23.54 (29.01)	26.96 (31.27)	23.95 (4.99)	19.74 (4.55)	21.85 (4.78)
V_2M_2	29.88 (29.88)	22.91 (28.58)	26.40 (30.90)	22.90 (4.89)	19.05 (4.48)	20.98 (4.69)
V_3M_0	23.51 (23.51)	19.49 (26.17)	21.50 (27.60)	22.18 (4.81)	19.54 (4.53)	20.86 (4.66)
V_3M_1	22.78 (22.78)	18.71 (25.61)	20.75 (27.08)	21.78 (4.77)	18.40 (4.40)	20.09 (4.59)
V_3M_2	22.07 (22.07)	17.81 (24.93)	19.94 (26.50)	21.06 (4.70)	17.67 (4.32)	19.37 (4.51)
$CD_{0.05}$	**0.10**	**0.12**	**0.11**	**0.03**	**0.02**	**0.01**

In the individual effect, pooled analysis showed that the variety V_1 (Naveen 2000^+) exhibited maximum severity of early blight (33.84%) while it

was minimum (20.73%) in V_3 (Solan Lalima). Among biofertilizers, B_0 exhibited maximum (28.23%) while B_1 observed minimum (26.20%) values for the disease severity. With regard to mulches, M_0 (No mulch) application exhibited maximum early blight (28.17%) while M_2 (Black polythene) mulch exhibited minimum (26.37%).

The data in Table 4.11b revealed that in the interaction between variety and biofertilizers, V_1B_0 recorded maximum (34.46%) while V_3B_1 observed minimum (18.77%) severity of early blight. Further treatment combination B_0M_0 recorded maximum (29.40%) while B_1M_2 recorded minimum (25.42%) severity of this disease. In the interaction between variety and mulch treatment combination, V_1M_0 recorded maximum (34.93%) whereas it was minimum (19.94%) in V_3M_2.

The second order interaction between different varieties, biofertilizers and mulches had also recorded significant differences for the severity of early blight. The pooled analysis of the data in the experiment of the both year revealed that maximum (35.68%) in severity of early blight in $V_1B_0M_0$ and minimum (18.05%) in $V_3B_1M_2$.

4.22 SEPTORIA BLIGHT (%)

The observation recorded on the severity of septoria blight disease has been presented in table 4.11a. The analysis of variance showed significant differences for severity of septoria blight. The observations recorded reflected the significant individual effects of varieties, biofertilizers and mulches during both the years and in pooled data. The first order interactions V×B, B×M and V×M were also found to be significant and results have been presented in Table 4.11b. The second order interaction V×B×M has also recorded significant effect (Table 4.11c).

A perusal of the data indicated that the variety V_1 (Naveen 2000^+) exhibited maximum septoria blight (22.96%) severity while minimum (20.11%) severity was recorded in V_3 (Solan Lalima). Among various biofertilizer levels,

B_0 exhibited maximum (22.36%) while B_1 observed minimum (21.07%) values for this disease. The use of mulches tended to reduce the severity of septoria blight. The use of black polyethylene mulch (M_2) recorded the lowest (20.75%) severity of septoria blight and unmulched plots recorded the highest (22.54%) severity.

Table 4.11c: Effect of V x B x M interaction for severity of early blight and septoria blight in tomato

Treatment combination	Early blight (%)			Septoria blight (%)		
	2011	2012	Pooled	2011	2012	Pooled
$V_1B_0M_0$	38.67 (38.44)	32.68 (34.85)	35.68 (36.66)	26.37 (5.23)	23.27 (4.93)	24.82 (5.08)
$V_1B_0M_1$	37.09 (37.51)	31.75 (34.28)	34.42 (35.91)	24.79 (5.08)	22.28 (4.83)	23.54 (4.95)
$V_1B_0M_2$	35.89 (36.79)	30.65 (33.60)	33.27 (35.21)	23.59 (4.96)	21.19 (4.71)	22.39 (4.84)
$V_1B_1M_0$	36.22 (36.99)	32.02 (34.45)	34.12 (35.73)	23.92 (4.99)	22.56 (4.85)	23.24 (4.92)
$V_1B_1M_1$	35.93 (36.82)	30.87 (33.74)	33.40 (35.29)	23.63 (4.96)	21.46 (4.74)	22.55 (4.85)
$V_1B_1M_2$	35.06 (36.30)	29.89 (33.13)	32.48 (34.73)	22.76 (4.88)	20.33 (4.62)	21.55 (4.75)
$V_1B_2M_0$	37.74 (37.89)	32.22 (34.57)	34.98(36.24)	25.44 (5.14)	22.73 (4.87)	24.08 (5.01)
$V_1B_2M_1$	35.97 (36.84)	31.18 (33.94)	33.58 (35.40)	23.67 (4.97)	21.78 (4.77)	22.72 (4.87)
$V_1B_2M_2$	35.18 (36.36)	29.99 (33.19)	32.58 (34.80)	22.88 (4.89)	20.58 (4.65)	21.73 (4.77)
$V_2B_0M_0$	32.91 (34.99)	25.47 (30.30)	29.19 (32.69)	26.13 (5.21)	21.67 (4.76)	23.90 (4.99)
$V_2B_0M_1$	31.45 (34.10)	24.06 (29.37)	27.76 (31.78)	24.67 (5.07)	20.19 (4.60)	22.43 (4.84)
$V_2B_0M_2$	30.18 (33.31)	23.53 (29.01)	26.85 (31.20)	23.40 (4.94)	19.62 (4.54)	21.51 (4.74)
$V_2B_1M_0$	29.75 (33.04)	24.66 (29.76)	27.21 (31.43)	22.97 (4.90)	20.83 (4.67)	21.90 (4.79)
$V_2B_1M_1$	30.06 (33.23)	23.08 (28.70)	26.57 (31.02)	23.28 (4.93)	19.32 (4.51)	21.30 (4.72)
$V_2B_1M_2$	29.24 (32.72)	22.21 (28.109)	25.72 (30.47)	22.46 (4.84)	18.44 (4.41)	20.45 (4.63)
$V_2B_2M_0$	30.67 (33.61)	24.92 (29.94)	27.80 (31.81)	23.45 (4.95)	21.12 (4.70)	22.29 (4.83)
$V_2B_2M_1$	29.62 (32.96)	23.47 (28.97)	26.55 (31.00)	23.89 (4.99)	19.72 (4.55)	21.80 (4.78)
$V_2B_2M_2$	30.23 (33.34)	22.99 (28.64)	26.61 (31.05)	22.84 (4.88)	19.10 (4.48)	20.97 (4.69)
$V_3B_0M_0$	25.58 (30.37)	21.07 (27.32)	23.33 (28.87)	22.91 (4.89)	20.39 (4.63)	21.65 (4.76)
$V_3B_0M_1$	24.41 (29.60)	19.89 (26.48)	22.15 (28.06)	22.74 (4.87)	18.98 (4.47)	20.86 (4.68)
$V_3B_0M_2$	23.48 (28.97)	19.43 (26.14)	21.45 (27.58)	21.81 (4.78)	18.40 (4.41)	20.11 (4.59)
$V_3B_1M_0$	21.36 (27.52)	17.39 (24.64)	19.38 (26.11)	21.69 (4.76)	18.82 (4.45)	20.26 (4.61)
$V_3B_1M_1$	20.85 (27.16)	16.91 (24.27)	18.88 (25.75)	21.18 (4.71)	17.94 (4.35)	19.56 (4.54)
$V_3B_1M_2$	20.32 (26.79)	15.77 (23.39)	18.05 (25.13)	20.65 (4.65)	17.00 (4.24)	18.83 (4.45)
$V_3B_2M_0$	23.60 (29.05)	19.99 (26.55)	21.80 (27.82)	21.93 (4.79)	19.41 (4.52)	20.67 (4.66)
$V_3B_2M_1$	23.08 (28.70)	19.35 (26.08)	21.21(27.42)	21.41 (4.73)	18.28 (4.39)	19.85 (4.57)
$V_3B_2M_2$	22.40 (28.24)	18.24 (25.27)	20.32(26.79)	20.73 (4.66)	17.61 (4.31)	19.17 (4.49)
$CD_{0.05}$	**0.17**	**0.20**	**0.19**	**0.04**	**0.03**	**0.02**

In V x B interaction, V_3B_1 resulted in lowest (19.55%) severity of seotoria blight whereas, it was highest (23.59%) in V_1B_0. Further treatment combination

B_0M_0 recorded maximum severity (23.46%) while B_1M_2 recorded the minimum (20.28%). Among VxM interactions, V_3M_2 showed minimum severity of septoria blight (19.37%) whereas it was maximum (24.05 %) in V_1M_0.

In second order interaction, the treatment combination $V_3B_1M_2$ recorded minimum severity (18.83%) which was followed by combinations $V_3B_2M_2$ (19.17%). The highest severity of septoria blight was found in $V_1B_0M_0$ (24.82%).

SOIL PARAMETERS

4.23 AVAILABLE NITROGEN (kg/ha)

The observation recorded on available nitrogen has been presented in Table 4.12a. The perusal of data revealed significant individual effect of varieties, biofertilizers and mulches during both the years and in pooled data. The first order interactions V×B, B×M and V×M were also found significant for this character and results have been presented in Table 4.12b. The second interaction between V×B×M has also recorded significant effect and has been presented in Table 4.12c.

Table 4.12a: Effect of tomato genotypes to different mulches and biofertilizers with respect to available nitrogen and organic carbon in soil

Treatment combination	Available Nitrogen (kg/ha)			Organic carbon (%)		
	2011	2012	Pooled	2011	2012	Pooled
Varieties (V)						
V_1 (Naveen 2000$^+$)	280.87	321.03	300.95	1.74 (1.65)	1.85 (1.69)	1.79 1.67)
V_2 (Sun-7711)	282.99	330.29	306.64	1.80 (1.67)	1.95 (1.72)	1.88 (1.70)
V_3 (Solan Lalima)	285.58	333.76	309.67	1.82 (1.68)	2.05 (1.75)	1.94 (1.72)
$CD_{0.05}$	**1.23**	**1.49**	**1.54**	**0.01**	**0.02**	**0.01**
Biofertilizers						
B_0(NPK recommended)	273.57	312.61	293.09	1.65 (1.63)	1.88 (1.69)	1.76 (1.66)
B_1(100% NPK+*Azotobacter* (1g/plant)+PSB(1g/plant)	288.31	345.09	316.70	1.92 (1.71)	2.01 (1.73)	1.97 (1.72)
B_2(75% NPK+*Azotobacter* (1g/plant)+PSB(1g/plant)	287.57	327.37	307.47	1.80 (1.67)	1.96 (1.72)	1.88 (1.70)
$CD_{0.05}$	**1.40**	**2.64**	**0.85**	**0.02**	**0.01**	**0.01**
Mulches (M)						
M_0 (No Mulch)	279.37	315.60	297.49	1.64 (1.63)	1.86 (1.69)	1.75 (1.66)
M_1 (Pine needle)	287.13	342.37	314.75	1.94 (1.71)	2.04 (1.74)	1.99 (1.73)
M_2 (Black polyethylene)	282.95	327.11	305.03	1.78 (1.67)	1.94 (1.72)	1.87 (1.69)
$CD_{0.05}$	**0.81**	**1.14**	**0.68**	**0.01**	**0.02**	**0.01**

Among different varieties, V_3 (Solan Lalima) recorded maximum available nitrogen (309.67 kg/ha) while V_1 (Naveen 2000^+) recorded minimum available nitrogen (300.95 kg/ha). Biofertilizers also significantly affected available nitrogen. Among various biofertilizers, treatments B_1 gave maximum available nitrogen (316.70 kg/ha) and minimum available nitrogen (293.09 kg/ha) was recorded with B_0. Among different mulches materials pine needle mulched plots produced maximum available nitrogen (314.75 kg/ha) whereas, M_0 (No mulch) plots recorded minimum value (297.49 kg/ha) for this parameter.

The data in Table 4.12b revealed that in the interaction between variety and biofertilizers, treatment combination V_2B_1 recorded maximum available nitrogen (320.16 kg/ha) which was statistically superior to all other treatments. Minimum value (291.11 kg/ha) was observed with V_1B_0. Further treatment combination B_1M_1 recorded maximum available nitrogen (327.40 kg/ha), whereas minimum (287.70 kg/ha) was found with B_0M_0. In the interaction between variety and much treatment combination V_3M_1 recorded maximum available nitrogen (320.05 kg/ha) and was found statistically superior to all other treatments.V_1M_0 recorded minimum value (293.41 kg/ha) for this trait.

The second order interaction between different varieties, biofertilizers and mulch materials had also significant differences for available nitrogen. The pooled analysis of data in the experiment of both the year revealed that maximum available nitrogen (332.96 kg/ha) was obtained with treatment combination $V_2B_1M_1$. Minimum available nitrogen (287.23 kg/ha) was recorded by treatment combination $V_1B_0M_0$.

