

**RESPONSE OF BELL PEPPER
HYBRID cv. BHARATH TO
CULTURAL PRACTICES**

THESIS

by

KULDEEP SINGH THAKUR

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*Submitted in partial fulfilment of the requirements for the
Degree of*

DOCTOR OF PHILOSOPHY

in

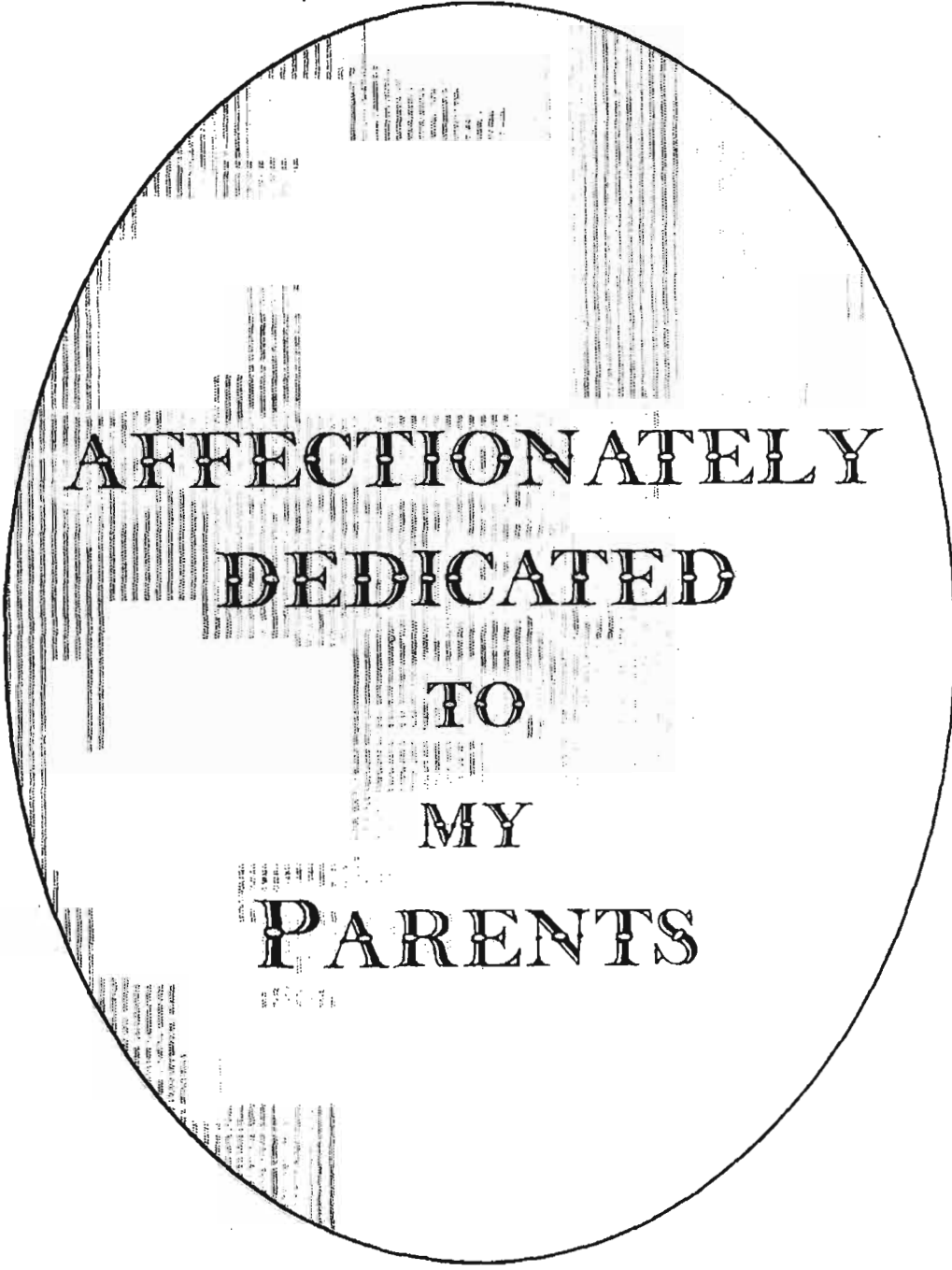
**HORTICULTURE
(Vegetable Crops)**



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INDIA
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CERTIFICATE-I

This is to certify that the thesis entitled “**Response of bell pepper hybrid cv. Bharath to cultural practices**”, submitted in partial fulfilment of the requirements for the award of the degree of **DOCTOR OF PHILOSOPHY in HORTICULTURE (Vegetable Crops)** to Dr Yashwant Singh Parmar University of Horticulture & Forestry, Nauni, Solan, is a bonafide research work carried out by **Mr Kuldeep Singh Thakur (H-96-16-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 have been fully acknowledged.

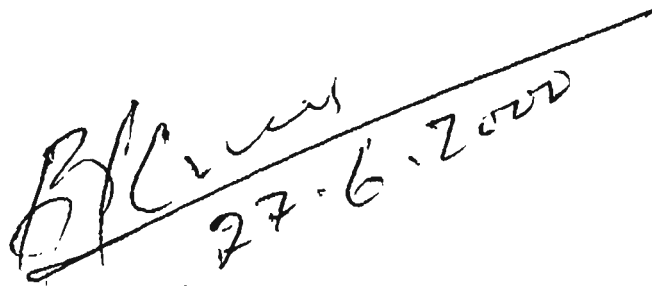
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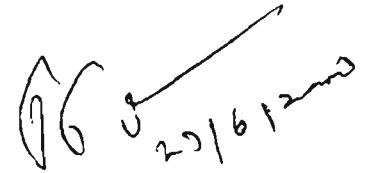

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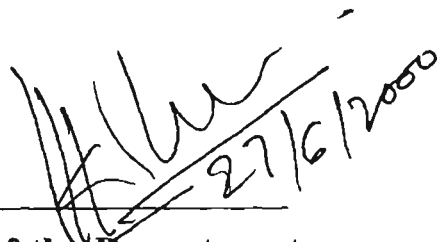
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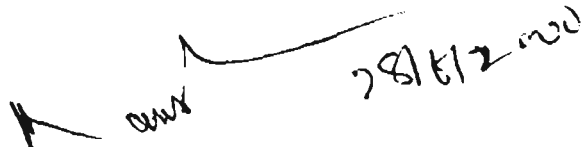
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Acknowledgements

The '**DIVINE FORCE**' which makes 'success to flow like water through the road of rocks' is to be thanked for helping me to go through this eventful phase of my life. However, the man who directed to attain this objective is my reverend advisor **Prof BS Mehta**. His creative thinking, deep scientific vision, confidence and frankness will beyond doubt be cherished by one and all. It is due to his encouragement only that I could achieve my destination successfully.

I seize this opportunity to extend my ecstatic thanks to Dr SK Sharma, Senior Vegetable Seed Production Officer, Dr NP Dohroo, Plant Pathologist and Dr KS Verma, Associate Professor (Soil Science and Water Management), the worthy members of my advisory committee for their valuable help and suggestions.

I express my venerable thanks to **Dr UK Kohli**, Professor and Head, Department of Vegetable Crops for his help and criticism throughout the course of the study.

My sincere thanks are also due to Drs BN Korla, MC Thakur, SK Sharma, HS Kanwar and MK Sharma who obliged me with their timely help.

The people whose help and cooperation can not be over looked are those working in the field and sweating it out to ensure the success of any research endeavour. I extend my sincere thanks to those people as well.

I have been fortunate in getting cooperation and valuable help from my esteemed friends Drs VK Dobhal, Devinder Mehta, Bhupinder Thakur, BS Dogra, Om Chand, Suresh Sharma, Vinay Bhardwaj and Raj Narayan during the course of these investigations.

Emotions do get high on me as I acknowledge fellows like Pathak, Arun, Ashok, Amit, Attri, Ravinder, Bhriagu, Maheshwar, Rajinder, Ambia, Shukla, Sanjeev, Bhupesh, Ranjeet, Laxmikant, Rakesh(s), Dinesh(s), Manoj, Pradeep, Mani Ram, Vikas, Umesh, Tuli, Shashi, Satish, Neelam, Seema, Deepa, Sonika, Meenu, Mamta and others for their help, cooperation and jovial company.

In fact, the words at my command are not adequate to express my heartfelt feelings to my reverend parents for their inspiration, encouragement and affection during my entire academic career. It gives me great pleasure in expressing my love and affection for my wife Manju and little Baby, whose feelings always give me inspiration to keep going on and on.

I am highly grateful to my brothers, brother-in-laws, sisters, sister-in-laws, cousins and all nephew and niece for the love and affection they bestowed upon me during my studies. I shall remain indebted to my uncle and aunts especially Smt and Sh HK Verma, Smt and Sh IS Mehta and Smt and Shri KR Mehta for their contribution in putting me close to my educational goal.

Thanks are also due to DPT Computer, Nauri to carry out the statistical analysis well in time.

Finally a word of special appreciation goes to Mr Asha Ram for his tireless and intense efforts in transforming this manuscript into a beautiful text.

Needless to say errors and omissions are mine.

Place: *Solan*

Date: April 18, 2000



(Kuldeep Singh Thakur)

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Chapter-1

INTRODUCTION

Bell pepper (*Capsicum annuum* L.) popularly known as Shimla Mirch is a high value vegetable and an important cash crop of temperate regions. It is a native of Mexico with secondary centre of origin in Guatemala (Bukasov, 1930 and Smith and Heiser, 1957). Bell pepper was introduced by the British in India in the 19th Century in Shimla hills. It is now widely cultivated in Himachal Pradesh, Karnataka, Tamil Nadu, Hills of Uttar Pradesh, Darjeeling district of West Bengal and Maharashtra.