4.24 ORGANIC CARBON (%)

The result obtained on soil organic carbon has been presented in Table 4.12a which shows significant individual effect of varieties, biofertilizers and mulches. The first order interaction V×B, B×M and V×M were found to be significant as presented in Table 4.12b. The second order interaction V×B×M also recorded significant effect for all treatment and has been presented in Table 4.12c.

Table 4.12b: Effect of different interactions V x B, B x M and V x M available nitrogen and organic carbon in soil

Treatment combination	Available Nitrogen (kg/ha)			Organic carbon (%)		
	2011	2012	Pooled	2011	2012	Pooled
$V_1 B_0$	275.17	307.05	291.11	1.59 (1.61)	1.77 (1.66)	1.68 (1.64)
$V_1 B_1$	282.40	338.55	310.48	1.85 (1.69)	1.90 (1.70)	1.88 (1.69)
$V_1 B_2$	285.04	317.48	301.26	1.76 (1.66)	1.86 (1.69)	1.81 (1.68)
$V_2 B_0$	272.04	312.41	292.23	1.67 (1.63)	1.88 (1.70)	1.78 (1.67)
$V_2 B_1$	288.84	351.49	320.16	1.92 (1.71)	2.01 (1.73)	1.97 (1.72)
$V_2 B_2$	288.09	326.96	307.53	1.81 (1.68)	1.97 (1.72)	1.89 (1.70)
$V_3 B_0$	273.50	318.37	295.94	1.68 (1.63)	1.99 (1.73)	1.84 (1.68)
$V_3 B_1$	293.68	345.25	319.46	1.98 (1.71)	2.12 (1.77)	2.05 (1.75)
$V_3 B_2$	289.58	337.67	313.62	1.82 (1.68)	2.05 (1.75)	1.94 (1.71)
$CD_{0.05}$	**2.43**	**4.57**	**1.48**	**0.01**	**0.02**	**0.01**
$B_0 M_0$	269.66	305.74	287.70	1.54 (1.59)	1.80 (1.67)	1.67 (1.64)
$B_0 M_1$	276.20	320.39	298.29	1.77 (1.66)	1.96 (1.72)	1.87 (1.69)
$B_0 M_2$	274.85	311.71	293.28	1.63 (1.62)	1.88 (1.69)	1.75 (1.66)
$B_1 M_0$	284.39	328.62	306.51	1.73 (1.65)	1.92 (1.71)	1.82 (1.68)
$B_1 M_1$	292.24	362.57	327.40	2.11 (1.76)	2.11 (1.76)	2.12 (1.77)
$B_1 M_2$	288.29	344.09	316.20	1.91 (1.71)	2.00 (1.73)	1.96 (1.72)
$B_2 M_0$	284.06	312.43	298.25	1.66 (1.63)	1.88 (1.69)	1.77 (1.66)
$B_2 M_1$	292.94	344.15	318.55	1.93 (1.71)	2.05 (1.75)	1.99 (1.73)
$B_2 M_2$	285.70	325.53	305.61	1.81 (1.68)	1.96 (1.71)	1.88 (1.69)
$CD_{0.05}$	**1.41**	**1.97**	**1.18**	**0.02**	**0.01**	**0.01**
$V_1 M_0$	277.82	309.00	293.41	1.61 (1.62)	1.75 (1.66)	1.68 (1.64)
$V_1 M_1$	283.50	332.59	308.05	1.86 (1.69)	1.95 (1.72)	1.88 (1.71)
$V_1 M_2$	281.29	321.49	301.39	1.74 (1.65)	1.83 (1.68)	1.81 (1.67)
$V_2 M_0$	278.60	318.11	298.35	1.64 (1.62)	1.87 (1.69)	1.78 (1.66)
$V_2 M_1$	288.23	344.07	316.15	1.97 (1.72)	2.03 (1.74)	1.97 (1.73)
$V_2 M_2$	282.14	328.68	305.41	1.79 (1.67)	1.95 (1.72)	1.89 (1.69)
$V_3 M_0$	281.70	319.69	300.70	1.67 (1.63)	1.97 (1.72)	1.84 (1.68)
$V_3 M_1$	289.65	350.45	320.05	1.98 (1.73)	2.14 (1.77)	2.05 (1.75)
$V_3 M_2$	285.41	331.16	308.28	1.82 (1.68)	2.04 (1.74)	1.94 (1.71)
$CD_{0.05}$	**1.41**	**1.97**	**1.18**	**0.02**	**0.01**	**0.01**

Maximum soil organic carbon (1.94%) was recorded with V_3 (Solan Lalima) while V_1 (Naveen 2000^+) exhibited minimum (1.79%) soil organic carbon. Biofertilizers affected the soil organic carbon significantly. B_1 showed maximum soil organic carbon (1.97%). However, B_0 registered minimum soil organic carbon (1.76%). Among varieties mulch treatments, soil treated with M_1 (Pine needle) exhibited maximum soil organic carbon (1.99%) and minimum soil organic carbon (1.75%) was obtained with M_0 (No mulch).

Table 4.12c: Effect of V x B x M interaction available nitrogen and organic carbon in soil

Treatment combination	Available Nitrogen (kg/ha)			Organic carbon (%)		
	2011	2012	Pooled	2011	2012	Pooled
$V_1B_0M_0$	272.95	301.51	287.23	1.52 (1.59)	1.71 (1.65)	1.61 (1.62)
$V_1B_0M_1$	276.98	311.38	294.18	1.67 (1.63)	1.83 (1.68)	1.75 (1.66)
$V_1B_0M_2$	275.59	308.26	291.93	1.59 (1.61)	1.77 (1.66)	1.68 (1.64)
$V_1B_1M_0$	278.31	325.18	301.75	1.68 (1.64)	1.79 (1.67)	1.74 (1.65)
$V_1B_1M_1$	285.16	352.08	318.62	2.04 (1.74)	1.96 (1.75)	2.05 (1.74)
$V_1B_1M_2$	283.74	338.38	311.06	1.84 (1.68)	1.89 (1.69)	1.86 (1.69)
$V_1B_2M_0$	282.20	300.31	291.26	1.63 (1.62)	1.90 (1.66)	1.69 (1.64)
$V_1B_2M_1$	288.37	334.30	311.34	1.88 (1.70)	2.10 (1.72)	1.93 (1.71)
$V_1B_2M_2$	284.54	317.84	301.19	1.78 (1.67)	1.97 (1.69)	1.82 (1.68)
$V_2B_0M_0$	267.60	307.60	287.60	1.54 (1.59)	1.80 (1.67)	1.67 (1.63)
$V_2B_0M_1$	275.38	318.89	297.13	1.84 (1.68)	2.05 (1.72)	1.90 (1.70)
$V_2B_0M_2$	273.13	310.75	291.94	1.63 (1.62)	1.87 (1.70)	1.76 (1.66)
$V_2B_1M_0$	283.90	331.80	307.85	1.72 (1.65)	1.92 (1.71)	1.82 (1.68)
$V_2B_1M_1$	294.82	371.10	332.96	2.11 (1.76)	2.09 (1.76)	2.10 (1.76)
$V_2B_1M_2$	287.80	351.56	319.68	1.93 (1.71)	2.01 (1.74)	1.97 (1.72)
$V_2B_2M_0$	284.29	314.91	299.60	1.66 (1.63)	2.03 (1.70)	1.78 (1.67)
$V_2B_2M_1$	294.50	342.22	318.36	1.95 (1.72)	2.20 (1.75)	2.00 (1.73)
$V_2B_2M_2$	285.49	323.74	304.61	1.82 (1.68)	2.12 (1.72)	1.89 (1.70)
$V_3B_0M_0$	268.44	308.10	288.27	1.57 (1.60)	1.75 (1.70)	1.74 (1.66)
$V_3B_0M_1$	276.25	330.89	303.57	1.80 (1.67)	1.97 (1.76)	1.95 (1.72)
$V_3B_0M_2$	275.82	316.12	295.97	1.66 (1.63)	1.86 (1.72)	1.82 (1.68)
$V_3B_1M_0$	290.96	328.88	309.92	1.78 (1.67)	1.90 (1.74)	1.91 (1.71)
$V_3B_1M_1$	296.74	364.52	330.63	2.19 (1.79)	2.05 (1.79)	2.20 (1.79)
$V_3B_1M_2$	293.35	342.34	317.84	1.96 (1.72)	1.96 (1.77)	2.05 (1.74)
$V_3B_2M_0$	285.70	322.08	303.89	1.67 (1.63)	1.98 (1.73)	1.83 (1.68)
$V_3B_2M_1$	295.96	355.93	325.94	1.95 (1.72)	2.13 (1.77)	2.04 (1.75)
$V_3B_2M_2$	287.06	335.00	311.03	1.83 (1.68)	2.04 (1.74)	1.94 (1.71)
$CD_{0.05}$	**2.44**	**3.41**	**2.03**	**0.02**	**0.01**	**0.01**

In V×B interaction, treatment combination V_3B_1 registered maximum (2.05%) soil organic carbon, whereas V_1B_0 gave minimum soil organic carbon (1.68%). The interaction effect between biofertilizers and mulches on this trait was found to be significant and the maximum (2.12%) value was obtained with B_1M_1. Whereas, minimum soil organic carbon (1.67%) was recorded with B_0M_0. Further with regard to V×M, V_3M_1 exhibited maximum soil organic carbon (2.05%) while V_1M_0 recorded minimum (1.68%) value for this trait.

Data in Table 4.12c clearly indicated the significant effect of V×B×M interaction on soil organic carbon of tomato field. Maximum soil organic carbon (2.20%) was observed with treatment combination $V_3B_1M_1$. However minimum soil organic carbon (1.61%) was recorded with treatment combination $V_1B_0M_0$.

4.25 AVAILABLE PHOSPHORUS (kg/ha)

The results obtained in table 4.13a which shows significant individual effects of varieties, biofertilizers and mulches. The first order interactions, V×B, B×M and V×M were also found significant for this character and results have been presented in Table 4.13b. The second order interaction (Table 4.13c) were also found to be significant.

Maximum available phosphorus (47.20 kg/ha) was observed with V_3 (Solan Lalima) while V_1 (Naveen 2000^+) exhibited minimum available phosphorus (37.93 kg/ha). Among biofertilizers, B_1 exhibited maximum available phosphorus (45.30 kg/ha). Minimum value (38.22 kg/ha) for this trait was recorded with B_0. Mulches also showed significant effect on the available phosphorus with maximum (46.28 kg/ha) being observed with M_1 (Pine needle) and minimum (38.86 kg/ha) being observed with M_0 (No mulch).

In V×B interaction, treatment combination V_3B_1 registered maximum (51.35 kg/ha) value whereas minimum (32.99 kg/ha) was recorded with V_1B_0. The interaction effect between biofertilizers and mulches on this trait was found to be significant and maximum (49.77 kg/ha) value was obtained with B_1M_1. Whereas minimum soil available phosphorus (34.87 kg/ha) was observed with B_0M_0. Further with regard to V×M, V_3M_1 exhibited maximum available phosphorus (51.22 kg/ha) while V_1M_0 recorded minimum (34.72 kg/ha) value for this trait.

Data in Table 4.13c clearly indicated the significant effect of V×B×M interaction on available phosphorus of tomato field. Maximum value (55.45 kg/ha) was recorded with $V_3B_1M_1$ and minimum (29.54 kg/ha) was observed with $V_1B_0M_0$.

Table 4.13a: Effect of tomato genotypes to different mulches and biofertilizers with respect to available phosphorus and potash in soil

Treatment combination	Available Phosphorus (kg/ha)			Available Potash (kg/ha)		
	2011	2012	Pooled	2011	2012	Pooled
Varieties (V)						
V_1 (Naveen 2000$^+$)	33.72	42.13	37.93	374.18	377.396	375.68
V_2 (Sun-7711)	37.59	47.99	42.79	386.54	385.059	385.84
V_3 (Solan Lalima)	41.63	52.77	47.20	388.31	394.080	391.20
$CD_{0.05}$	**0.24**	**1.78**	**0.89**	**1.10**	**0.39**	**0.55**
Biofertilizers						
B_0 (NPK recommended)	33.30	43.14	38.22	372.02	378.619	375.29
B_1 (100% NPK + *Azotobacter* (1g/plant) + PSB (1g/plant)	41.86	50.13	45.30	390.94	392.521	391.71
B_2 (75% NPK + *Azotobacter* (1g/plant) + PSB(1g/plant)	37.79	49.62	43.71	386.06	385.395	385.71
$CD_{0.05}$	**0.44**	**0,64**	**0.40**	**0.94**	**0.52**	**0.50**
Mulches (M)						
M_0 (No Mulch)	34.02	43.69	38.86	366.61	365.815	366.25
M_1 (Pine needle)	41.41	51.16	46.28	384.57	387.590	386.03
M_2 (Black polyethylene)	37.52	48.04	42.78	397.84	403.13	400.43
$CD_{0.05}$	**0.31**	**0.271**	**0.22**	**0.67**	**0.40**	**0.42**

4.26 Available Potash (kg/ha)

The observation recorded on available potash has been presented in Table 4.13a. The perusal of data revealed significant individual effect of varieties, biofertilizers and mulches during both the years and in pooled data. The first order interactions V×B, B×M and V×M were also found significant for this character and results have been presented in Table 4.13b. The second interaction between V×B×M has also recorded significant effect and has been presented in Table 4.13c.

Among different varieties, V_3 (Solan Lalima) recorded maximum available potash (391.20 kg/ha) while V_1 (Naveen 2000$^+$) recorded minimum available potash (375.68 kg/ha). Biofertilizers also significantly affected available potash. Among various biofertilizers, treatments B_1 gave maximum available potash (391.71 kg/ha) and minimum available potash (375.29 kg/ha)

was recorded with B_0. Among different mulches materials black polythene mulched plots produced maximum available potash (400.43 kg/ha) whereas, M_0 (No mulch) plots recorded minimum value (366.25 kg/ha) for this parameter.

Table 4.13b: Effect of different interactions V x B, B x M and V x M available phosphorus and potash in soil

Treatment combination	Available Phosphorus(kg/ha)			Available Potash (kg/ha)		
	2011	2012	Pooled	2011	2012	Pooled
$V_1 B_0$	30.03	35.94	32.99	369.73	371.58	370.49
$V_1 B_1$	37.30	44.96	41.13	378.40	383.05	380.61
$V_1 B_2$	33.83	45.49	39.66	374.40	377.57	375.93
$V_2 B_0$	32.50	43.83	38.17	371.87	379.18	375.58
$V_2 B_1$	41.72	49.31	45.51	393.39	390.98	392.24
$V_2 B_2$	38.56	50.83	44.70	394.35	385.02	389.69
$V_3 B_0$	37.35	49.65	43.50	374.48	385.10	379.79
$V_3 B_1$	46.57	56.12	51.35	401.03	403.54	402.29
$V_3 B_2$	40.97	52.54	46.76	389.43	393.60	391.52
$CD_{0.05}$	**0.76**	**1.11**	**0.69**	**1.63**	**0.89**	**0.87**
$B_0 M_0$	29.89	39.85	34.87	353.65	359.91	356.84
$B_0 M_1$	37.72	46.29	42.01	374.21	379.25	376.62
$B_0 M_2$	32.28	43.28	37.78	388.21	396.70	392.40
$B_1 M_0$	38.09	45.53	41.81	375.99	371.72	373.92
$B_1 M_1$	45.52	54.02	49.77	391.94	395.71	393.77
$B_1 M_2$	41.98	50.84	46.41	404.88	410.13	407.45
$B_2 M_0$	34.07	45.70	39.88	370.19	365.81	368.01
$B_2 M_1$	40.98	53.15	47.07	387.55	387.81	387.68
$B_2 M_2$	38.31	50.01	44.16	400.44	402.56	401.45
$CD_{0.05}$	**0.53**	**0.47**	**0.38**	**1.17**	**0.70**	**0.72**
$V_1 M_0$	31.05	38.40	34.72	356.70	358.80	357.75
$V_1 M_1$	36.61	45.98	41.30	374.70	378.77	376.57
$V_1 M_2$	33.50	42.02	37.76	391.13	394.61	392.71
$V_2 M_0$	34.87	42.81	38.84	374.12	364.32	369.28
$V_2 M_1$	40.36	52.30	46.33	386.72	386.54	386.63
$V_2 M_2$	37.54	48.85	43.20	398.77	404.31	401.60
$V_3 M_0$	36.13	49.87	43.00	369.03	374.32	371.73
$V_3 M_1$	47.25	55.19	51.22	392.29	397.46	394.88
$V_3 M_2$	41.52	53.25	47.39	403.62	410.46	406.99
$CD_{0.05}$	**0.53**	**0.47**	**0.38**	**1.17**	**0.70**	**0.72**

The data in Table 4.13b revealed that in the interaction between variety and biofertilizers, treatment combination V_3B_1 recorded maximum available potash (402.29 kg/ha) which was statistically superior to all other treatments. Minimum value (370.49 kg/ha) was observed with V_1B_0. Further treatment combination B_1M_2 recorded maximum available potash (407.45 kg/ha), whereas minimum (356.84 kg/ha) was found with B_0M_0. In the interaction between variety and much treatment combination V_3M_2 recorded maximum available potash (406.99kg/ha) and was found statistically superior to all other treatments. V_1M_0 recorded minimum value (357.75 kg/ha) for this trait.

Table 4.13c: Effect of V x B x M interaction available phosphorus and potash in soil

Treatment combination	Available Phosphorus(kg/ha)			Available Potash (kg/ha)		
	2011	2012	Pooled	2011	2012	Pooled
$V_1B_0M_0$	27.04	32.04	29.54	351.67	354.10	352.89
$V_1B_0M_1$	33.78	40.52	37.15	370.83	371.23	371.03
$V_1B_0M_2$	29.27	35.27	32.27	386.69	388.39	387.54
$V_1B_1M_0$	34.96	41.42	38.19	361.47	363.07	362.27
$V_1B_1M_1$	39.54	48.18	43.86	378.58	384.86	381.72
$V_1B_1M_2$	37.39	45.29	41.34	395.14	400.53	397.83
$V_1B_2M_0$	31.15	41.73	36.44	356.94	359.23	358.09
$V_1B_2M_1$	36.50	49.25	42.88	374.68	379.22	376.95
$V_1B_2M_2$	33.85	45.50	39.67	391.57	393.92	392.75
$V_2B_0M_0$	30.61	39.67	35.14	352.66	358.58	355.62
$V_2B_0M_1$	34.22	47.37	40.80	375.50	379.83	377.66
$V_2B_0M_2$	32.67	44.45	38.56	387.44	399.47	393.46
$V_2B_1M_0$	38.87	42.22	40.55	387.54	370.36	378.95
$V_2B_1M_1$	45.29	54.71	50.00	389.42	393.13	391.27
$V_2B_1M_2$	40.99	50.99	45.99	403.20	409.78	406.49
$V_2B_2M_0$	35.13	46.54	40.84	382.15	364.36	373.25
$V_2B_2M_1$	41.58	54.82	48.20	395.23	386.67	390.95
$V_2B_2M_2$	38.96	51.12	45.04	405.68	404.02	404.85
$V_3B_0M_0$	32.01	47.85	39.93	356.62	367.38	362.00
$V_3B_0M_1$	45.16	51.00	48.08	376.31	386.02	381.17
$V_3B_0M_2$	34.89	50.11	42.50	390.50	401.90	396.20
$V_3B_1M_0$	40.45	52.95	46.70	378.97	382.06	380.52
$V_3B_1M_1$	51.71	59.19	55.45	407.82	408.81	408.31
$V_3B_1M_2$	47.55	56.23	51.89	416.29	419.75	418.02
$V_3B_2M_0$	35.92	48.82	42.37	371.49	373.85	372.67
$V_3B_2M_1$	44.87	55.39	50.13	392.73	397.54	395.14
$V_3B_2M_2$	42.13	53.41	47.77	404.08	409.41	406.75
$CD_{0.05}$	**0.92**	**0.81**	**0.67**	**2.02**	**1.20**	**1.25**

The second order interaction between different varieties, biofertilizers and mulch materials had also significant differences for available potash. The pooled analysis of data in the experiment of both the year revealed that maximum available potash (418.02 kg/ha) was obtained with treatment combination $V_3B_1M_2$. Minimum available potash (352.89 kg/ha) was recorded by treatment combination $V_1B_0M_0$.

4.27 SOIL pH

The results obtained on soil pH have been presented in Table 4.14a which shows significant individual effect of varieties, biofertilizers and mulches. Among the first order as well as second order interaction did not show any significant differences during both the years of study (4.14b & 4.14c).

Table 4.14a: Effect of tomato genotypes to different mulches and biofertilizerswith respect to pH and EC in soil

Treatment combination	pH			EC (dS/m)		
	2011	2012	Pooled	2011	2012	Pooled
Varieties (V)						
V_1 (Naveen 2000$^+$)	7.10	7.21	7.16	0.261	0.247	0.254
V_2 (Sun-7711)	7.05	7.16	7.12	0.252	0.240	0.247
V_3 (Solan Lalima)	7.06	7.17	7.12	0.243	0.232	0.238
$CD_{0.05}$	**0.03**	**0.03**	**0.03**	**0.02**	**0.01**	**0.01**
Biofertilizers						
B_0 (NPK recommended)	7.13	7.24	7.19	0.299	0.285	0.292
B_1(100% NPK+*Azotobacter* (1g/plant)+PSB(1g/plant)	7.06	7.17	7.12	0.274	0.263	0.269
B_2(75% NPK+*Azotobacter* (1g/plant)+PSB(1g/plant)	7.03	7.14	7.09	0.183	0.172	0.178
$CD_{0.05}$	**0.05**	**0.04**	**0.05**	**0.01**	**0.02**	**0.01**
Mulches (M)						
M_0 (No Mulch)	7.13	7.24	7.19	0.264	0.246	0.255
M_1 (Pine needle)	7.03	7.13	7.08	0.243	0.234	0.239
M_2 (Black polyethylene)	7.07	7.18	7.13	0.248	0.240	0.244
$CD_{0.05}$	**0.03**	**0.03**	**0.03**	**0.01**	**0.02**	**0.01**

Individual effects, pooled data of both years showed that the variety V_1 (Naveen 2000$^+$) recorded the highest soil pH (7.16), while variety V_2 (Sun-7711) recorded the lowest soil pH (7.10). Among biofertilizers, B_0 exhibited the highest soil pH (7.19) while B_2 showed the lowest pH (7.09). With regard to different mulch materials, highest soil pH (7.19) was recorded with M_0 (No mulch) while lowest soil pH (7.08) was observed with M_1 (Pine needle).

4.28 SOIL EC (dS/m)

The observation recorded on soil EC has been presented in Table 4.14a. The perusal of data revealed significant individual effect of varieties, biofertilizers and mulch material during both the years and in pooled data. The first order interactions were also found significant for this character and results have been presented in Table 4.14b. Whereas, all the first order V×B, B×M VxM and second order interaction V×B×M as presented in Table 4.14c did not show significant differences during both the years of study.

Table 4.14b: Effect of different interactions V x B, B x M and V x M pH and EC in soil

Treatment combination	pH			EC (dS/m)		
	2011	2012	Pooled	2011	2012	Pooled
$V_1 B_0$	7.16	7.27	7.22	0.305	0.289	0.297
$V_1 B_1$	7.08	7.19	7.14	0.277	0.268	0.273
$V_1 B_2$	7.05	7.16	7.11	0.200	0.185	0.192
$V_2 B_0$	7.13	7.24	7.19	0.303	0.286	0.294
$V_2 B_1$	7.04	7.15	7.10	0.275	0.263	0.269
$V_2 B_2$	7.00	7.11	7.06	0.179	0.173	0.176
$V_3 B_0$	7.09	7.20	7.15	0.289	0. 281	0.285
$V_3 B_1$	7.06	7.17	7.12	0.268	0.259	0.264
$V_3 B_2$	7.03	7.14	7.09	0.171	0.157	0.164
$CD_{0.05}$	NS	NS	NS	NS	NS	NS
$B_0 M_0$	7.19	7.30	7.25	0.308	0.291	0.300
$B_0 M_1$	7.07	7.18	7.13	0.293	0.280	0.287
$B_0 M_2$	7.12	7.23	7.18	0.295	0.284	0.290
$B_1 M_0$	7.11	7.22	7.17	0.291	0.269	0.280
$B_1 M_1$	7.02	7.13	7.08	0.262	0.257	0.260
$B_1 M_2$	7.06	7.17	7.12	0.268	0.263	0.266
$B_2 M_0$	7.08	7.19	7.14	0.193	0.178	0.186
$B_2 M_1$	6.98	7.09	7.04	0.175	0.165	0.170
$B_2 M_2$	7.02	7.13	7.08	0.181	0.172	0.177
$CD_{0.05}$	NS	NS	NS	NS	NS	NS
$V_1 M_0$	7.15	7.26	7.21	0.272	0.241	0.263
$V_1 M_1$	7.05	7.16	7.11	0.253	0.248	0.247
$V_1 M_2$	7.10	7.21	7.16	0.257	0.246	0.253
$V_2 M_0$	7.12	7.23	7.18	0.266	0.234	0.257
$V_2 M_1$	7.01	7.12	7.07	0.243	0.241	0.239
$V_2 M_2$	7.04	7.15	7.10	0.248	0.240	0.245
$V_3 M_0$	7.11	7.22	7.17	0.254	0.227	0.247
$V_3 M_1$	7.01	7.12	7.07	0.235	0.230	0.231
$V_3 M_2$	7.054	7.16	7.11	0.240	0.289	0.235
$CD_{0.05}$	NS	NS	NS	NS	NS	NS

In the individual effect, pooled analysis showed that the variety V_1 (Naveen 200^+) exhibited maximum soil EC (0.254 dS/m) while minimum value (0.238 dS/m) was recorded with V_3 (Solan Lalima). The treatment B_0 recorded

maximum soil EC (0.292 dS/m) with minimum (0.178 dS/m) being observed with B_2. Among different mulches, M_0 (No mulch) recorded maximum soil EC (0.255 dS/m) whereas M_1 (Pine needle) resulted in minimum soil EC (0.239 dS/m).