Himachal Pradesh is a leading supplier of fresh bell pepper to the plains during summer and rainy seasons. The crop is off-season to the plains thus fetches high prices. Bell pepper besides being a cash crop, is also an important vegetarian food because of its high nutritional value, particularly of Vitamin C ranging from 150-180 mg per 100 g quantity and Vitamin A constituting upto 12 per cent of total pigment content (Vyrodova *et al.*, 1988).

Bell pepper is mainly grown in mid and high hills of Himachal Pradesh. The area of bell pepper in the state by clubbing it with pungent chillies is 2045 hectares with a production of 10,241 tonnes (Anonymous, 1996).

The production technology of bell pepper is high input oriented as it demands

more input as compared to other crops (Kalloo, 1997). It is known to exhibit a high positive response to the application of nitrogenous, phosphoric and potassium fertilizers particularly in light soils. Of the three major nutrients, nitrogen is very important for the plants. It is an essential part of nucleic acids and chlorophyll molecules (Devlin, 1972). The deficiency of nitrogen checks the growth and reduces the yield. Phosphorus and potassium are also essential to plant growth, the former is known to participate in energy transfer and carbohydrate metabolism, whereas the latter takes part in number of biological reactions and translocations of food material to different plant parts. Thus, the fertilization is one of the most important factors for exploiting the yield potential of this crop.

In the mid hills, bell pepper is grown in summer and rainy seasons. Bell pepper require more friable and well aerated soils for the good crop health. Because of the poor drainage in rainy season, there is sometimes total crop failure due to the water logging in root zone, thus causing huge losses to the farmers. This problem can be overcome by transplanting the seedlings on ridges as it improve soil drainage and decrease disease incidence.

The advantages of mulching in vegetable crops production have been well documented. Use of mulches helps in increasing the total yield, controlling weed growth, improves fruit quality by modifying soil temperature, conserving soil moisture, facilitate fertilizer placement, reduces the loss of plant nutrients through leaching and provides a barrier to soil pathogens thereby reduces the incidence of fruit rot.

So far much work has not been done in this respect on bell pepper especially in the hills. Thus keeping in view the advantages of above said various agronomical practices and importance of bell pepper as major cash crop of mid hills of Himachal Pradesh, the present investigation was undertaken to study the response of bell pepper hybrid

cv. Bharath to cultural practices with the following objectives:

- 1. To determine the optimum doses of fertilizers for growth and fruit yield of bell pepper hybrid Bharath.**
- 2. To study the effect of planting methods**
- 3. To evaluate influence of different mulches on growth yield, quality traits, weed and disease incidence.**
- 4. To work out the benefit-cost ratio.**

Chapter-2

REVIEW OF LITERATURE

The available literature pertaining to the response of mulch materials, planting methods and fertility levels on growth and fruit yield of bell pepper is reviewed as under:

2.1 Effect of mulch

2.1.1 Growth, yield and yield contributing characters

In a four year experiment, Locascio and Fiskell (1977) observed that mulching with polyethylene increased the yield of bell pepper (*Capsicum annuum*) in three of the years. In an another experiment, Locascio and Fiskell (1979) found that bell pepper cv. Yolo Wonder produced highest fruit yields with the application of paper or polyethylene mulch. Szabo (1979) reported a higher yield from mulched than from unmulched pepper plants while Porter and Etzel (1982) reported that mulching had no effect on pepper yields. On the other hand, Pisarczyk (1982) reported that non-mulched control plants gave consistently higher total yields than the plants mulched with black polyethylene.

Goyal *et al.* (1984) observed that transparent plastic caused lowest plant height and fruit weight, while white, black and silver coated black plastic increased pepper yield by 28, 46 and 132 per cent, respectively compared with non-mulched plots.

Stephen and Stewart (1987) obtained greater number of fruits per plant, mean weight of marketable fruits from mulched than from un-mulched pepper plants. Crespo (1988) observed that the commercial yields of sweet peppers were markedly higher on mulched plots.

VanDerwerken and Wilcox (1988) working at Cornell University, USA found that raised beds and plastic mulch advanced flowering and increased the yields of bell pepper cv. California Wonder.

Brown *et al.* (1989) reported that disease incidence and severity were lower and yields were higher in plots with black polyethylene mulch and black polyethylene mulch + spun bonded polyester than in plots with base soil while working on bell pepper cv. Skipper.

Decoteau *et al.* (1990) observed that bell pepper plants grown with red mulch were taller than plants grown over black, yellow or white mulch. He also reported higher shoot dry mass with red mulch than with black or yellow mulch. Wivutvongvana *et al.* (1991) found that marketable yields of sweet pepper were markedly increased by the use of silvery grey polyethylene plastic mulch, compared with bare soil and straw mulch.

Castellane *et al.* (1992) reported that bell pepper cv. Ikeda showed higher plant growth and fruit production in the plots mulched with black polyethylene than the unmulched plots. In the trials on the Indian chilli (*Capsicum annuum*) cv. B16 A-1, it was reported that plastic mulch enhanced plant growth and produced higher dry matter per plant in the mulched plots (Gollifer, 1993).

Roberts and Anderson (1994) reported that the yields of *Capsicum annuum* cv. California Wonder reduced markedly in the black plastic mulched plots than the plots

covered with organic mulch. Roe *et al.* (1994) evaluated the performance of various organic mulches as alternatives to polyethylene mulch as it causes disposal problems. They found that yield were highest in polyethylene mulched plots compared with organic mulches.

Siti *et al.* (1994) obtained greater fruit yield, number and size from capsicum plants grown under aluminium painted plastic mulch. In a greenhouse experiment, Cebula (1995) reported the highest percentage of fruit set in plants mulched with transparent plastic film. He further observed that compared with the unmulched control, yields of sweet pepper were 38.6 and 19.0 per cent higher with transparent and black mulches, respectively.

Vos and Sumarni (1997) observed that mulches induced faster plant growth, earlier fruiting and produced higher yields in most of the cases, while evaluating the performance of hot pepper cultivars at different location of Malaysia. Borosic *et al.* (1998) in a two year trial on bell pepper hybrid cv. Istria reported that the yields of marketable fruits grown under various mulches were higher by 14-89 per cent in 1995 and by 30-99 per cent in 1996.

Flores and Ibarra (1998) observed statistically significant differences between the mulch treatments for number of fruits per plant, length and diameter of fruits, plant height and fruit yields in case of *Capsicum annuum* cv. Anaheim.

2.1.2 Soil moisture and temperature

Clarkson (1960) reported that the average soil temperatures at various soil depths under a black polyethylene mulch were usually higher (1 to 5°F) than at comparative soil depths under non-mulched condition. Liptay and Tiessen (1970) reported that soil temperature on sunny days were increased markedly under the clear polyethylene and

polyethylene on black paper mulch. Maximum and minimum daily soil temperatures were 9.5°C and 2.8°C higher under clear polyethylene and 8.9° and 3.0°C under clear polyethylene on black paper mulches, respectively. They also observed that moisture loss from the mulched plots was substantially less than from the bare soil plots.

Porter and Etzel (1982) reported that black polyethylene promotes higher soil temperatures and hence increases the fruit yield of bell pepper. Ashworth and Harrison (1983) found that organic mulches maintained soil temperature significantly cooler than the plastic mulches. On the other hand highest soil moisture levels were found under the bark mulch and least under clear polyethylene treatment.

Wein and Minotti (1987) observed that tomato produced more number of branches and more fruit yields in plots mulched with clear or black polyethylene. They further concluded that stimulated root growth by increased soil temperature and soil moisture status under the mulch may have resulted in increased yield response.

Siti *et al.* (1994) reported that soil temperature varied with types of mulching. Under plastic mulches, soil temperatures were higher than coconut frond mulch and bare ground. They also observed that soil moisture under coconut frond mulch was 13 per cent and 7.5 per cent higher than that without mulches and Al-painted plastic mulches, respectively.

Roberts and Anderson (1994) while working with bell pepper cv. California Wonder, reported that the plots with black plastic mulch had less soil moisture and higher soil temperature than the plots mulched with white plastic or straw mulch.

Hatt *et al.* (1994) reported that use of white film mulch in bell pepper gave the best results with regard to growth and yields as it maintained the favourable soil temperature for the proper growth and development of the plants.

Vos and Sumarni (1997) observed that soil temperature under rice straw mulch was significantly lower than in the 'no mulch' treatment.

2.1.3 Weed control

Integrated weed management based on plastic mulching has been suggested by Liu *et al.* (1987). Kwon *et al.* (1988) reported that black and white films restricted weed growth and they recommended black mulch as most suitable for mulching of peppers cv. Shinhong in Korea. Carter and Johnson (1988) observed better weed control with black plastic compared with bare ground and newspaper mulch. Mulches kill weeds by excluding light and by forming physical barrier to growth (Putnam, 1990).

Asiegbu (1991) found that black plastic sheet clearly suppressed weed growth in the tomato plots, in comparison to organic mulches and bare soil and resulted in more crop growth and higher fruit yield. He also observed that weed dry matter was reduced significantly by using black plastic mulch.

Gollifer (1993) observed that plant growth of *Capsicum annuum* was enhanced by using plastic mulch as it reduced weed competition for soil K. Singh (1994) found effective control of several weeds in tomato (cv. Pant Bahar) field when mulched with leaves, dry sugar cane leaves, rice straw, rape and dry poplar leaves during summer season crop.

In a studies of lower chemical input techniques for weed control in vegetables by Edwards *et al.* (1995), it was concluded that mulching was the best method to control weeds in peppers and tomatoes.

Patil *et al.* (1997) in a trial in Karnataka found that surface applied mulches significantly suppressed weed growth and increased the yield of pepper cv. Sankeshwar. They further reported that sugar cane trash was the best mulch in terms of its affects on

growth, yield and weed suppression. Russo *et al.* (1997) reported in USA that weed control was not required in the vegetable fields covered with black polyethylene mulch.

2.2 Effect of planting method

Raised beds improves soil drainage thereby increasing the soil temperature in the root zone of the plant (Chipman, 1961; Gubbles, 1971). Velev (1973) found that raised beds were more suitable than sunken beds for capsicum growing. Ramaiah and Lal (1987) while working with the capsicum cv. Pant C-1 in the trai region of Uttar Pradesh, concluded that the ridge method was the most suitable for the rainy season crop. It gave the highest pod yield and income per hectare.

VanDerwerken and Wilcox (1988) reported that raised beds covered with plastic mulch advanced flowering and increased early yields of bell pepper cv. California Wonder. Call and Courter (1989) from their experiment observed that raised beds had little effect on fruit yield of bell pepper but total yields were increased by 1.7 lb/plant on raised mulched beds. Cavero *et al.* (1996) reported that higher yields were obtained with raised beds than with flat ground sowing of pepper cv. Piguillo de Lodosa.

2.3 Effect of fertilization

Albregts (1971) reported that the highest yield and best quality fruits of bell pepper were obtained from the plants receiving N at 336 and K₂O at 279 kg ha⁻¹. Lal and Pundrik (1971) obtained highest yield of chillies in response to 80 kg N, 90 kg P₂O₅, and 50 kg K₂O. They also reported that fruit size, fruit weight and plant height increased with increasing N application.

Bangash and Shaikh (1972) concluded from their experiment that NPK @ 100 lb acre⁻¹ each, gave the maximum yield of capsicum fruits which was 109 per cent more than the control.

Gill *et al.* (1974) reported that the highest dose of nitrogen (375 kg ha^{-1}) and P_2O_5 (250 kg ha^{-1}) combination reduced the number of days to flowering. They also observed that the number of branches and fruits per plant significantly increased by higher doses of nitrogen and P_2O_5 .

Ludilov and Ludilova (1976) recorded an increase of 54 per cent in capsicum yields on clayey soils when N, P_2O_5 and K_2O were applied at 120 kg ha^{-1} each. Yield increases were mainly due to greater fruit set rather than to fruit weight. Sinha (1975) obtained highest fruit yield of bell pepper with 105 kg N ha^{-1} .

Covarelli (1976) tried 0, 100 and 200 kg N ha^{-1} ; 0, 150 and $300 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ and 0, 150 $\text{kg K}_2\text{O ha}^{-1}$. He found that highest rate of nitrogen application increased the capsicum yields by 60 q ha^{-1} with increased fruit weight. Phosphorus was effective by increasing the fruit weight and the number of early fruits but potash application did not showed any effect. Khan and Suryanarayana (1978) reported that NPK at 120:45:45 kg ha^{-1} gave the best results with regard to capsicum growth, dry matter accumulation and fruit yield (1440 kg ha^{-1}).

Chougule and Mahajan (1979) found that NPK at 150:120:60 kg ha^{-1} was the best combination for obtaining highest marketable yield. Rastogi *et al.* (1980) used three levels of nitrogen, viz. 45, 60 and 75 kg ha^{-1} on soils of average fertility. They found that 45 kg N ha^{-1} was the optimum dose for obtaining high bell pepper yields, since the higher doses of nitrogen did not significantly increase the yields.

Ramchandran and Subbiah (1981) observed that capsicum cv MDU-1 produced the highest yield ha^{-1} of dry fruits (2358.83 kg) when nitrogen was applied @ 120 kg ha^{-1} .

Srinivas and Prabhakar (1982) conducted experiment with cv. California Wonder at Hessarghatta, Bangalore and noticed that N fertilization increased fruit yield, plant

height, number of branches and fruit size. The highest fruit yield (111.3 q ha⁻¹) was obtained at 150 kg N ha⁻¹. Singh *et al.* (1983), however, obtained the maximum fruit yield with 90 kg N ha⁻¹.

Graifenberg *et al.* (1983) reported that for the production of 419 q fruits ha⁻¹, requirements of N, P and K, were 132.9, 43.9 and 147.8 kg ha⁻¹, respectively in Yolo Wonder variety of capsicum. Valsikova (1983), while working in Czechoslovakia, reported that NPK fertilization did not reduce the crop quality of capsicum and suggested that higher application rates could be safely used for economic yields.

Doikova *et al.* (1984) in Bulgaria found that increasing the NPK rates increased the vegetative growth and fruit yield of capsicum and the highest fruit yield was obtained by the highest rate at NPK 360 kg ha⁻¹ each with or without 50 t FYM ha⁻¹. Similar results were obtained by Doikova *et al.* (1986). Osman and George (1984) in a greenhouse trial with cv. World Beater reported that, 1900 kg N, 640 kg P and 2800 kg K ha⁻¹ gave the highest fruit yield. Joseph and Pillai (1985) obtained the highest yields of dry fruits of chilli under rainfed conditions at the highest NPK levels (112.5:60:30 kg ha⁻¹). However, the most economical NPK level were 90:52:30 kg ha⁻¹. Frontela and Morejon (1987) observed that application of 207 kg N, 100 kg P₂O₅ and 161 kg K₂O ha⁻¹ recorded the highest capsicum yields (24.83 t ha⁻¹). Hegde (1987a) carried out studies with cv. California Wonder and found linear increase in yield upto 180 kg N ha⁻¹. Highest yield (115.4 q ha⁻¹) of capsicum cv. California Wonder was recorded at 160 kg N ha⁻¹ by Manchanda and Bhopal Singh (1987). Pandev *et al.* (1987) compared fertilizer requirement of 5 cultivars and 4 of their hybrids and concluded that hybrids took up more available soil nutrients and required less N, P and K for the production of 100 kg fruits than the cultivars.

Shukla *et al.* (1987) while conducting trials with cv. California Wonder, found a

linear increase in yield upto 180 kg N ha⁻¹ with the highest yield of 83 q ha⁻¹ with the application of 180 kg N and 50 kg P₂O₅ ha⁻¹, respectively. Hegde (1987b) concluded that nitrogen fertilization increased growth, dry matter production, yield and nitrogen uptake of bell pepper cv. California Wonder and the optimum dose was 168 kg N ha⁻¹.

Belichki (1988) observed that application of N:P:K at 320:320:80 or 320:320:60 kg ha⁻¹ were the most economically effective treatments, increasing total yields by 67.4 and 43.3 per cent, respectively.

Manchanda and Bhopal Singh (1988) reported that increasing rates of N increased plant height, primary branches per plant, number of fruits per plant, fruit length, fruit breadth and fruit yield of bell pepper.

Surlekov and Rankov (1989) obtained the highest yields of cv. Kurtovsko Kapiya with the application of N:P:K at 100:80:100 kg ha⁻¹.

Medhi *et al.* (1990) conducted trials with a chilli cultivar at Barapani, Meghalaya and concluded that NPK at 20, 40, 60 or 80 kg ha⁻¹ increased growth and yield with increasing levels of NPK. Singh and Naik (1990) reported that the highest net returns were obtained when 50 kg N and 150 kg P₂O₅ ha⁻¹ were applied.

Chailloux *et al.* (1992) observed tallest plants of capsicum cvs. California Wonder and Tropical CW-3 with the highest N rate (270 kg ha⁻¹) and found positive linear correlation between plant height and total yield. Olsen *et al.* (1993) while working in Australia reported that dry weight of bell pepper fruits, leaves and stems increased significantly with applied N. They further found that maximum fresh weight of marketable fruits correspond with N at 220 and 280 kg ha⁻¹. Siti *et al.* (1993) studied the effect of different nitrogen levels viz. 112, 224, 336 or 488 kg N ha⁻¹ on *Capsicum annum* cv. Lady Bell and concluded that doubling the N rate from 112 to 224 kg ha⁻¹

increased the number of flower buds by 21 per cent but per cent fruit set, early and total fruit yield decreased with increasing N application rate. Hochmut~~et al.~~ (1994) reported maximum fruit yield of bell pepper when potassium was applied at 60 lb K acre⁻¹.

Mishriky and Alphonse (1994) observed that increasing the N rate significantly increased plant height, fresh weight and dry weight per plant, number and weight of fruits per plant and total fruit yield.

Madero and Olaya (1995) evaluated the performance of a new *Capsicum annuum* cultivar (IAC003) at 6 urea application rates (0-250 kg N ha⁻¹) and found that yield increased with increasing N application rate.

Russo (1996) observed that recommended fertilizer rate (NPK @ 112:112:325 kg ha⁻¹) increased yields of 'Sweet Banana #504' and decreased that of 'Mitla' compared to the higher rate.

Srivastava (1996) in his fertilizer trial on capsicum hybrid Bharath at Jabalpur, India concluded that days to 50 per cent flowering were delayed by 4-6 days in plants receiving highest rate of fertilizers. He also observed that the highest number of fruits per plant (10.66), fresh weight per fruit (128 g), yield per plant (637.5 g) and yield per hectare (92.95 q ha⁻¹) were obtained from plants treated with 250 kg N + 200 kg P + 200 kg K ha⁻¹).

Maya *et al.* (1997) reported that growth parameters and fruit yield of sweet pepper cv. California Wonder increased as N and P application rates increased. Flores and Ibarra (1998) reported that capsicum yields were reduced at highest level of NPK (200:100:100 kg ha⁻¹). Simonne *et al.* (1998) observed similar trend in bell pepper yields when nitrogen application was increased.

2.4 Nutrient content

Somos *et al.* (1973) reported that rising NPK supply raised the nutrient content of stem and leaves in capsicum plants.