Table 4.14c: Effect of V x B x M interaction pH and EC in soil

Treatment combination	pH			EC (dS/m)		
	2011	2012	Pooled	2011	2012	Pooled
$V_1B_0M_0$	7.23	7.34	7.29	0.315	0.294	0.305
$V_1B_0M_1$	7.10	7.21	7.16	0.298	0.282	0.290
$V_1B_0M_2$	7.15	7.26	7.21	0.302	0.290	0.296
$V_1B_1M_0$	7.12	7.23	7.18	0.293	0.289	0.291
$V_1B_1M_1$	7.04	7.15	7.10	0.268	0.280	0.274
$V_1B_1M_2$	7.08	7.19	7.14	0.271	0.287	0.279
$V_1B_2M_0$	7.09	7.20	7.15	0.209	0.291	0.250
$V_1B_2M_1$	7.01	7.12	7.07	0.192	0.276	0.234
$V_1B_2M_2$	7.05	7.16	7.11	0.198	0.275	0.237
$V_2B_0M_0$	7.19	7.30	7.25	0.314	0.271	0.293
$V_2B_0M_1$	7.07	7.18	7.13	0.294	0.263	0.279
$V_2B_0M_2$	7.12	7.23	7.18	0.299	0.269	0.284
$V_2B_1M_0$	7.09	7.20	7.15	0.290	0.270	0.280
$V_2B_1M_1$	6.99	7.10	7.05	0.266	0.256	0.261
$V_2B_1M_2$	7.03	7.14	7.09	0.269	0.263	0.266
$V_2B_2M_0$	7.06	7.17	7.12	0.194	0.265	0.230
$V_2B_2M_1$	6.95	7.06	7.01	0.167	0.253	0.210
$V_2B_2M_2$	6.98	7.09	7.04	0.174	0.257	0.216
$V_3B_0M_0$	7.16	7.27	7.22	0.296	0.190	0.243
$V_3B_0M_1$	7.04	7.15	7.10	0.288	0.179	0.233
$V_3B_0M_2$	7.08	7.19	7.14	0.283	0.185	0.234
$V_3B_1M_0$	7.10	7.21	7.16	0.288	0.180	0.234
$V_3B_1M_1$	7.02	7.13	7.08	0.253	0.166	0.209
$V_3B_1M_2$	7.06	7.17	7.12	0.264	0.173	0.219
$V_3B_2M_0$	7.08	7.19	7.14	0.177	0.163	0.170
$V_3B_2M_1$	6.99	7.10	7.05	0.165	0.151	0.158
$V_3B_2M_2$	7.02	7.13	7.08	0.172	0.158	0.165
$CD_{0.05}$	NS	NS	NS	NS	NS	NS

4.29 COST OF PRODUCTION FOR FRUIT YIELD (Rs/ha)

The data pertaining to cost of production of tomato fruit for different treatments combination have been presented in the Table 15 and Appendix II. An examination of the data revealed that highest cost of production (Rs.86956.99) was recorded in $V_2B_1M_2$, whereas lowest (Rs.74084.49) was observed in the treatment $V_3B_2M_0$.

Table 15 : Economics of tomato genotypes to different mulches and biofertilizers

Treatments combination	Fruit yield (q/ha)	Cost of cultivation for treatments (₹)	Gross income (₹)	Net income (₹)	B: C Ratio
$V_1B_0M_0$	527.27	76833.5	263635	186801.51	2.43
$V_1B_0M_1$	571.12	81833.49	285560	203726.51	2.49
$V_1B_0M_2$	608.51	85033.49	304255	219221.51	2.58
$V_1B_1M_0$	663.70	77633.49	331850	254216.51	3.27
$V_1B_1M_1$	739.41	82633.49	369705	287071.51	3.47
$V_1B_1M_2$	811.58	85833.49	405790	319956.51	3.73
$V_1B_2M_0$	700.29	77633.49	350145	272511.51	3.51
$V_1B_2M_1$	776.86	78281.99	388430	310148.01	3.96
$V_1B_2M_2$	833.49	81481.99	416745	335263.01	4.11
$V_2B_0M_0$	711.18	77956.99	355590	277633.01	3.56
$V_2B_0M_1$	772.59	82956.99	386295	303338.01	3.66
$V_2B_0M_2$	829.92	86156.99	414960	328803.01	3.82
$V_2B_1M_0$	864.69	78756.99	432345	353588.01	4.49
$V_2B_1M_1$	923.17	83756.99	461585	377828.01	4.51
$V_2B_1M_2$	992.01	86956.99	496005	409048.01	4.70
$V_2B_2M_0$	902.03	74405.49	451015	376609.51	5.06
$V_2B_2M_1$	978.20	79405.49	489100	409694.51	5.16
$V_2B_2M_2$	1037.33	82605.49	518665	436059.51	5.28
$V_3B_0M_0$	585.67	77635.99	292835	215199.01	2.77
$V_3B_0M_1$	636.78	82635.99	318390	235754.01	2.85
$V_3B_0M_2$	689.26	85835.99	344630	258794.01	3.01
$V_3B_1M_0$	689.89	78435.99	344945	266509.01	3.40
$V_3B_1M_1$	800.69	83435.99	400345	316909.01	3.80
$V_3B_1M_2$	864.32	86635.99	432160	345524.01	3.99
$V_3B_2M_0$	714.72	74084.49	357360	283275.51	3.82
$V_3B_2M_1$	831.11	79084.49	415555	336470.51	4.25
$V_3B_2M_2$	883.70	82284.49	441850	359565.51	4.37

Similarity maximum gross income (Rs.518665) was observed with $V_2B_2M_2$, and it was followed by $V_2B_1M_2$ (Rs.496005), while minimum gross income (Rs.263635) was recorded in $V_1B_0M_0$, which was found significantly low for this treatment.

$V_2B_2M_2$ resulted in maximum net returns (Rs.436059.51), which was followed by $V_2B_2M_1$ (Rs.409694.51). In the mean while, minimum net returns (Rs.186801.51) were obtained with $V_1B_0M_0$.

In overall, maximum benefit: cost ratio (5.28:1) was recorded in $V_2B_2M_2$ for the production of tomato and minimum (2.43:1) was calculated in $V_1B_0M_0$.

Chapter-5

DISCUSSION

In India, increasing population has necessitated the demand for huge quantity of produce and quality seed, since seed is the basic and cheapest input which enables the vegetable growers to get highest returns per unit area and time. Therefore, in order to meet out vegetable requirement of the country there is a need to increase the production as well as the productivity. After the green revolution, production of vegetables and quality seeds has increased to a great extent due to use of chemical fertilizers. But, extensive use of chemical fertilizers has led to soil sickness, ecological hazards and depletion of non-renewable sources of energy. Therefore, there is a need to find out an alternate way to work out other sources of nutrients which may enhance the yield without having adverse effects on soil properties. Proper and regular application of mulches and bio-inoculants are of utmost importance in maintaining the fertility and productivity of agricultural soils. Biofertilizers help in improving biological activities of desirable microorganisms in the soil and also improve the crop yield and quality of produce. Therefore, use of mulches and biofertilizers is the only answer for obtaining quality produce and disease free any ill effects on soil. Keeping in view the above facts in mind, the present investigations entitled "**Response of tomato genotypes to different mulches and biofertilizers"** were undertaken and the results so obtained have been discussed thoroughly in the light of available literature.

NUMBER OF DAYS TO FIRST FLOWERING AND FIRST HARVEST

Tomato is the main summer and rainy season vegetable crop of mid hills of Himachal Pradesh. The early flowering results in early harvest. The early produce fetches premium prices in the markets of North Indian plains during off-season. Hence, the number of days to first flowering and number of days to first harvest is off utmost importance. Therefore, any technique that can improve fruit quality and early yield is the need of the hour.

The agrotechniques and cultural practices that promote early flowering and early harvest are considered desirable. In the present investigation, among various varieties, the variety V_2 (Sun-7711) showed minimum number of days to first flowering and first harvest. Earliness with the application of biofertilizers might be attributed to the faster enhancement of vegetative growth and availability of strong sufficient reserve food material for differentiation of vegetative buds into flowers (Kuppuswamy *et al*. 1992). These studies are in confirmation with the findings of Shukla *et al*. (2006), Singh (2012), Kumar *et al*. (2007) and Thakur (1996). Among mulches, black polythene mulch took minimum number of days to first flowering and first harvest. The early flowering and harvest under black polythene mulch might be due to better growth of plants as a result of high soil temperature and moisture. Hilal (1982) observed that the greater mulch thickness was more effective in preventing surface soil water evaporation which resulted in faster growth and early flowering of the plant. These results are in accordance with the findings of Pierce and Crispi (1989), Hooda *et al*. (1999) and Nair (1999).

HARVEST DURATION

Longer harvest duration is an important aspect to avoid gluts in the market and to ensure maximum returns. This trend is also desirable to catch early market thus ensures higher returns to small and marginal farmers of the hilly state like Himachal Pradesh. Among varieties, the maximum harvest duration was recorded with V_2 (Sun-7711). Maximum harvest duration was recorded with B_1 (100% NPK+*Azotobacter* (1g/plant)+PSB (1g/plant). 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 due to 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). However, Shukla *et al.* (2009) reported no significant decreases in harvest duration with the application of biofertilizers. Black polythene had increased harvest duration. Regarding

mulch material used, maximum harvest duration was recorded with M_2 (Black polythene mulch) and minimum with M_0 (No mulch).

FRUIT WEIGHT

Fruit weight is the most important yield contributing character for fresh market tomato. The present studies showed that among various varieties, fruit weight was maximum in V_2 (Sun-7711). Among biofertilizers, B_1(100% NPK+*Azotobacter* (1g/plant)+PSB (1g/plant) recorded maximum fruit weight. Increased fruit weight by using biovita and organic manure may be due the presence of certain elements like calcium, boron, sodium, magnesium, sulphur, iron, manganese, copper, zinc and growth promoters like cytokinins and auxins as well as proteins and amino acids. These elements and growth promoters have played significant role in enhancing the average fruit weight. Moreover, combined application of biovita and biofertilizers may have produced complementary effects resulting into increased availability of essential nutrient elements leading to balanced growth and development of plants, particularly of fruits, enabling more absorption of water and nutrients. These substances, besides increasing the availability of nitrogen and soil phosphorus play a major role in better root and shoot development. On the other hand lowest fruit weight in control, is due the lack of essential nutrients required for proper growth and development of plant and fruits. The importance of these nutrients in hastening fruiting and fruit development have also been reported by Martinez *et al.* (1993) and Singh (2012) in tomato, Chatoo *et al.* (1997) and Nagaraju *et al.* (2001) in knol-khol and onion, respectively.

Similarly, fruit weight was significantly influenced by mulch materials. Black polythene mulch produced the maximum fruit weight and minimum fruit weight was obtained with control or no mulch. These results are in agreement with the results of Ashworth and Harrison (1983), Haddadin *et al*. (1985), Ubaidullah *et al*. (2002), Hedau and Kumar (2002) and Bala (2012).

PLANT HEIGHT

Plant height has a direct contribution to yield particularly when indeterminate varieties are grown. The present studies showed that among

various varieties, plant height was maximum in V_3 (Solan Lalima). The varietal effect may be attributed to its growth habit governed by genetic traits. Similar findings were reported by Kumar *et al*. (2004) and Zaman *et al*. (2011). Regarding biofertilizers, B_2 (75% NPK+*Azotobacter* (1g/plant)+PSB (1g/plant) recorded maximum plant height. The increase in plant height as a result of application of biofertilizers may be attributed to the fact that they are known to synthesize the growth promoting substances besides nitrogen fixation, as a result of this, the plant shows luxurious growth (Chauhan *et al*., 1995). 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). Jackson *et al*. (1964) reported increase in plant height as a result of *Azotobacter* application which was attributed to decomposition of organic matter by the biofertilizers with subsequent release of available nutrients to the plants from the soil. 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. These findings are in conformity with Sharma and Thakur (2001) and Gajbhiye *et al* (2003). Badaway and Amar (1974) and Martinez *et al*. (1993) reported in tomato that the better vegetative growth with biofertilizers inoculation may be because of better plant stand and direct contribution of biofertilizers in improving the fertility condition of soil because of bacterial activity. Similarly, plant height was significantly affected by mulch materials. Black polythene mulch produced the maximum plant height. The possible reason may be the 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) and Kashyap and Jyotishi (1967) 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. Kadam *et al*. (1993) and Kumar and Srivastava (1997) also reported increased growth in tomato by means of

mulching. The higher values of growth and yield attributes could be due to increased availability of soil moisture due to more frequent irrigations.