In an another experiment, Locascio *et al.* (1985) reported that leaf tissue N concentration of bell pepper decreased from 4.67 per cent to 3.74 per cent about 5 to 11 weeks after transplanting in the mulched plots. They further observed that leaf N increased as the N rate increased from 56-224 kg ha⁻¹.

Siti *et al.* (1994) observed that mulches significantly affect N and K contents in leaf tissues at final harvesting of the chilli crop. With mulches N and K contents were higher than those without mulches. However, P content was not affected by mulches. They further reported that K contents increased with increased K rates.

Roe *et al.* (1997) found that bell pepper leaf NPK concentration increased with increasing fertilizer rates. Vos and Sumarni (1997) reported that concentration of N in hot pepper leaves, were significantly higher in plastic mulched than in bare soil plots, whereas P concentrations were lower in plastic mulched than in bare soil plots. K concentrations in leaves were higher in plots mulched with rice straw than in bare soil and plastic mulched plots.

2.5 Interaction effects of mulches, planting methods and fertilization

Locascio and Fiskell (1977) in a four year trial concluded that the average yields of bell pepper obtained by mulching combined with a single annual application of N were 10-25 per cent higher than those obtained after three split application of N and no mulching. Highest yields were recorded when urea was applied broadcast with black polyethylene mulch (Locascio *et al.*, 1981).

Call and Courter (1989) reported that total yields of bell pepper were increased by 1.7 lb/plant on raised mulched beds. Siti *et al.* (1994) suggested that K fertilizer @ 132 kg ha⁻¹ and mulching are promising for yield increase in chilli production.

Flores and Ibarra (1998) reported that NPK @ 160:80:80, 180:90:90 or 200:100:100 kg ha⁻¹ along with blue polyethylene mulch produced 17.027, 17.864 and 14.696 t ha⁻¹ of capsicum fruit yield.

Chapter-3

MATERIALS AND METHODS

The present investigations were carried out at the experimental farm of the Department of Vegetable Crops, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan (Himachal Pradesh) during the Kharif seasons of 1998 and 1999. The farm is situated in the mid hill zone of Himachal Pradesh at 30°-51' North latitude and 77°-11' East longitude. The elevation of the farm is 1260 meters above mean sea level.

3.1 Environmental conditions

The climate in general, is sub-temperate and characterised by mild summer. May and June are the hottest months and December to February are the coldest ones. The annual rainfall ranges between 1000 to 1300 mm, of which 75 per cent is received during June to September. Winter rains are also received during the months of January and February with occasional rainfall.

During the course of investigations mean weekly meteorological data for the growing seasons recorded at the Agro-meteorology Observatory of the Department of Soil Science and Water Management is presented in Appendix-I. The monthly mean weather data is depicted in Fig. 1a and 1b. This data clearly indicated that May and June were hottest months, whereas, maximum rainfall was recorded in the month of July during both the years. The weather remained favourable throughout the crop growing seasons during 1998 and

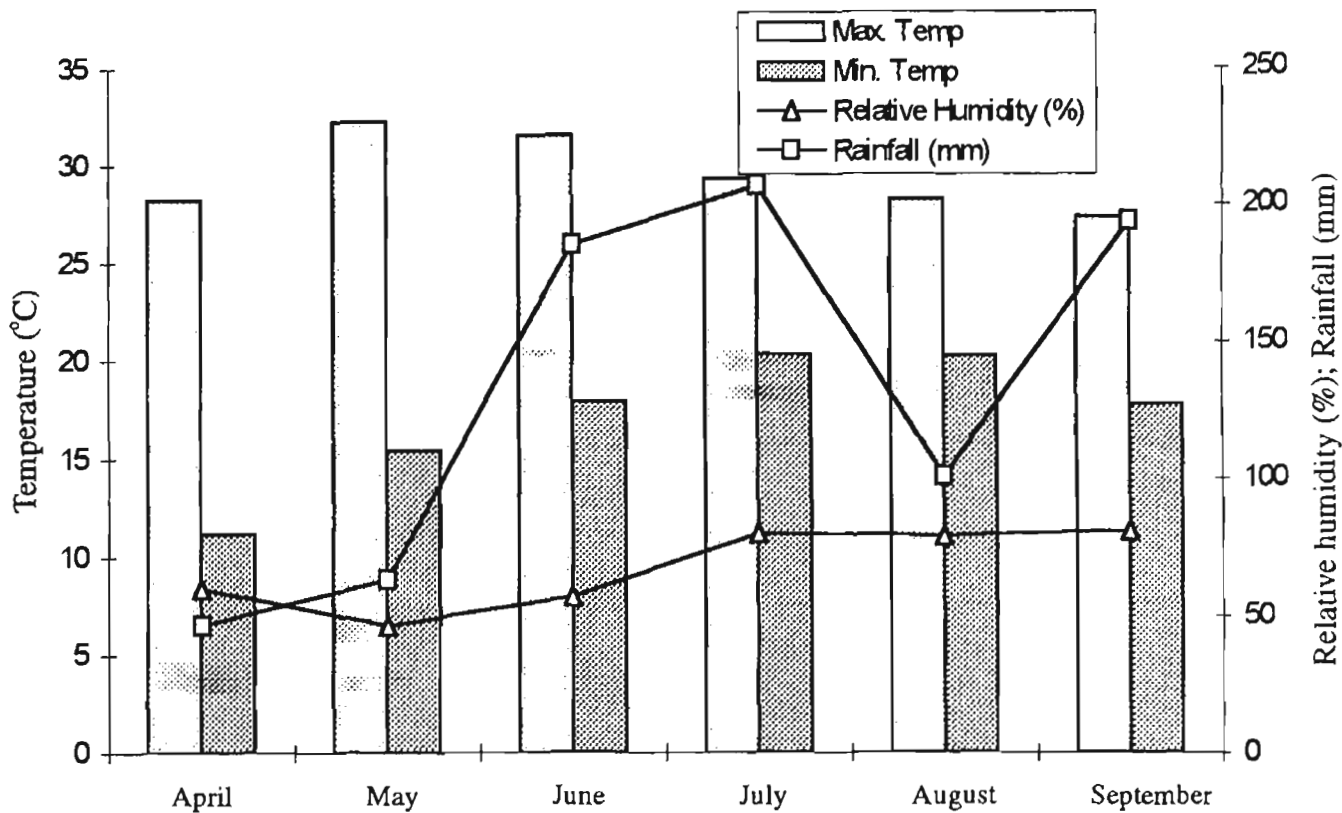


Fig.1a. Mean monthly weather data for the crop growing season during 1998

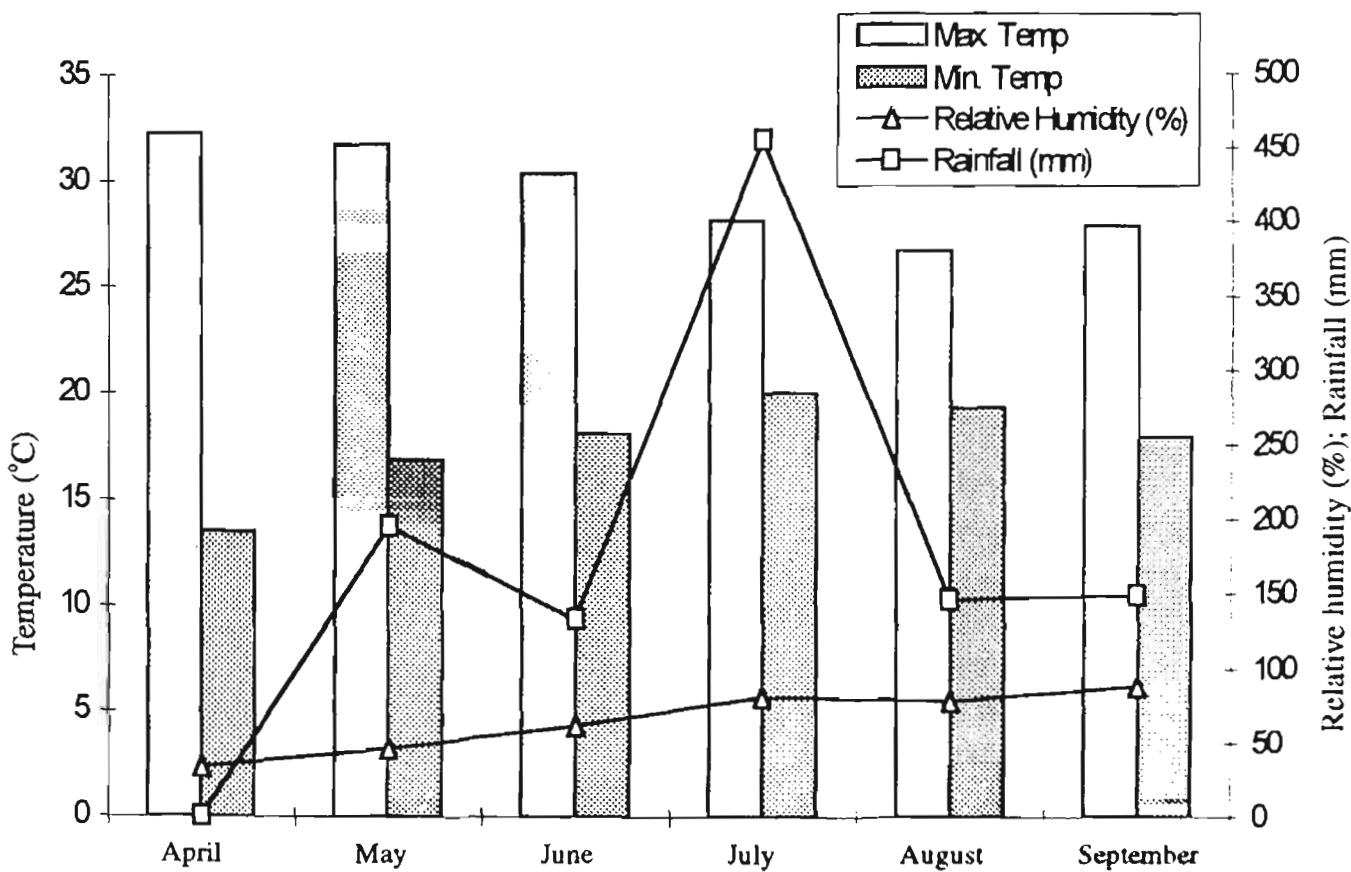


Fig.1b. Mean monthly weather data for the crop growing season during 1999

1999. However, a drier spell was observed during 1998.

3.2 Physico-chemical properties of the soil

Composite soil samples were collected at 0-15 cm depth before transplanting from each replication during both the years and analysed for their physico-chemical properties as given in Table 1.

Table 1. Physico-chemical properties of the soil

Particulars	Amount present		Method and reference
	1998	1999	
Mechanical Analysis			
Coarse sand (%)	31.94	32.12	International Pipette Method (Piper, 1966)
Fine sand (%)	13.46	14.02	
Silt (%)	30.92	31.23	
Clay (%)	23.60	22.55	
Texture	Sandy loam	Sandy loam	
Chemical Analysis			
Soil pH (1:2.5)	6.83	6.96	Digital pH meter
Organic carbon (%)	0.84	0.92	Walkley and Black's rapid titration method (Piper, 1966)
Available nitrogen (kg ha ⁻¹)	330.46	335.23	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
Available phosphorus (kg ha ⁻¹)	32.34	34.24	Olsen's method (Olsen <i>et al.</i> , 1954)
Available potassium (kg ha ⁻¹)	270.52	275.00	Flame emission Spectroscopy (Jackson, 1973)

It is evident from the above table that the soil was sandy loam in texture, slightly acidic, rich in organic carbon, medium in available nitrogen and phosphorus and rich in available potassium.

3.3 Experimental details

The experimental details are as under:

A. Treatment

1. Main Plots:

Mulch materials	Thickness
M ₁ - Black polyethylene mulch	50 micron
M ₂ - Transparent polythene mulch	50 micron
M ₃ - Pine needle mulch	3 inches
M ₄ - Control (No mulch)	

2. Sub-Plots: Planting methods

- P₁ - Ridge method
- P₂ - Flat bed method

3. Sub-sub Plots: Fertility levels (kg ha⁻¹)

	N	P ₂ O ₅	K ₂ O
L ₁	190	45	50
L ₂	250	60	75
L ₃	310	75	100
L ₄	370	90	125

B. Total treatments:

32

C. Replication(s)

3

D. Design :

Split-split plot design

E. Spacing:

60x45 cm

F. Cultivar:

Bharath

G. Plot sizes:

Main plot size	19.20x2.25 m
Sub plot size	9.60x2.25 m
Sub-sub plot size	2.40x2.25 m

Table 2. Treatment combinations used in the experimental plots

1.	$M_1P_1L_1$:	(BPM+ RM + 190:45:50 NPK kg ha ⁻¹)
2.	$M_1P_1L_2$:	(BPM + RM + 250:60:75 NPK kg ha ⁻¹)
3.	$M_1P_1L_3$:	(BPM + RM + 310:75:100 NPK kg ha ⁻¹)
4.	$M_1P_1L_4$:	(BPM + RM + 370:90:125 NPK kg ha ⁻¹)
5.	$M_1P_2L_1$:	(BPM + FM + 190:45:50 NPK kg ha ⁻¹)
6.	$M_1P_2L_2$:	(BPM + FM + 250:60:75 NPK kg ha ⁻¹)
7.	$M_1P_2L_3$:	(BPM + FM + 310:75:100 NPK kg ha ⁻¹)
8.	$M_1P_2L_4$:	(BPM + FM + 370:90:125 NPK kg ha ⁻¹)
9.	$M_2P_1L_1$:	(TPM + RM + 190:45:50 NPK kg ha ⁻¹)
10.	$M_2P_1L_2$:	(TPM + RM + 250:60:75 NPK kg ha ⁻¹)
11.	$M_2P_1L_3$:	(TPM + RM + 310:75:100 NPK kg ha ⁻¹)
12.	$M_2P_1L_4$:	(TPM + RM + 370:90:125 NPK kg ha ⁻¹)
13.	$M_2P_2L_1$:	(TPM + FM + 120:45:50 NPK kg ha ⁻¹)
14.	$M_2P_2L_2$:	(TPM + FM + 250:60:75 NPK kg ha ⁻¹)
15.	$M_2P_2L_3$:	(TPM + FM + 310:75:100 NPK kg ha ⁻¹)
16.	$M_2P_2L_4$:	(TPM + FM + 370:90:125 NPK kg ha ⁻¹)
17.	$M_3P_1L_1$:	(PNM + RM + 190:45:50 NPK kg ha ⁻¹)
18.	$M_3P_1L_2$:	(PNM + RM + 250:60:75 NPK kg ha ⁻¹)
19.	$M_3P_1L_3$:	(PNM + RM + 310:75:100 NPK kg ha ⁻¹)
20.	$M_3P_1L_4$:	(PNM + RM + 370:90:125 NPK kg ha ⁻¹)
21.	$M_3P_2L_1$:	(PNM + FM + 190:45:50 NPK kg ha ⁻¹)
22.	$M_3P_2L_2$:	(PNM + FM + 250:60:75 NPK kg ha ⁻¹)
23.	$M_3P_2L_3$:	(PNM + FM + 310:75:100 NPK kg ha ⁻¹)
24.	$M_3P_2L_4$:	(PNM + FM + 370:90:125 NPK kg ha ⁻¹)
25.	$M_4P_1L_1$:	(NM + RM + 190:45:50 NPK kg ha ⁻¹)
26.	$M_4P_1L_2$:	(NM + RM + 250:60:75 NPK kg ha ⁻¹)
27.	$M_4P_1L_3$:	(NM + RM + 310:75:100 NPK kg ha ⁻¹)
28.	$M_4P_1L_4$:	(NM + RM + 370:90:125 NPK kg ha ⁻¹)
29.	$M_4P_2L_1$:	(NM + FM + 190:45:50 NPK kg ha ⁻¹)
30.	$M_4P_2L_2$:	(NM + FM + 250:60:75 NPK kg ha ⁻¹)
31.	$M_4P_2L_3$:	(NM + FM + 310:75:100 NPK kg ha ⁻¹)
32.	$M_4P_2L_4$:	(NM + FM + 370:90:125 NPK kg ha ⁻¹)

Note: BPM - Black Polyethylene Mulch; TPM - Transparent Polyethylene Mulch; PNM - Pine Needle Mulch; NM - No Mulch; RM - Ridge Method; FM - Flat bed Method

3.4 Field preparation

The experimental field was prepared thoroughly by ploughing with tractor followed by planking 15 days prior to actual date of transplanting of seedlings. The stubbles of the previous crop, weeds and grasses were removed. Finally, the field was well levelled for the layout of the experiment.

3.5 Experimental planting

Bell pepper hybrid cv. Bharath was used for this study. The normal operations were followed for raising the healthy nursery. The seeds were sown in the nursery beds on 20th and 10th March in 1998 and 1999, respectively. Entire dose of phosphorus in the form of single super phosphate (16% P_2O_5), potassium in the form of muriate of potash (60% K_2O) and one third dose of nitrogen in the form of calcium ammonium nitrate (25% N) was applied at the time of field preparation as per the treatment. According to the treatment combinations ridges (50 cm wide and 15 cm high) were constructed on the sub-plots with the help of spade. Seedlings of almost equal size and vigour were transplanted on May 17 and May 3 during the years 1998 and 1999, respectively. The remaining nitrogen was applied in two split doses, successively at one month interval from transplanting. Recommended cultural practices along with plant protection measures were followed strictly from sowing to harvesting to ensure good healthy crop. Mulching was done after one week of the transplanting date when seedlings were established. Plastic mulches viz., black and transparent polyethylene mulch and pine needle mulch were used to cover the experimental plots. Plastic sheets were laid in between the rows such that each strip was 5 cm apart from the plants. The ends of plastic sheets were burried in the soil for secure placement. After placement, the plastic sheets were perforated with a sharp object to let rain water into the soil. Pine needles (4 kg/plot) were evenly applied to the appropriate plots.

3.6 Observations recorded

The data were recorded on five randomly selected plants for all the characters. During the course of the random selection of plants, the border plants were excluded. The following characters were studied:

1. Days to 50 per cent flowering

The number of days taken by 50 per cent of the plants to produce first flower from the date of transplanting were counted.

2. Plant height (cm)

The height of the plant was measured after the final picking from the soil line to the highest tip of the plant.

3. Number of branches per plant

The total number of branches arising from main stem were counted and mean number of branches per plant worked out.

4. Fruit length (cm)

Ten fruits from second picking were selected randomly and their length was measured from the tip of the fruit to the point of contact of the fruit with the base.

5. Fruit breadth (cm)

The fruit breadth was measured from the peduncle end, middle and near apex with a digital vernier calliper. The average of these three values were taken as fruit breadth. The same fruits which were used to measure fruit length were also utilized to measure fruit breadth.

6. Fruit weight (g)

It was calculated by dividing the total marketable yield in grams with total number of marketable fruits for each treatment.

7. Fruits per plant

The total number of fruits harvested at every picking were taken into consideration to work out as mean number of fruits per plant.

8. Fruit yield per plant (g)

The fruit yield from the randomly selected plants was pooled and average yield per plant was worked out.