NUMBER OF FRUITS PER PLANT

Number of fruits per plant is an important character since it ultimately reflects the total marketable yield. It is a major yield contributing character as more the number of fruits per plant, more will be the yield and ultimately more remunerative returns. Mean performance of various varieties in the present investigations revealed that maximum number of fruits per plant were recorded with V_3 (Solan Lalima). This may be attributed to the genetic traits as reported by Kumar *et al*. (2004) and Zaman *et al*. (2011). Among biofertilizers maximum number of fruits per plant were recorded with B_2 (75% NPK + *Azotobacter* (1g/plant)+PSB (1g/plant). 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). These findings are in conformity with Sharma and Thakur (2001) and Gajbhiye *et al*. (2003). Another reason might be that nitrogen being a constituent of protein and chlorophyll plays a vital role in photosynthesis. It enhances accumulation of carbohydrates, which in turn increase number of fruits per plant (Sengupta *et al*., 2002). This might be due to better nutritional environment in the root zone for growth and development of plant which accelerated the process of cell division which in turn showed luxuriant vegetative growth of plant and increased the yield and yield contributing parameters by application of bioinoculants. These results are in close conformity with the results of Negi *et al*. (2004), Singh and Asrey (2005) and Rohit *et al*. (2009).

The highest number of fruits per plant were produced with M_2 (Black polythene) treatment and lowest number in unmulched plots. 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, 2012). Increase in fruit number with the use of black polythene mulch was also reported by El Hassan (1986), Chanabaavanna *et al*. (1989), Gonzale *et al*. (1993), Headau

and Kumar (2002), Sannigrahi and Borah (2002) and Singh (2005). Black polythene mulch increased yield which could be attributed to more efficient weed suppression and conservation of soil moisture for longer time (Aruna *et al*., 2007; Sweeney, 1987).

YIELD (kg per plant, kg per plot and quintal per ha)

Yield potential of any variety directly determines the yield per unit area. The present studies showed that among various varieties, yield was maximum in V_2 (Sun-7711). The varietal effect may be attributed to its growth habit governed by genetic traits. Among biofertilizers maximum yield was observed with B_2 (75% NPK + *Azotobacter* (1g/plant) + PSB (1g/plant). This may be due to better root proliferation, more photosynthesis efficiency, enhanced food accumulation, increased availability of atmospheric nitrogen and soil phosphorus by microbial inoculants and synthesis of plant growth hormones at all the essential stages of growth and development by the combined application of biofertilizers and organic manure (Chatoo *et al*., 2007).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 which accelerated the process of cell division and hence fruit yield. Anburani and Manivannan (2002) reported high yield in brinjal with biofertilizers which might be due to the apportioning efficiency part and hormonal balance in the plant system. The increase in fruit yield might have been due to better assimilation of plant nutrients through biofertilizers (Nanthkumar and Veergavathatham, 2000). 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). Similar trend of work has been noted by Devi *et al*. (2002) and Wange and Kale (2004) in brinjal.

Mulches showed pronounced effect on yield. Highest fruit yield was observed with M_2 (Black polythene). The increased yield under black polythene

mulch have been reported by Haddadin *et al*. (1985), Gutal *et al*. (1992), Loudurja *et al*. (1996), Hedau *et al*. (2001) and Bala (2012). The increase in the yield might be attributed to conservation of soil moisture under mulches by retarding evaporation (Hillel, 1982); weed control (Gutal *et al*. 1992), reduced nutrient, leaching and favourable soil temperature and moisture (Bhella, 1988). 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. Similar findings were reported by Wein and Minotii (1987), Channabavanna *et al*. (1989), Ubaidullah Jan *et al*. (2002) and Sannigrahi and Borah (2002).

FRUIT SIZE

Fruit size is an important fruit quality character. The variety V_3 (Solan Lalima) recorded maximum fruit size which might be attributed to its growth habit governed by genetic traits. Among biofertilizers, the maximum fruit size was recorded with B_2 (75% NPK+*Azotobacter* (1g/plant)+PSB (1g/plant). Gaine *et al*. (2009) reported in garden pea that biofertilizers recorded maximum pod length. This might be due to superior rate of carbohydrate in reproductive parts of the plant. Regarding different mulch materials used, maximum fruit size was recorded with M_2 (Black polythene). Ali and Gaur (2007) reported maximum fruit size with black polythene. Kaur and Singh (2009) reported that mulching treatments had beneficial effect on fruit size and black polythene mulch recorded maximum fruit size. The positive response of mulching treatment might be due to increase availability of moisture and nutrients, favorable soil temperature and lower weed population. Similar results were obtained by Renquest *et al*. (1982) and Gupta and Acharya (1993).

PERICARP THICKNESS, FRUIT FIRMNESS AND SHELF LIFE

Shelf life plays an important role in determining keeping quality of the fruits which directly depends upon pericarp thickness and firmness of the fruits. Fruits having higher pericarp thickness, fruit firmness and shelf life can be transported to distant markets, whereas fruits with poor shelf life are vulnerable

to faster quality deterioration thereby reducing long distance transport and minimum incidence of diseases. Maximum pericarp thickness, fruit firmness and shelf life of fruits was recorded in V_2 (Sun-7711). Among the biofertilizers B_2 (75% NPK+*Azotobacter* (1g/plant)+PSB (1g/plant) recorded maximum pericarp thickness, fruit firmness and shelf life of fruits. The possible reason for better shelf life may be attributed to better growth resulting into firm fruits with more pericarp thickness, on account of proper and adequate availability of all macro and micro nutrients (Gosavi *et al*., 2010). Results of present study are in line with the findings of Chaurasia *et al*. (2001) reported that soil application of biofertilizers before transplanting, significantly prolonged the shelf life of tomato at least for two days, depending on variety than by soil application alone. Similar results have been reported by Mishutin and Naumova (1962), Mehotra and Lehri (1971) and Kumarswamy and Madlageri (1990). Sharma *et al*. (2010) also reported higher pericarp thickness with biofertilizers. This might be due to better availability of water and nutrients, increased uptake of water and nutrients resulting in more photosynthesis and enhanced food accumulation in the edible part of fruit which ultimately increased the fruit quality. Similar results have been reported by Bhadoria *et al*. (2005). Similarly Gosavi *et al*. (2010) also reported better pericarp thickness in tomato fruits with biofertilizers application. This might be due to proper and adequate provision of all macro and micro nutrients as reported by Parvathan and Vijayan (1989). Thakur and Thakur (2012) reported maximum pericarp thickness of tomato and shelf life of fruit with the application of *Azotobacter*. Similar results were observed by Kumar and Sharma (2006) and Shukla *et al*. (2006) who observed more pericarp thickness by the use of organic manures and biofertilizers. Differences in shelf life of fruit might be attributed to high firmness and thicker pericarp of fruits obtained with biofertilizers application. Considering different mulch material used, maximum pericarp thickness, shelf life and fruit firmness were recorded with black polythene mulch while, minimum values for these parameters were observed with no mulch.

TOTAL SOLUBLE SOLIDS AND TITRATABLE ACIDITY

Total soluble solids content in the fruit is an important quality parameters. Maximum TSS and titratable acidity were recorded in V_3 (Solan Lalima) and V_1

(Naveen 2000^{+}) respectively which might be due to the genetic traits of the varieties. Among biofertilizers, maximum TSS and titratable acidity were recorded with B_2 (75% NPK+*Azotobacter* (1g/plant)+PSB (1g/plant) and B_0 (Recommended dose of NPK) respectively. The improvement in quality characters like TSS and titratable acidity content by application of biofertilizers may be due to their nutritional, stimulatory and therapeutic behavior as reported by Karuthamani *et al*. (1995), Chatoo *et al*. (1997) and Thiikavally and Ramaswamy (1999). Further results of present study are in conformity with findings of Prebakaran and Pitchai (2002), Yadav *et al*. (2004) and Shukla *et al*. (2006) who also reported increased TSS with application of biofertilizers. Gosavi *et al*. (2010) also reported increased fruit TSS and titratable acidity with biofertilizers application. It might be due to proper and adequate provision of micro and macro nutrients. Biofertilizers also enhanced production of growth regulating substances as reported by Parvathan and Vijayan (1989).

Regarding different mulch materials used, the maximum fruit TSS and titratable acidity were recorded with M_2 (Black polythene) and M_0 (No mulch) respectively. This increase in fruit quality attributes with mulch application was also reported by Aruna (2007), Singh *et al*. (2005) and Chritopher *et al*. (1997). Titratable acidity was recorded high with black polythene mulch application by Srivastava *et al*. (1994) and Kaur and Singh (2009). 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, 2009) and (Ali and Gaur, 2007). These results are also in conformity with Crotez *et al*. (1995).

ASCORBIC ACID

Ascorbic acid content in the fruits is an important quality parameter from nutrition point of view. It was significantly affected by different varieties. The highest ascorbic acid content of the fruits was recorded in V_3 (Solan Lalima). The possible reason might be the genetic traits which varies from variety to variety. Among the biofertilizers the highest ascorbic acid content was observed with B_1

(100% NPK+*Azotobacter* (1g/plant)+PSB (1g/plant). The possible reason for increase in ascorbic acid content in tomato fruits may be due to longer phase of fruit development and thus more accumulation of carbohydrates which is the major source of vitamin C synthesis (Maronik and Vasilchenko, 1964). Bahadur *et al.* (2003) were also of the opinion that *Azotobacter* inoculation influenced enzyme reaction and formation of metabolites for carbohydrates and proteins synthesis, whereas, enhanced phosphorus availability helped in utilization of sugar and starch, there by resulted in increased ascorbic acid content. Results of current study are in conformity with the findings of Gosavi *et al.* (2010), who recorded maximum ascorbic acid content with the application of organic manures and biofertilizers. This might be due to adequate provision of all the macro and micro nutrients and enhanced production of growth regulating substances by biofertilizers. Similar findings were also reported by Parvathan and Vijayan (1989) and Bahadur *et al*. (2006) in chinese cabbage. The mulch material used significantly affected the ascorbic acid content of tomato. The highest content was recorded with M_2 (Black polythene). The increase in ascorbic acid content with black polythene was also recorded by Aruna *et al*. (2007), Ali and Gaur (2007), Crotez *et al*. (1995), Kaur and Singh (2009) and Srivastava *et al*. (1994). The positive reason was due to increased availability of moisture and nutrients, favourable soil temperature and lower weed population.

LYCOPENE CONTENT

Lycopene content is one of the major fruit quality character of tomato fruits. Among different varieties, maximum lycopene content was observed in V_3 (Solan Lalima). Biofertilizers had significant effect on the fruits lycopene content. The application of B_1 (100% NPK+*Azotobacter* (1g/plant)+PSB (1g/plant) was found to give maximum lycopene content. The possible reason for this might be that the biofertilizers enhanced the fruit quality by biological nitrogen fixation and producing hormones, vitamins and other growth factors required for better plant growth which affected the fruit quality (Bhattacharya *et al*., 2000). The increased lycopene content with biofertilizers application was also recorded by Gosavi *et al*. (2010). Similar results were also reported by Parvathan

and Vijayan (1989). Among different mulch material used, the application of M_2 (Black polythene) resulted in maximum while M_0 (No mulch) recorded minimum lycopene content of the fruits.

DISEASES PARAMETERS

Incidence of buckeye-rot

Buckeye rot of tomato, causes upto 75% loss in yield under mid hill agroclimatic conditions of Himachal Pradesh (Bhardwaj, 1991). Among varieties, the variety V_2 (Sun-7711) was found to record minimum incidence of buckeye rot. The varietal effect may be attributed to its growth habit governed by genetic traits. Among biofertilizers, minimum incidence was recorded with B_2 (75% NPK+*Azotobacter* (1g/plant)+PSB (1g/plant). Regarding mulch material used, the minimum incidence of the disease was recorded with M_2 (Black polythene). Awodoyin *et al*. (2007) also reported minimum buckeye rot incidence with mulching in tomato. Similarly, Bala (2012) and Mehta *et al*. (2010) also observed that black polythene mulch registered the lowest incidence of buckeye rot. The possible reason for this might be that by preventing fruits from touching the soil, rotting and incidence of soil borne diseases can be reduced in tomato (Chen and Lal, 1999). Polythene mulch was as effective as fungicide for controlling buckeye rot disease in tomato (Dodan *et al.*,1994) where *Phytophthora nicotianae* var. *parasitica* inoculums was splashed to the foliage through rain splashes. Pine needle mulch used also reduced the disease incidence in the present study. Fruit rot (*Phytophthora nicotianae* var. *nicotianae*) in bell pepper can be kept in check if field floor is mulched with pine needles before the onset of monsoon rains as the infection of the disease take place with rain splashed zoospores (Gupta and Jarial, 2008).

Early blight

Early blight is one of the major foliar diseases causing serious problem in tomato fruit production. Among varieties, the minimum severity was observed with V_3 (Solan Lalima). The possible reason might be the genetic traits of the varieties. Regarding biofertilizers, minimum severity of the disease was recorded

with B_1 (100% NPK+*Azotobacter* (1g/plant)+PSB (1g/plant). Mulching also had significant effect on the occurance of the disease and minimum severity of disease was recorded with M_2 (Black polythene). Mulching and staking reduced the severity of early and late blight of tomato cv. Moneymaker (5-20%) caused by *Alternaria solani* and *Phytophthora infestance* respectively (Lyimo *et al*., 1998). Bala (2012) also reported that black polythene mulch had minimum value for early blight severity.

Bacterial leaf spot

Bacterial leaf spot is the most important diseases of tomato causing significant reductions both in terms of quality and quantity of fruits (Shukla, 2001). The effect of mulch and biofertilizers on severity of bacterial leaf spot, it was observed that there was appreciable reduction in disease severity as compared to control. Among varieties, the variety V_3 (Solan Lalima) was found to record minimum severity of bacterial leaf spot. The varietal effect may be attributed to its growth habit governed by genetic traits (Kumar *et al*., 2004). Somodi *et al*. (1989) observed the variety Hawai 7998 to be resistant against the bacterial leaf spot. Regarding biofertilizers, minimum severity was recorded with B_1 (100% NPK+*Azotobacter* (1g/plant)+PSB (1g/plant). Among different mulches, minimum disease severity (M_2) was recorded in black polythene mulched plots. Mulching can influence pathogen infection and disease development in plants (Walters, 2009). Black polythene mulch decreased the severity of infection by *Xanthomonas campestris* pv. *vesicatoria* (Stirling and Eden, 2008). Pine needle mulched plots were observed to be most efficient in inhibiting the growth of bacterium in tomato (Shukla, 2001).

Septoria blight

Septoria species have been reported to cause huge losses in term of yield in the crop. It causes heavy defoliation during the flower formation on the set of monsoon as reported by Horst in 1997. Lim (1980) and Pataky and Lim (1981) also reported severe losses in case of soyabean where 12-34 % yield gets destroyed due to *Septoria glycines*. Among varieties, the variety V_3 (Solan

Lalima) was found to record minimum severity of *Septoria* blight. These findings were in accordance with the studies conducted for germplasm evaluation by Madhumeeta *et al*. (1989) and Sen and Pathania (1997). Regarding biofertilizers, minimum severity was recorded with B_1 (100% NPK+*Azotobacter* (1g/plant)+PSB (1g/plant). Among different mulches, minimum disease severity were recorded with black polythene mulched plots (M_2). Black polthene sheet used as mulch was found to be best in reducing the disease severity (Chandel, 2003). Sohi and Sokhi (1973) also reported the same findings in *Septoria lycopersici* infected tomato plants.

SOIL PARAMETERS

Avaialable nitrogen

The maximum available nitrogen was recorded with V_3 (Solan Lalima) which might be attributed to the growth habit of the varieties which is governed by the genetic traits. Biofertilizers had significant effect on the available nitrogen status. The maximum available nitrogen content was recorded with B_1 (100% NPK+*Azotobacter* (1g/plant)+PSB (1g/plant). This may be attributed to the synergistic effect of nitrogen fixing bacteria and mineralization of native organic matter, which resulted in higher accumulation of N in the soil (Asoken, 2000). Krishnappa (1993) demonstrated that microbial inoculants like *Azotobacter* helped to fix atmospheric N and translocate minor elements like boron, magnesium, manganese, zinc, sodium, sulphur and calcium to the plant, produced plant growth promoting hormones, vitamins, minerals and control plant pathogenic fungi. All these activities improved the soil health and crop production. The results are in agreement with the findings of Bairwa *et al.* (2009), Nath *et al*. (2011) and Zaman *et al*. (2011). Mulch also significantly affected the available nitrogen status. Highest value of available nitrogen was recorded with M_1 (Pine needle). Hundal *et al*. (2000) also reported maximum available nitrogen content content with grass mulch applied plots. Similarly, Sharma *et al*. (2009) observed increase in available nitrogen content in the soil after mulching was done. Nedunchezhiyan (2009) also reported that mulching along with optimum dose of fertilizer nutrient application improved the available

nutrient status. Verma *et al*. (2005) reported in apple that the soil available nitrogen increased in the mulched plots during both the years of study.

Available phosphorus

The available phosphorus content was influenced by varieties, biofertilizers and mulching treatments in tomato. Among varieties, the maximum available phosphorus was recorded with V_3 (Solan Lalima). Biofertilizers also affected the available phosphorus in the tomato plots. Maximum available phosphorus was recorded with B_1 (100% NPK+*Azotobacter* (1g/plant)+PSB (1g/plant). According to Lapeyne *et al.* (1991) the activity of certain microbes (PSB) released organic acids which converted unavailable phosphorus to available form. The mineralization of soil organic matter by microbes also increased available phosphorus content in soil. Jat *et al.* (2000) and Jat and Sakhtawat (2001) and Zaman *et al.* (2011) also reported increased available phosphorus in soil with the application of biofertilizers in combination with organic manures. Application of mulch materials also had significant effect on available phosphorus content in the soil. The highest available phosphorus was observed with M_1 (Pine needle). Shama *et al.* (2009) and Verma *et al.* (2005) reported increased available phosphorus content in soil with mulching.

Available potassium

The available potassium content was significantly affected by varieties, biofertilizers and mulching. Among varieties, the maximum available potassium content was observed with V_3 (Solan Lalima). The application of B_1 (100% NPK+*Azotobacter* (1g/plant)+PSB (1g/plant) recorded the maximum available potassium content. The possible reason might be the synergistic interaction between biofertilizers and organic manures which resulted in enhanced growth promoting substances like gibberellins, auxins and dihydrozeatin and had positive influence on more uptake of potassium. Archana (2007) reported that certain microbes (KSB) released organic acids which made the conversion of unavailable potassium to available form. Similar findings were reported by Ghuge *et al*. (2007) and Despande *et al.* (2006). Zaman *et al.* (2011) recorded maximum available potassium with the application of biofertilizers. Mulch also significantly

affected the available nitrogen status. Highest value of available potassium was recorded with M_2 (Black polythene). Nedunchezhiyan (2009) and Verma *et al.* (2005) reported increased available potassium content in soil with mulching.

Soil Organic Carbon

The organic carbon content in the soil is one of the important physico-chemical soil properties. The plots where V_3 (Solan Lalima) was grown recorded the maximum soil OC. This might be attributed to the different genetic traits of different varieties used. The biofertilizers also significantly affected the soil OC content. The maximum soil OC was recorded with B_1 (100% NPK+*Azotobacter* (1g/plant)+PSB (1g/plant). Singh (2012) observed that the organic carbon content in soil was more with conjoint application of organic manures and biofertilizers due to increased microbial and enzymatic activity and might have led to lower bulk density and subsequent increase in organic carbon content. Similar findings were reported by Mukherjee *et al.* (2000). Nedunchezhiyan (2010) reported in greater yam and maize that mulching significantly showed higher soil organic carbon than in non mulched plots. Verma *et al*. (2005) also recorded in apple that organic carbon improved in grass mulched plots which might be due to the direct addition of organic matter through decomposition of grass mulch and recycling of organic materials in the form of crop residues like roots and leaf fall.

Soil pH and EC

The minimum pH and EC was observed in soil where variety V_3 (Solan Lalima) was grown. Among biofertilizers, the minimum pH and EC were observed with B_2 (75% NPK+*Azotobacter* (1g/plant)+PSB (1g/plant). The decline in soil pH and EC with the application of biofertilizers might be due to the production of organic acids by the microbial activity (Singh, 2012). Similar results were reported by Srikanth *et al.* (2000). The minimum pH and EC was recorded with M_1 (Pine needle). Verma *et al*. (2005) also reported that the minimum pH and EC were recorded with grass mulched plots. The possible reason for this might be due to direct addition of organic matter through decomposition of grass mulch and recycling of organic materials. Similar results were reported by Jones *et al*. (1977).

Chapter-6

SUMMARY AND CONCLUSION

Tomato is one of the most important cash crop of Himachal Pradesh growing during summer season. Although the produce fetches a lucrative returns in the plains of Northern India, however, its production is threatened by various factors viz., diseases, insect-pests and weeds which ultimately affects the fruit yield and quality. Thus, present investigation entiled "Response of tomato genotypes to different mulches and biofertilizers" was carried out at the Experimental Farm of Dr Y S Parmar U H F, Horticulture Research Station, Kandaghat, Solan, under mid hill conditions of Himachal Pradesh during 2011 and 2012. The experiment comprised of three genotypes viz., V_1 (Naveen 2000^+), V_2 (Sun-7711) and V_3 (Solan Lalima), three biofertilizers viz., B_0 (NPK recommended doses), B_1 (NPK recommended doses + *Azotobacter* (1g/plant) + PSB (1g/plant) and B_2 (75% NPK recommended doses + *Azotobacter* (1g/plant) + PSB (1g/plant), three mulch materials viz., M_0 (No mulch), M_1 (Pine needle) and M_2 (Black polyethylene). Thus, there were 27 treatment combinations in all replicated thrice in Split-Split Plot Design. The seed of genotypes were sown during the first week of April during both the years. Seedlings after twenty five to thirty days were transplanted in already prepared fields. The recommended cultural practices and plant protection measures were followed as per package of practices right from sowing up to harvesting. The salient findings of the investigations are summarized as below:

AMONG THE DIFFERENT GENOTYPES THE FOLLOWING OBSERVATIONS WERE RECORDED:

The variety V_2 (Sun-7711) gave best performance for the following characters: Number of days to first flowering, number of days to first harvest, harvest duration, yield (kg/plant, kg/plot, q/ha), fruit weight, pericarp thickness, fruit firmness, shelf life, incidence of buckeye rot and soil pH. Whereas, the variety V_3 (Solan Lalima) was recorded best performance in the following characters: Plant height, number of fruits/plant, fruit length, fruit breadth, TSS,

titratable acidity, ascorbic acid, lycopene content, bacterial leaf spot, early bligth, septoria bligth, soil available nitrogen, phosphorus, potash, organic carbon and soil electrical conductivity.

AMONG THE DIFFERENT BIOFERTILIZERS THE FOLLOWING OBSERVATIONS WERE RECORDED:

The biofertilizer B_1 (100% NPK + *Azotobacter* (1g/plant + PSB) (1g/plant) recorded best results for the following: Number of days to first flowering, number of days to first harvest, harvest duration, fruit weight, fruit firmness, shelf life, TSS, acidity, ascorbic acid, lycopene content, bacterial leaf spot, early blight, septoria blight, available nitrogen, phosphorus, potash and organic carbon. The biofertilizer B_2 (75% NPK + *Azotobacter* (1g/plant) + PSB (1g/plant) performed best in terms of plant height, number of fruits/plant, yield (kg/plant, kg/plot, q/ha), fruit length, fruit breadth, pericarp thickness, buckeye rot, soil pH and electrical conductivity.

AMONG THE DIFFERENT MULCHES THE FOLLOWING OBSERVATIONS WERE RECORDED:

The mulch material M_2 (Black polythene) gave best performance for the following characters: Number of days to first flowering, number of days to first harvest, harvest duration, plant height, number of fruits/plant, yield (kg/plant, kg/plot, q/ha), fruit length, fruit breadth, fruit weight, pericarp thickness, fruit firmness, shelf life, TSS, ascorbic acid, lycopene, incidence of buckeye rot, bacterial leaf spot, early blight, septoria blight and soil K. While the mulch material M_1 (Pine needle) was recorded best in the terms of soil available nitrogen, phosphorus and organic carbon, pH and electrical conductivity.

AMONG THE 1st ORDER INTERACTION BETWEEN VARIETIES AND MULCHES, VARIETIES AND BIOFERTILIZERS AND BIOFERTILIZERS AND MULCHES THE FOLLOWING OBSERVATIONS WERE RECORDED:

In case of varieties and mulch V_2M_2 (Sun-7711 + Black polythene) recorded the maximum harvest duration, yield (kg/plant, kg/plot, q/ha), fruit weight, pericarp thickness, fruit firmness, shelf life and minimum incidence of

buckeye rot. V_3M_2 (Solan Lalima + Black polythene) observed maximum plant height, number of fruits/plant, ascorbic acid, lycopene content, severity of bacterial leaf spot, early blight, septoria blight and soil K whereas the maximum soil organic carbon and available nitrogen and phosphorus was recorded with V_3M_1 (Solan Lalima + Pine needle).