9. Fruit yield per plot and per hectare

The total yield of the marketable fruits harvested from the net plot area was recorded and expressed in kg per plot on basis of this yield in $q\ ha^{-1}$ was calculated.

10. Harvest duration (days)

Days were counted from first picking to final picking of marketable fruit for each treatment.

11. Fruit rot incidence (%)

Fruit rot incidence was recorded as per cent of rotten fruits in every plot during total crop growth period.

12. Shoot biomass

Three plants (from outer rows) at random were selected from each plot at final picking. These plants were washed with tap water to make them free of extraneous

matter and then with 0.1 N HCl, single distilled water and finally with double distilled water. The samples were over dried at $65\pm 5^{\circ}\text{C}$ till constant weight attained. Dry weight thus obtained was expressed in kg ha^{-1} by the following formula:

$$\text{Shoot biomass (kg ha}^{-1}\text{)} = \frac{\text{Dry weight of 3 plants} \times 10000}{\text{Area covered by 3 plants} \times 1000}$$

13. Weed count

Weed count data were collected at 60 days after transplanting from each plot with the help of a quadrat of 50×50 cm (0.25 m^2). For weed count the quadrat was placed randomly in the each plot and the total number of weeds growing within this area were counted.

14. Fresh and dry weight of weeds ($\text{g}/0.25 \text{ m}^2$)

Observation on fresh and dry weight of weeds were recorded at 60 days after transplanting from an area of 50×50 cm (0.25 m^2). Fresh weight was recorded just after the collection of weeds while dry weight was recorded after drying of weeds in oven at $65\pm 5^{\circ}\text{C}$ and expressed as $\text{g}/0.25 \text{ m}^2$.

15. Soil moisture content (%)

Soil moisture was measured at 10-15 cm depth at fortnight intervals by a gravimetric method. A composite of 3 cores soil from each main plot were randomly sampled, weight and oven dried in aluminium boxes at 105°C for 24 hours and reweight^{ed} to determine percentage of moisture.

16. Soil temperature ($^{\circ}\text{C}$)

Soil temperature was monitored at about 2.00 PM at 10 cm depth by placing the soil probe thermometer in each main plot, mid-way between two plants. Soil temperature

was recorded at fortnight intervals throughout the growing seasons during both the years.

17. Plant analysis

Five plants at random were selected from each plot at final picking for estimation of NPK content. The newly expanded leaf samples were collected and weighed immediately. These samples were brought to the laboratory in paper bags and were washed with tap water to make them free from extraneous matter and then with 0.1N HCl followed by distilled water. The samples were oven dried at $65\pm 5^{\circ}\text{C}$ till constant weight attained. Dried samples were then ground to powdery mass and subjected to chemical analysis. For the estimation of P and K, 0.5 g of the plant sample was digested in 4:1 nitroperchloric acid ($\text{HNO}_3:\text{HClO}_4$) mixture. The digest was distilled in double distilled water and filtered into 100 ml volumetric flask. In order to have complete transfer of the digestion material, three washings of the digestion flask were given with distilled water and volume was made to 100 ml. Phosphorus in the extract was determined by Vanado-molybdate yellow colour method and potassium was determined flame photometrically (Jackson, 1973). For estimation of N, 0.5 g of plant material was digested in concentrated H_2SO_4 (12 ml) in the presence of digestion mixture containing capsules and was determined by Tecator Kjeldahl Auto Analyzer.

18. Soil analysis

Soil samples from 0-15 cm depth were collected from each plot, after the harvest of the crop. Samples were dried, ground and mixed thoroughly and used for the determination of available nutrient contents viz. N, P and K by using the standard methods as given in Table 2.

19. Economic analysis

After taking into consideration the variables as well as fixed inputs and corresponding rates, the cost incurred on each treatment was worked out (Appendix-IV). Simultaneously gross returns were worked out for each treatment based on market prices of the produce. Net returns were then worked out by deducting the cost incurred from the gross returns of the particular treatment.

20. Statistical analysis

The data recorded were subjected to statistical analysis by following Gomez and Gomez (1984) for split-split plot design. The results have been interpreted on the basis of 'F' test and critical difference (CD) at 5 per cent level of significance. The two years data were subjected to pooled analysis with a view to arriving a valid conclusions and for better appraisal of treatments.

Chapter-4

EXPERIMENTAL RESULTS

The present investigations were undertaken to study the effect of different cultural practices viz. mulch materials, planting methods and NPK fertilizers on the growth and yield components of bell pepper hybrid cv. Bharath. The results obtained from the experiments conducted have been presented characterwise as under:

4.1 Days to 50 per cent flowering

The observations recorded on this attribute are presented in Table 3. A perusal of the data in the table revealed that main effects of mulches and planting methods were found to be significant during both the years and in pooled data but fertility levels had significant effect in the year 1998 and in pooled data (Appendix-II).

It was observed from pooled data that M_1 treatment resulted in early flowering (33.15 days), which was statistically at par with M_2 and M_3 . Similar results were obtained during 1998 and 1999. Minimum days to 50 per cent flowering were taken when planting was done on ridges (P_1). With regard to fertility levels, the minimum days (34.79 days) were observed at L_2 level in pooled data. Similar trend was found during 1999. However, flowering was earliest at L_1 level in the year 1998.

All the first order as well as second order interactions were found to be non-significant during both the years.

Table 3. Effect of mulches, planting methods and fertility levels on days to 50 per cent flowering, plant height and number of branches per plant in bell pepper hybrid cv. Bharath

Treatments	Days to 50% flowering			Plant height (cm)			Number of branches per plant		
	1998	1999	Pooled	1998	1999	Pooled	1998	1999	Pooled
Mulches									
Black polyethylene mulch (M ₁)	31.88	34.42	33.15	59.10	59.23	59.17	3.70	4.09	3.89
Transparent polyethylene mulch (M ₂)	32.46	36.37	34.42	54.65	60.55	57.60	3.43	3.88	3.65
Pine needle mulch (M ₃)	31.92	36.08	34.00	58.88	63.11	60.99	3.94	4.16	4.05
No mulch (M ₄)	38.75	42.04	40.40	51.38	55.45	53.41	3.57	3.83	3.70
SE(d) _±	0.91	1.22	0.77	0.98	1.87	1.05	0.22	0.22	0.16
CD at 5%	2.25	3.00	1.67	2.41	4.58	2.31	NS	NS	NS
Planting methods									
Ridge method (P ₁)	33.13	36.04	34.58	56.98	60.46	58.72	3.67	4.00	3.83
Flat bed method (P ₂)	34.38	38.42	36.40	55.03	58.71	56.87	3.65	3.98	3.82
SE(d) _±	0.42	0.74	0.43	0.84	1.13	0.70	0.07	0.08	0.05
CD at 5%	0.97	1.72	0.91	1.93	NS	1.49	NS	NS	NS
Fertility levels (NPK kg ha⁻¹)									
190:45:50 (L ₁)	32.96	36.67	34.81	55.07	58.01	56.54	3.57	3.86	3.71
250:60:75 (L ₂)	33.50	36.08	34.79	55.81	59.29	57.55	3.62	3.95	3.84
310:75:100 (L ₃)	33.92	37.79	35.85	55.96	60.64	58.30	3.71	4.07	3.85
370:90:125 (L ₄)	34.62	38.37	36.50	57.16	60.40	58.78	3.74	4.07	3.89
SE(d) _±	0.48	1.01	0.56	0.75	0.66	0.50	0.08	0.09	0.06
CD at 5%	0.97	NS	1.12	NS	1.33	0.99	NS	NS	NS
Year Effects									
Year Effects	33.75	37.23		56.00	59.59		3.66	3.99	
SE(d) _±		0.54			0.75			0.11	
CD at 5%		1.18			1.63			0.24	

Significant differences between the years were observed on this attribute. Early flowering occurred in the first year than in the second year.

4.2 Plant height (cm)

Observations on plant height as affected by various treatments have been summarised in Table 3.

An inquisition of the data revealed that main effects of mulches were found to be significant during the year 1998. Planting methods during 1998 and fertility levels during 1999 had significant effects, whereas pooled data was found to be significant (Appendix-II). Maximum plant height (59.10 and 63.11 cm) was obtained with M_1 in the year 1998 and with M_3 during 1999, respectively. Pooled data revealed that maximum plant height (60.99 cm) was obtained with M_3 , which was at par with M_1 . Minimum plant height (53.41 cm) was recorded in the unmulched treatment (M_4). Taller plants were produced during both the years when planting was done on ridges. Highest fertility level (370:90:125 NPK kg ha⁻¹) gave the maximum plant height (58.78 cm), when data was pooled. In general, plant height increased with the increase in fertility level. Similar trend was observed during both the years. Significantly taller plants were produced during the year 1999 than 1998.

First order interactions MxP, MxL and PxL were significant in pooled analysis (Table 4,5,6). During both the years of investigations it was observed that MxL had significant effects on plant height whereas MxP and PxL interactions were found to be significant during 1998 only. Pooled data in Table 4 reveals that M_3 produced significantly taller plants than M_2 or M_1 when planting was done on ridges (P_1). Similar trend was observed in both the years. However, MxP effects were non-significant in the second year. In MxL interactions, maximum plant height (65.29 cm) was obtained with M_3 , L_1 combinations, where as minimum plant height (52.12 cm) was registered with L_3 level

Table 4. Interaction effects of mulches and planting methods (MxP) on plant height (cm) of bell pepper hybrid cv. Bharath

Mulches	Planting methods		SE(d) _±		CD at 5%	
	P ₁	P ₂	A	B	A	B
1998						
M ₁	58.51	59.69				
M ₂	55.94	53.37	1.67	1.54	3.85	3.64
M ₃	62.37	55.39				
M ₄	51.10	51.65				
1999						
M ₁	56.97	61.50				
M ₂	61.84	59.27	2.26	2.46	NS	NS
M ₃	66.04	60.17				
M ₄	56.99	53.90				
Pooled						
M ₁	57.74	60.60				
M ₂	58.89	56.32				
M ₃	64.20	57.78	1.41	1.45	2.98	3.11
M ₄	54.05	52.77				

A=SE(d)_± and CD at 5% for mulches at same planting method

B=SE(d)_± and CD at 5% for planting methods at same or different mulches

Table 5. Interaction effects of mulches and fertility levels (MxL) on plant height (cm) of bell pepper hybrid cv. Bharath

Mulches	Fertility levels				SE(d) \pm		CD at 5%	
	L ₁	L ₂	L ₃	L ₄	A	B	A	B
1998								
M ₁	61.68	58.96	57.33	58.42				
M ₂	52.42	52.09	54.86	59.24	1.50	1.63	3.03	3.55
M ₃	57.36	58.28	62.40	57.48				
M ₄	51.79	50.95	49.27	53.50				
1999								
M ₁	58.79	58.32	58.74	61.08				
M ₂	58.47	59.44	60.67	63.63	1.33	2.19	2.67	5.11
M ₃	63.63	59.32	68.17	61.31				
M ₄	56.28	54.94	54.98	55.59				
Pooled								
M ₁	60.23	58.64	58.04	59.75				
M ₂	55.45	55.77	57.76	61.43	1.00	1.87	1.99	3.94
M ₃	60.49	58.80	65.29	59.39				
M ₄	54.03	52.94	52.12	54.55				

A=SE(d) \pm and CD at 5% for mulches at same fertility level

B=SE(d) \pm and CD at 5% for fertility levels at same or different mulches

Table 6. Interaction effects of planting methods and fertility levels (PxL) on plant height (cm) in bell pepper hybrid cv. Bharath

Planting methods	Fertility levels				SE(d) _±		CD at 5%	
	L ₁	L ₂	L ₃	L ₄	A	B	A	B
1998								
P ₁	55.43	57.67	58.21	56.59				
P ₂	56.19	52.47	53.72	57.73	1.06	1.12	2.14	2.41
1999								
P ₁	60.76	58.52	61.62	60.89				
P ₂	57.82	57.44	59.66	59.91	0.94	1.39	NS	NS
Pooled								
P ₁	58.10	58.12	59.92	58.74				
P ₂	57.00	54.96	56.69	58.82	0.71	1.86	1.41	3.83

A=SE(d)_± and CD at 5% for planting methods at same fertility level

B=SE(d)_± and CD at 5% for fertility levels at same or different planting methods

in unmulched treatment (M_4L_3). Amongst the $P \times L$ interaction tallest plants (59.92 cm) were produced at L_3 level when planting was done on ridges. Similar trend was observed during both the years.

Second order interaction $M \times P \times L$ had significant effect on this attribute (Table 7). Maximum plant height (68.05 cm) was produced with $M_3P_1L_3$ treatment, whereas $M_4P_2L_2$ gave the lowest plant height in the pooled data.

4.3 Number of branches per plant

Observations on mean number of branches per plant have been summarised in Table 3 and their corresponding analysis of variance have been appended in Appendix-II.

The data indicated that main effects of mulches, planting methods and fertility levels were found to be non-significant with respect to this attribute during both the years of investigations and in the pooled analysis. However, maximum number of branches with respect to mulches, planting method and fertility levels were observed with M_3 (4.05), P_1 (3.83) and L_3 (3.89) respectively in the pooled analysis. There were significant differences between the years and significantly more number of branches were produced in the second year studies.

Among the first order interactions only $M \times L$ interaction were found to be significant during both the years of studies (Table 8). The application of pine needle mulch (M_3) produced maximum number of branches when NPK was applied @ 310:75:100 kg ha⁻¹ during the year 1998 and in the pooled data. However, maximum number of branches (4.46) were observed at M_1L_3 treatment during the year 1999.

Among the second order interactions the treatment $M_3P_2L_3$ produced maximum number of branches i.e. 4.58 and 4.54, whereas $M_4P_2L_3$ recorded the minimum, i.e.

Table 7. Interaction effects of mulches, planting methods and fertility levels (MxPxL) on plant height (cm) of bell pepper hybrid cv: Bharath

Treatment	P ₁				P ₂				SE(d) _±			CD at 5%		
	L ₁	L ₂	L ₃	L ₄	L ₁	L ₂	L ₃	L ₄	A	B	C	A	B	C
1998														
M ₁	59.88	58.43	58.25	57.47	63.47	59.50	56.42	59.38						
M ₂	52.20	56.80	57.75	56.99	52.63	47.38	51.97	61.49						
M ₃	61.67	62.82	64.97	60.02	53.05	53.75	59.83	54.93	2.13	2.48	2.40	4.28	5.33	5.17
M ₄	47.98	52.65	51.88	51.88	55.59	49.24	46.65	55.12						
1999														
M ₁	57.10	55.85	54.44	60.49	60.47	60.80	63.05	61.67						
M ₂	60.25	59.92	63.05	64.13	56.70	58.97	58.29	63.13						
M ₃	70.29	61.17	71.13	61.58	56.97	57.47	65.22	61.04	1.88	2.78	2.95	3.77	6.13	6.71
M ₄	55.40	57.33	57.87	57.37	57.15	52.54	52.08	53.82						
Pooled														
M ₁	58.49	57.14	56.34	58.98	61.97	60.15	59.73	60.53						
M ₂	56.22	58.36	60.40	60.56	54.67	53.17	55.13	62.31						
M ₃	65.98	61.99	68.05	60.80	55.01	55.61	62.52	57.99	1.42	1.19	1.90	2.81	2.45	3.96
M ₄	51.69	54.99	54.88	54.62	56.37	50.89	49.37	54.47						

A=SE(d)_± and CD at 5% for two mulches at same combination of planting methods and fertility levels

B=SE(d)_± and CD at 5% for two planting methods at same combination of mulches and fertility levels

C=SE(d)_± and CD at 5% for two fertility levels at same combination of mulches and planting methods

Table 8. Interaction effects of mulches and fertility levels (MxL) on number of branches in bell pepper hybrid cv. Bharath

Mulches	Fertility levels				SE(d) \pm		CD at 5%	
	L ₁	L ₂	L ₃	L ₄	A	B	A	B
1998								
M ₁	3.63	3.56	3.88	3.75				
M ₂	3.51	3.57	3.38	3.25	0.16	0.21	0.33	0.49
M ₃	3.88	3.54	4.25	4.08				
M ₄	3.46	3.63	3.33	3.88				
1999								
M ₁	4.21	3.83	4.46	3.88				
M ₂	4.04	3.83	3.79	3.83	0.19	0.28	0.38	0.64
M ₃	4.33	3.79	4.38	4.12				
M ₄	3.71	4.00	3.67	3.95				
Pooled								
M ₁	3.92	3.69	4.17	3.81				
M ₂	3.78	3.70	3.58	3.54	0.13	0.19	0.25	0.41
M ₃	4.10	3.67	4.31	4.10				
M ₄	3.58	3.81	3.50	3.92				

A=SE(d) \pm and CD at 5% for mulches at same fertility level

B=SE(d) \pm and CD at 5% for fertility levels at same or different mulches

3.00 and 3.25 during 1998 and in the pooled data, respectively. However, this interaction was found to be non-significant during 1999 (Table 9).

4.4 Fruit length (cm)

Data recorded on fruit length showed non-significant differences for all the treatments during both the years of investigations and hence in the pooled data (Table 10, Appendix-II). However, maximum fruit length (8.29 cm) was obtained with M_1 (Black polyethylene mulch), closely followed by M_3 and M_2 , where, respective fruit length recorded were 8.28 and 8.26 cm in the pooled data. The year effects were found to be significant with respect to fruit length as more fruit length (8.41 cm) was obtained during the first year of studies.

All the first and second order interactions were found to be non-significant (Appendix-II).

4.5 Fruit breadth (cm)

It was observed from Table 10 and Appendix-II, that the fruit width of bell pepper hybrid Bharath did not affected significantly with respect to planting method and fertilization treatment during either of the year. However, application of mulches exhibited significant effect in the first year and in the pooled data on this attribute. Maximum fruit breadth (6.24 cm) was recorded with M_3 treatment being statistically at par with M_1 and M_2 and superior to M_4 . Similar trend was observed during 1998.

There were significant differences between the years and more fruit breadth was recorded during the second year.

All the interactions failed to exhibit any effect on this attribute.