Among the varieties and biofertilizers V_2B_1 (Sun-7711 + 100 % NPK + *Azotobacter* (1g/plant) + PSB (1g/plant) recorded maximum harvest duration, fruit weight, fruit firmness, shelf life, soil available N and minimum incidence of buckeye rot. V_3B_1 (Solan Lalima + 100 % NPK + *Azotobacter* (1g/plant) + PSB (1g/plant) observed with the maximum ascorbic acid, lycopene content, soil organic carbon, phosphorus, potash and minimum severity of bacterial leaf spot, early blight, septoria blight. Whereas,V_2B_2 (Sun-7711 + 100% NPK + *Azotobacter* (1g/plant) + PSB(1g/plant) exhibited maximum plant height, yield (kg/plant, kg/plot, q/ha) and pericarp thickness.

With regards to biofertilizers and mulches, B_1M_2 (100 % NPK + *Azotobacter* (1g/plant) + PSB(1g/plant)+Black Polythene) were recorded maximum harvest duration, plant height, fruit weight, fruit firmness, shelf life, ascorbic acid, lycopene content, soil K and minimum severity of early blight and septoria blight. B_2M_2 (75% NPK + *Azotobacter* (1g/plant) + PSB (1g/plant) + Black Polythene) observed maximum number of fruits/plant, yield (kg/plant, kg/plot, q/ha), fruit length, fruit breadth, pericarp thickness, soil phosphorus and minimum incidence of buckeye rot and lowest severity of bacterial leaf spot.

AMONG THE 2nd ORDER INTERACTION BETWEEN VARIETIES, BIOFERTILIZERS AND MULCHES THE FOLLOWING OBSERVATIONS WERE RECORDED:

$V_2B_2M_2$ (Sun-7711+75% NPK + *Azotobacter* (1g/plant) + PSB (1g/plant) + Black Polythene) gave the best performance in terms of yield (kg/plant, kg/plot, q/ha) and pericarp thickness. However, $V_2B_1M_2$ (Sun-7711 + 100% NPK + *Azotobacter* (1g/plant) + PSB (1g/plant) + Black Polythene) was observed to be the best in terms of harvest duration, fruit weight, fruit firmness, shelf life and incidence of buck eye rot.

$V_3B_1M_2$ (Solan Lalima + 100% NPK + *Azotobacter* (1g/plant) + PSB (1g/plant) + Black Polythene) performed best in terms of plant height, TSS, ascorbic acid, lycopene, incidence of bacterial leaf spot, early blight, septoria blight and soil K whereas, $V_3B_1M_1$ (Solan Lalima + 100% NPK + *Azotobacter* (1g/plant) + PSB (1g/plant) + Pine needle) gave best results in terms of soil phosphorus and organic carbon.

Although, the maximum yield was observed with the variety V_2, but the fruit quality characters as well as the ability to resist disease incidence/severity was observed with the variety V_3 (Solan Lalima). Hence, V_3 was observed to be the best variety. Among the biofertilizers B_1 (100% NPK + *Azotobacter* (1g/plant) + PSB (1g/plant) and mulch material used M_2 (Black polythene) were recorded to be the best regarding the fruit yield and quality as well as soil nutrient status. The maximum yield was observed with the combination $V_2B_2M_2$. Considering the fruit quality and disease resistance $V_3B_1M_2$ was the best treatment combination.

Gross income for fruit yield was found maximum with $V_2B_2M_2$ (Rs.518665) as well as net income was obtained highest (Rs. 436059.51) with $V_2B_2M_2$. In nut shell, benefit cost ratio was found maximum with the treatment $V_2B_2M_2$ (5.28).

Chapter-7

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DR. Y.S. PARMAR UNIVERSITY OF HORTICULTURE AND FORESTRY
NAUNI, SOLAN (HP) 173 230

DEPARTMENT OF VEGETABLE SCIENCE

Title of Thesis	:	**"Response of tomato genotypes to different mulches and biofertilizers"**
Name of the Student	:	Sandeep Kumar Singh
Admission Number	:	H-2010-15-D
Major Advisor	:	Dr. H R Sharma
Major Field	:	Vegetable Science
Minor Field(s)	:	i) Plant Pathology ii) Soil Science
Degree Awarded	:	Ph.D. Vegetable Science
Year of Award of Degree	:	2013
No. of pages in Thesis	:	134+III
No. of words in Abstract	:	374

ABSTRACT

The present study entitled "**Response of tomato genotypes to different mulches and biofertilizers**" was carried out at the experimental farm of Horticulture Research Station, Kandaghat, Dr Y S Parmar U H F, Solan, Himachal Pradesh, during 2011 and 2012. The experiment comprised 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). Thus, there were 27 treatment combinations which were replicated thrice in Split-Split Plot Design. The observations were recorded on number of days to first flowering, number of days to first harvest, harvest duration, number of fruits/plant, average fruit weight (g), fruit length (cm), fruit width (cm), plant height (m), yield (kg/plant), yield (kg/plot), yield (q/ha), pericarp thickness (mm), TSS (^{0}Brix), acidity (%), shelf life (days)**,** fruit firmness (g per 0.503cm^2**)** ascorbic acid (mg/100g), lycopene content (mg/100g), incidence of buckeye rot (%), severity of bacterial leaf spot (%), early blight (%), *septoria* blight (%) available nitrogen (kg/ha), phosphorus (kg/ha), potash (kg/ha), organic carbon (%), pH and electrical conduvtivity. Among varieties, maximum yield was observed with the variety V_2 (Sun-7711), but the fruit quality characters as well as the ability to resist disease incidence/severity was 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, quality and soil nutrient status as well as disease incidence/severity. 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) with maximum net returns (Rs. 436059.51) and highest cost benefit ratio (1:5.28) was obtained with the treatment combination of Sun-7711, 75% NPK + *Azotobacter* (1g/plant) + PSB (1g/plant) and black polyethylene mulch ($V_2B_2M_2$).

Signature of Major Advisor **Signature of the student**

Countersigned

Professor and Head
Department of Vegetable Science
Dr. Y.S. Parmar University of Horticulture & Forestry
Nauni, Solan, (H.P.) - 173 230

APPENDIX-I

Meteorological data observed during the year 2011and 2012

Months	Temperature (^{0}C)			Relative humidity (%)	Rainfall (mm)
	Maximum	Minimum	Mean		
April, 2011	25.43	09.93	17.68	48.00	08.85
May	31.95	15.45	23.70	46.00	04.05
June	30.70	16.88	23.79	52.00	32.58
July	27.85	19.10	23.48	78.00	53.13
August	27.70	19.68	23.69	82.00	32.38
Sep	27.83	18.75	23.29	79.00	44.23
Oct	28.20	14.88	21.54	72.00	06.00
April, 2012	26.70	11.60	19.20	50.00	01.86
May	32.20	15.30	23.80	40.00	00.16
June	34.10	18.80	26.50	48.00	01.25
July	28.80	19.50	24.20	71.00	10.20
August	27.00	18.80	22.90	84.00	08.70
Sep	27.70	15.90	21.80	75.00	07.20
Oct	26.00	08.20	17.10	52.00	00.11

Source: **Meteorological Observatory, Department of Soil Science and Water Management, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan (H P) - 173230 India**

APPENDIX-II

Cost of tomato cultivation over variable cost (₹) for fruit yield

Particulars	Particulars	Rate (₹)	Total Cost (₹)
(A.) Cost of variable Resources:			
1. Seed cost for			
V_1- Naveen 2000$^+$	150g	35000/kg	5250.00
V_2- Sun 7711	150g	42000/kg	6300.00
V_3- Solan Lalima	400g	15000/kg	6000.00
2. Manures and Fertilizers cost:			
FYM	10000kg	1.5/kg	15000.00
CAN	600kg	9.67/kg	5802.00
SSP	750kg	7.70/kg	5775.00
MOP	100kg	16.80/kg	1680.00
3. Plant protection cost:			
(a) Pesticides/insecticides:			
Malathion	500g	80.00/ 500g	80.00
Decis	1.5 lit	600/lit	900.00
Ektara	500g	1250/250g	2500.00
(b) Fungicide:			
Ridomil	500g	100/250g	200.00
Dithane M-45	500g	180/ 500g	180.00
Bavistin	500g	60/500g	120.00
4. Labour cost:			
(a) Nursery & Irrigation	1manday	120/ mandays	120.00
(b) Land preparation			
(b_1) Ploughing	5 mandays	120/ mandays	600.00
(b_2) Preparation bed	20 mandays	120/mandays	2400.00
(c) Transplanting	10 mandays	120/mandays	1200.00
(d) Manures and Fertilizers application	12 mandays	120/mandays	1440.00
(e) Interculture operations	28 mandays	120/mandays	3360.00
(f) Staking	15 mandays	120/mandays	1800.00
(g) Irrigation	40 mandays	120/mandays	4800.00
(h) Plant protection	15 mandays	120/mandays	1800.00
(i) Harvesting	40 mandays	120/mandays	4800.00
(j) Transportation			4000.00
(k) Packing/electricity charges			3000.00
5. Bullock/Tractor cost:	5hrs	1000/ hrs	5000.00
Total fixed cost			**65885.00**
Total fixed cost for genotypes			
V_1- Naveen 2000$^+$			71807
V_2- Sun 7711			72857
V_3- Solan Lalima			72557
6. Miscellaneous(2% of total cost)			
V_1- Naveen 2000$^+$			1436.14
V_2- Sun 7711			1457.14
V_3- Solan Lalima			1451.14
7. Interest on working capital (5%)			
V_1- Naveen 2000$^+$			3590.35
V_2- Sun 7711			3642.85
V_3- Solan Lalima			3627.85
Total Variable cost			
V_1- Naveen 2000$^+$			76833.49
V_2- Sun 7711			77956.99
V_3- Solan Lalima			77635.99

APPENDIX-III

ANOVA for the year 2011 for different characters

Source of variance	df	Mean Sum of Squares								
		Number of days to first flowering	Number of days to first Harvest	Harvest duration (Days)	Plant height (m)	Number of fruits per plant	Yield kg per plant	Yield kg per plot	Yield q per hectare	Fruit length (cm)
Replication	2	0.39	8.98	1.65	0.01	0.25	0.01	0.52	143.09	0.01
Factor Varieties (V)	2	131.64	189.42	1,102.10	0.81	353.20	6.14	1,983.53	537493.96	0.65
Error (v)	4	1.24	11.03	5.80	0.01	0.01	0.01	0.04	7.80	0.01
Factor Biofertilizers (B)	2	17.94	45.35	34.87	0.09	928.81	5.58	1,806.38	489502.32	11.21
V X B	4	1.46	2.62	5.07	0.13	2.88	0.06	19.15	5187.03	0.70
Error (b)	12	1.53	0.85	0.78	0.01	0.02	0.01	0.04	10.64	0.01
Factor Mulch (M)	2	33.24	73.05	41.11	0.84	84.89	1.27	411.82	111634.23	2.15
V X C	4	1.70	5.38	1.42	0.04	2.74	0.02	6.49	1759.99	0.20
B X M	4	1.05	1.09	2.77	0.01	1.17	0.02	5.76	1555.05	0.19
V X B X M	8	0.74	1.45	1.58	0.02	0.85	0.01	1.16	315.41	0.08
Error (m)	36	2.00	2.51	0.39	0.01	0.03	0.01	0.04	10.68	0.01
Total	80									

ANOVA for the year 2011 for different characters

Source of variance	Df	Mean Sum of Squares							
		Fruit breadth (cm)	Fruit weight (g)	Pericarp thickness (mm)	Fruit firmness (g/0.503cm^2)	Shelf life (Days)	TSS (^{0}Brix)	Titratable acidity (%)	Ascorbic acid (mg/100g)
Replication	2	0.01	-0.3	0.01	5289.28	24.24	0.01	0.01	-0.01
Factor Varieties (V)	2	0.44	2,529.57	10.51	575409.81	176.83	5.12	0.02	24.79
Error (v)	4	0.01	0.03	0.01	484.37	9.85	0.08	0.01	0.01
Factor Biofertilizers (B)	2	4.79	97.18	0.05	6751.27	8.98	1.48	0.01	7.67
V X B	4	0.39	5.56	0.01	319.64	10.81	0.07	0.01	0.02
Error (b)	12	0.01	0.01	0.01	101.83	14.68	0.05	0.01	0.01
Factor Mulch (M)	2	1.27	207.58	0.03	18775.44	61.64	1.45	0.01	50.68
V X C	4	0.22	1.53	0.01	536.52	14.09	0.01	0.01	3.92
B X M	4	0.04	4.22	0.01	375.01	8.51	0.02	0.01	0.04
V X B X M	8	0.04	1.18	0.01	108.61	11.87	0.01	0.01	0.09
Error (m)	36	0.01	0.01	0.01	441.29	13.85	0.03	0.01	0.01
Total	80								

ANOVA for the year 2011 for different characters

Source of variance	df	Mean Sum of Squares										
		Lycopene content (mg/100g)	Incidence of buck eye-rot (%)	Severity of bacterial leaf spot (%)	Severity of early blight (%)	Severity of septoria blight (%)	Available nitrogen (kg/ha)	Available phosphorus (kg/ha)	Available potash (kg/ha)	Organic carbon (%)	Soil pH	Soil EC
Replication	2	0.01	0.01	0.10	0.10	0.01	13.37	2.01	3.45	0.01	0.02	0.01
Factor Varieties (V)	2	1.32	0.98	924.65	505.05	0.48	151.16	422.59	1,600.38	0.01	0.02	0.08
Error (v)	4	0.01	0.01	0.01	0.01	0.01	2.67	0.10	2.12	0.01	0.01	0.08
Factor Biofertilizers (B)	2	0.86	0.22	14.09	15.22	0.18	1862.24	495.67	2,602.84	0.04	0.07	0.50
V X B	4	0.02	0.01	1.35	1.91	0.01	103.77	7.34	307.77	0.01	0.01	0.06
Error (b)	12	0.01	0.01	0.01	0.01	0.01	5.59	0.55	2.53	0.01	0.01	0.05
Factor Mulch (M)	2	1.37	0.37	6.03	6.90	0.16	407.13	369.17	6,632.06	0.05	0.07	0.08
V X C	4	0.02	0.01	0.26	0.16	0.01	11.26	23.52	103.08	0.01	0.01	0.03
B X M	4	0.02	0.01	0.35	0.73	0.01	19.63	4.80	22.36	0.01	0.01	0.09
V X B X M	8	0.01	0.01	0.21	0.15	0.01	5.29	6.05	50.09	0.01	0.01	0.03
Error (m)	36	0.01	0.02	0.01	0.01	0.01	2.17	0.31	1.49	0.01	0.02	0.02
Total	80											

ANOVA for the year 2012 for different characters

Source of variance	df	Mean Sum of Squares								
		Number of days to first flowering	Number of days to first Harvest	Harvest duration (Days)	Plant height (m)	Number of fruits per plant	Yield kg per plant	Yield kg per plot	Yield q per hectare	Fruit length (cm)
Replication	2	0.98	3.20	3.83	0.01	0.05	0.01	0.04	6.24	0.01
Factor Varieties (V)	2	120.53	730.24	823.75	0.43	1,028.15	2.19	708.91	192068.20	0.68
Error (v)	4	0.98	1.68	0.24	0.01	0.04	0.01	0.05	14.42	0.01
Factor Biofertilizers (B)	2	8.38	21.38	84.30	0.05	362.75	3.17	1028.78	278756.05	11.45
V X B	4	1.88	1.36	6.09	0.06	5.25	0.03	8.74	2369.64	0.68
Error (b)	12	0.51	0.48	1.50	0.01	0.12	0.01	0.22	60.92	0.01
Factor Mulch (M)	2	38.72	76.16	46.32	0.59	81.51	1.43	465.53	126143.69	2.15
V X C	4	0.77	7.92	3.68	0.03	1.89	0.02	4.92	1333.37	0.20
B X M	4	0.40	0.79	1.96	0.03	2.09	0.04	12.89	3491.94	0.18
V X B X M	8	0.24	0.13	2.60	0.02	1.54	0.01	2.74	742.77	0.08
Error (m)	36	0.57	1.51	0.67	0.01	0.22	0.01	0.36	98.77	0.01
Total	80									

ANOVA for the year 2012 for different characters

Source of variance	Df	Mean Sum of Squares							
		Fruit breadth (cm)	Fruit weight (g)	Pericarp thickness (mm)	Fruit firmness (g/0.503cm^2)	Shelf life (Days)	TSS (^{0}Brix)	Titratable acidity (%)	Ascorbic acid (mg/100g)
Replication	2	0.01	0.08	0.01	8996.33	1.13	0.15	0.01	-0.01
Factor Varieties (V)	2	0.44	2,184.04	10.71	584314.16	251.49	4.28	0.02	24.79
Error (v)	4	0.01	0.02	0.01	907.80	1.92	0.08	0.01	0.01
Factor Biofertilizers (B)	2	4.83	60.80	0.05	11311.48	15.57	1.49	0.02	7.67
V X B	4	0.40	2.30	0.01	881.99	0.36	0.05	0.01	0.03
Error (b)	12	0.01	0.01	0.01	180.40	0.69	0.04	0.01	0.01
Factor Mulch (M)	2	1.28	175.52	0.04	22217.11	36.83	1.17	0.02	50.68
V X C	4	0.22	2.36	0.01	629.22	0.62	0.03	0.01	3.92
B X M	4	0.05	1.93	0.01	412.16	0.20	0.02	0.02	0.04
V X B X M	8	0.04	1.46	0.01	112.47	0.33	0.01	0.01	0.09
Error (m)	36	0.01	0.02	0.01	369.10	0.81	0.03	0.03	0.01
Total	80								

ANOVA for the year 2012 for different characters

Source of variance	Df		Mean Sum of Squares									
		Lycopene content (mg/100g)	Incidence of buck eye-rot (%)	Severity of bacterial leaf spot (%)	Severity of early blight (%)	Severity of septoria blight (%)	Available nitrogen (kg/ha)	Available phosphorus (kg/ha)	Available potash (kg/ha)	Organic carbon (%)	Soil pH	Soil EC
Replication	2	0.01	0.01	0.01	0.10	0.01	4.85	1.78	7.79	0.02	0.01	0.01
Factor Varieties (V)	2	1.33	1.03	1,425.79	505.05	0.85	1,172.57	766.28	1,884.48	0.01	0.02	0.10
Error (v)	4	0.01	0.01	0.02	0.01	0.01	3.94	5.59	0.27	0.01	0.01	0.01
Factor Biofertilizers (B)	2	1.02	0.06	10.68	15.22	0.09	7,144.09	409.82	1,305.86	0.03	0.07	0.01
V X B	4	0.02	0.01	3.91	1.91	0.01	205.42	32.96	34.75	0.01	0.01	0.01
Error (b)	12	0.01	0.01	0.01	0.01	0.01	19.84	1.16	0.76	0.01	0.01	0.01
Factor Mulch (M)	2	1.25	0.62	12.59	6.90	0.34	4,871.14	379.40	9,487.08	0.02	0.07	0.01
V X C	4	0.04	0.01	0.08	0.16	0.01	45.35	11.46	20.10	0.01	0.01	0.01
B X M	4	0.02	0.01	0.03	0.73	0.01	251.41	2.93	13.19	0.01	0.01	0.01
V X B X M	8	0.01	0.01	0.01	0.15	0.01	27.96	3.75	2.63	0.02	0.01	0.01
Error (m)	36	0.01	0.01	0.01	0.01	0.01	4.24	0.24	0.53	0.01	0.01	0.01
Total	80											

ANOVA for pooled analysis of different characters

Source of variance	df	Mean Sum of Squares								
		Number of days to first flowering	Number of days to first Harvest	Harvest duration (Days)	Plant height (m)	Number of fruits per plant	Yield kg per plant	Yield kg per plot	Yield quintals per hectare	Fruit length (cm)
Replication	2	0.59	4.00	1.17	0.01	0.02	0.01	0.10	26.76	0.01
Factor Varieties (V)	2	126.01	404.11	953.37	0.60	474.91	3.23	1,047.62	283835.20	0.67
Error (v)	4	1.07	3.56	1.74	0.01	0.02	3.22	0.02	4.57	0.01
Factor Biofertilizers (B)	2	11.58	31.79	55.40	0.06	454.87	0.01	1,041.60	282255.99	11.33
V X B	4	1.29	0.97	4.78	0.09	0.54	0.01	2.81	760.26	0.69
Error (b)	12	0.56	0.30	0.76	0.01	0.03	1.35	0.07	18.22	0.01
Factor Mulch (M)	2	35.82	74.57	43.61	0.70	83.15	0.01	438.26	118769.11	2.15
V X C	4	0.63	6.07	1.38	0.03	1.34	0.02	2.66	721.91	0.20
B X M	4	0.59	0.44	0.94	0.02	0.97	0.01	6.72	1822.78	0.18
V X B X M	8	0.17	0.34	0.76	0.02	0.47	0.01	1.23	333.11	0.08
Error (m)	36	0.75	0.77	0.32	0.01	0.05	0.02	0.09	24.75	0.01
Total	80									

ANOVA for pooled analysis of different characters

Source of variance	Df	Mean Sum of Squares							
		Fruit breadth (cm)	Fruit weight (g)	Pericarp thickness (mm)	Fruit firmness (g/0.503cm^2)	Shelf life (Days)	TSS (^{0}Brix)	Titratable acidity (%)	Ascorbic acid (mg/100g)
Replication	2	0.01	0.11	0.01	6990.46	5.34	0.07	0.01	0.01
Factor Varieties (V)	2	0.44	2,352.23	10.60	579735.90	212.33	4.68	0.03	24.83
Error (v)	4	0.01	77.99	0.01	625.04	3.69	0.07	0.01	0.01
Factor Biofertilizers (B)	2	4.82	0.61	0.05	8854.42	11.44	1.48	0.01	7.67
V X B	4	0.40	0.00	0.01	541.27	2.15	0.06	0.02	0.02
Error (b)	12	0.01	191.12	0.01	104.94	3.00	0.04	0.01	0.01
Factor Mulch (M)	2	1.27	1.59	0.04	20465.06	47.34	1.31	0.02	50.78
V X C	4	0.22	2.63	0.01	532.84	4.09	0.01	0.01	3.90
B X M	4	0.04	0.76	0.01	353.52	2.41	0.02	0.01	0.03
V X B X M	8	0.04	0.01	0.01	95.65	3.61	0.01	0.02	0.10
Error (m)	36	0.01	2,352.23	0.01	374.58	3.68	0.03	0.01	0.01
Total	80								

ANOVA for pooled analysis of different characters

Source of variance	df	Mean Sum of Squares										
		Lycopene content (mg/100 g)	Incidence of buck eye-rot (%)	Severity of bacterial leaf spot (%)	Severity of early blight (%)	Severity of septoria blight (%)	Available nitrogen (kg/ha)	Available phosphorus (kg/ha)	Available potash (kg/ha)	Organic carbon (%)	Soil pH	Soil EC
Replication	2	0.01	0.01	0.04	0.11	0.01	0.35	0.02	4.00	0.02	0.01	0.01
Factor Varieties (V)	2	1.33	0.99	1,142.61	487.13	0.62	527.55	581.04	1,677.89	0.01	0.02	0.09
Error (v)	4	0.01	0.01	0.01	0.01	0.01	4.22	1.39	0.54	0.01	0.00	0.02
Factor Biofertilizers (B)	2	0.93	0.11	11.79	12.68	0.13	3820.23	431.29	1,865.40	0.03	0.07	0.13
V X B	4	0.02	0.01	2.21	2.55	0.01	68.13	11.97	114.82	0.01	0.00	0.02
Error (b)	12	0.01	0.01	0.01	0.01	0.01	2.07	0.45	0.72	0.01	0.01	0.01
Factor Mulch (M)	2	1.31	0.47	8.76	9.08	0.24	2019.54	372.76	7,950.96	0.03	0.07	0.02
V X C	4	0.03	0.01	0.03	0.07	0.01	21.04	2.10	24.03	0.01	0.00	0.01
B X M	4	0.02	0.02	0.08	0.16	0.01	83.74	2.22	4.27	0.03	0.00	0.02
V X B X M	8	0.01	0.01	0.04	0.06	0.02	8.17	2.22	18.42	0.01	0.00	0.01
Error (m)	36	0.01	0.01	0.00	0.02	0.01	1.51	0.16	0.57	0.02	0.00	0.01
Total	80											

CURRICULUM VITAE

Name	**:**	**Mr Sandeep Kumar Singh**
Father's Name	**:**	Sh Digvijai Singh
Mother's Name	**:**	Smt. Geeta Devi
Date of Birth	**:**	30-12-1988
Sex	**:**	Male
Marital Status	**:**	Unmarried
Nationality	**:**	Indian
E-mail	**:**	sandeephort0233@gmail.com

Educational qualifications:

Certificate/Degree	Class/ Grade	Board/ University	Year
Matric	Second	UP Board, Allahabad	2002
10+2	First	UP Board, Allahabad	2004
B.Sc. (Agriculture)	First	S.V.B.P.U.A&T, Meerut	2008
M.Sc. Ag. Horticulture (FP&PHT)	First	S.H.I.A.T.S, Naini, Allahabad	2010

Whether sponsored by some State/ Central Govt./Univ./SAARC : No

Scholarship/Stipend/Fellowship/ or any other financial assistance received during the study period : No

Place: Nauni, Solan
Dated: Dec, 2013 **(Sandeep Kumar Singh)**