Table 9. Interaction effects of mulches, planting methods and fertility levels (MxPxL) on number of branches per plant in bell pepper hybrid cv. Bharath

Treatment	P ₁				P ₂				SE(d) _±			CD at 5%		
	L ₁	L ₂	L ₃	L ₄	L ₁	L ₂	L ₃	L ₄	A	B	C	A	B	C
1998														
M ₁	4.00	3.37	4.00	4.00	3.25	3.75	3.75	3.50						
M ₂	3.50	3.63	3.50	3.25	3.52	3.50	3.25	3.50						
M ₃	3.92	3.42	3.92	4.00	3.83	3.67	4.58	4.17	0.23	0.25	0.32	0.47	0.53	0.72
M ₄	3.50	3.50	3.67	3.75	3.42	3.75	3.00	4.00						
1999														
M ₁	4.42	3.67	4.67	3.75	4.00	4.00	4.25	4.00						
M ₂	4.00	3.92	3.92	3.92	4.08	3.75	3.67	3.75	0.27	0.28	0.34	NS	NS	NS
M ₃	4.50	3.67	4.25	3.92	4.17	3.92	4.50	4.33						
M ₄	3.75	3.92	3.83	3.83	3.67	4.08	3.50	4.08						
Pooled														
M ₁	4.21	3.52	4.33	3.88	3.63	3.88	4.00	3.75						
M ₂	3.75	3.78	3.71	3.46	3.80	3.63	3.46	3.63						
M ₃	4.21	3.54	4.08	3.96	4.00	3.79	4.54	4.25	0.18	0.19	0.23	0.36	0.38	0.48
M ₄	3.63	3.71	3.75	3.79	3.54	3.92	3.25	4.04						

A=SE(d)_± and CD at 5% for two mulches at same combination of planting methods and fertility levels

B=SE(d)_± and CD at 5% for two planting methods at same combination of mulches and fertility levels

C=SE(d)_± and CD at 5% for two fertility levels at same combination of mulches and planting methods

Table 10. Effect of mulches, planting methods and fertility levels on fruit length, breadth and weight of bell pepper hybrid cv. Bharath

Treatments	Fruit length (cm)			Fruit breadth (cm)			Fruit weight (g)		
	1998	1999	Pooled	1998	1999	Pooled	1998	1999	Pooled
Mulches									
Black polyethylene mulch (M ₁)	8.75	7.84	8.29	6.05	6.26	6.15	57.37	59.19	58.28
Transparent polyethylene mulch (M ₂)	8.59	7.93	8.26	5.96	6.18	6.07	59.76	61.99	60.88
Pine needle mulch (M ₃)	8.38	8.19	8.28	6.07	6.42	6.24	62.04	65.11	63.58
No mulch (M ₄)	7.93	8.01	7.97	5.23	6.17	5.70	52.73	56.16	54.45
SE(d)±	0.35	0.27	0.22	0.22	0.17	0.14	1.42	2.31	1.36
CD at 5%	NS	NS	NS	0.54	NS	0.31	3.48	5.66	2.96
Planting methods									
Ridge method (P ₁)	8.37	8.10	8.24	5.92	6.28	6.10	59.24	61.53	60.39
Flat bed method (P ₂)	8.46	7.88	8.17	5.73	6.23	5.98	56.71	59.70	58.20
SE(d)±	0.26	0.14	0.17	0.19	0.14	0.12	0.85	0.76	0.57
CD at 5%	NS	NS	NS	NS	NS	NS	1.96	1.75	1.21
Fertility levels (NPK kg ha⁻¹)									
190:45:50 (L ₁)	8.40	7.99	8.20	5.86	6.27	6.06	56.84	59.71	58.28
250:60:75 (L ₂)	8.48	7.89	8.18	5.96	6.14	6.05	58.04	60.23	59.13
310:75:100 (L ₃)	8.41	8.00	8.21	5.90	6.30	6.10	59.07	61.59	60.33
370:90:125 (L ₄)	8.35	8.09	8.22	5.59	6.33	5.96	57.94	60.93	59.44
SE(d)±	0.31	0.24	0.19	0.15	0.16	0.11	1.08	1.23	0.82
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Year Effects									
Year Effects	8.41	7.99		5.83	6.26		57.97	60.61	
SE(d)±	0.16			0.10			0.96		
CD at 5%	0.34			0.22			2.09		

4.6 Fruit weight (g)

The data pertaining to the fruit weight as influenced by various treatments have been presented in Table 10 (Appendix-II).

An inquisition of the data revealed that there was a pronounced effect on fruit weight with respect to the mulches and planting methods during both the cropping seasons and in the pooled data while fertilizer failed to produce significant effect on this attribute in either of the year. Maximum fruit weight (63.58 g) was obtained with M_3 in the pooled data, whereas minimum fruit weight (54.45 g) was obtained with M_4 (No mulch) treatment. Similar results were observed during both the years. All the mulches produced significantly heavier fruits than the unmulched control. M_3 treatment was at par with M_2 but superior to M_1 . However, M_1 and M_2 were statistically at par with each other. Ridge method (P_1) significantly enhanced fruit weight as compared to flat bed method of planting during both the years and in the pooled data. Maximum fruit weight (61.53 g) was obtained during 1999 with P_1 and minimum weight (56.71 g) with P_2 treatment during first year of studies. Fruit weight increased non-significantly from L_1 to L_3 and then declined at L_4 . Significantly higher fruit weight was observed during second year of experimentation.

All the first order interactions except $P \times L$ and second order interactions were found to be non-significant with respect to fruit weight of bell pepper hybrid Bharath (Appendix-II). $P \times L$ interactions exhibited significant effects in the year 1999 and in the pooled data (Table 11). However, this interaction had non-significant effects during 1998. Maximum fruit weight (63.01 g) was observed at P_1L_3 (Ridge method + 310:75:100 kg NPK ha⁻¹) and lowest weight (58.04 g) at P_2L_1 (Flat bed + 190:45:50 kg NPK ha⁻¹).

Table 11. Interaction effects of planting methods and fertility levels (PxL) on fruit weight (g) of bell pepper hybrid cv. Bharath

Planting methods	Fertility levels				SE(d) \pm		CD at 5%	
	L ₁	L ₂	L ₃	L ₄	A	B	A	B
1998								
P ₁	58.85	59.28	60.61	58.22	1.53	1.57	NS	NS
P ₂	54.84	56.80	57.54	57.66				
1999								
P ₁	61.38	62.22	63.01	59.51	1.74	1.69	3.50	3.49
P ₂	58.04	58.24	60.16	62.35				
Pooled								
P ₁	60.11	60.75	61.81	58.87	1.15	1.16	2.30	2.33
P ₂	56.44	57.52	58.85	60.01				

A=SE(d) \pm and CD at 5% for planting methods at same fertility level

B=SE(d) \pm and CD at 5%. for fertility levels at same or different planting methods



Plate 1: Bell pepper plants growing on ridges



Plate 2: Bell pepper plants growing in pine needle mulch

Number of fruits per plant

The data for the number of fruits per plant as influenced by mulches, planting method and fertilization are presented in Table 12 and the corresponding analysis of variance in Appendix-II. The analysis of variance revealed that treatment differences were highly significant.

Application of pine needle mulch (M_3) significantly produced more number of fruits during both the years and in pooled data. The highest number of fruits (10.89) were produced with the M_3 treatment closely followed by M_2 and lowest number (8.29) in M_4 treatment. The number of fruits were found to be significantly more (10.14) with the P_1 treatment than the P_2 treatment. The increase in fertility levels linearly increased the number of fruits during the year 1998 and in the pooled data. However fruit numbers increased up to L_3 level in the year 1999. There were significant differences between the years and the higher number of fruits (9.72) were obtained during the first year of studies.

It is clear from the Tables 13 and 14 that first order interactions $M \times L$ and $P \times L$ exhibited significant effects during the year 1998 and in the pooled data. The highest number of fruits (11.97) were recorded at the highest level of fertilization when pine needle mulch (M_3) was applied. However, this value was at par with M_3L_3 and M_2L_3 treatments during the year 1998, whereas maximum number of fruits (11.56) in the pooled data were obtained with M_3L_4 and M_2L_3 treatment. Minimum number of fruits i.e. 7.94 and 7.66 were recorded at the lowest level of fertilizers (190:45:50 kg NPK ha⁻¹), when no mulch was applied during the year 1998 and in the pooled data, respectively. Maximum number of fruits per plant (10.81 and 10.74) were obtained at P_1L_4 during the year 1998 and in the pooled data. During the year 1999 both these interactions exhibited non-significant effects. The interaction $M \times P$ was found to be non-significant during both the years of investigations.

TABLE 12. EFFECT OF MULCHES, PLANTING METHODS AND FERTILITY LEVELS ON FRUIT NUMBER PER PLANT, YIELD PER PLANT AND PER HECTARE IN BELL PEPPER HYBRID cv. Bharath

Treatments	No. of fruits per plant			Fruit yield per plant(g)			Fruit yield per ha (q)		
	1998	1999	Pooled	1998	1999	Pooled	1998	1999	Pooled
Mulches									
Black polyethylene mulch (M ₁)	8.57	8.62	8.59	492.10	509.30	500.70	182.30	188.60	185.40
Transparent polyethylene mulch (M ₂)	10.59	10.46	10.52	633.20	648.80	641.00	234.50	240.30	237.40
Pine needle mulch (M ₃)	11.25	10.53	10.89	696.50	684.90	690.70	258.00	253.70	255.80
No mulch (M ₄)	8.49	8.09	8.29	448.40	453.00	450.70	166.10	167.80	166.90
SE(d)±	0.23	0.24	0.17	17.27	15.97	11.76	6.39	5.91	4.36
CD at 5%	0.55	0.59	0.36	42.25	39.07	25.62	15.65	14.47	9.49
Planting methods									
Ridge method (P ₁)	10.14	9.96	10.05	603.10	615.20	609.10	223.40	227.90	225.60
Flat bed method (P ₂)	9.31	8.89	9.09	532.00	532.80	532.40	197.10	197.30	197.20
SE(d)±	0.11	0.27	0.14	11.48	14.87	9.39	4.25	5.51	3.48
CD at 5%	0.26	0.61	0.31	26.48	34.29	19.91	9.81	12.70	7.38
Fertility levels (NPK kg ha⁻¹)									
190:45:50(L ₁)	8.99	8.54	8.77	514.20	512.50	513.30	190.40	189.80	190.10
250:60:75(L ₂)	9.48	9.40	9.44	554.80	568.50	561.70	205.50	210.60	208.00
310:75:100(L ₃)	10.11	9.95	10.03	602.00	616.30	609.10	223.00	228.30	225.60
370:90:125(L ₄)	10.31	9.82	10.06	599.20	598.80	599.00	221.90	221.80	221.80
SE(d)±	0.18	0.23	0.14	12.99	12.75	9.10	4.81	4.72	3.37
CD at 5%	0.36	0.46	0.29	26.11	25.64	18.07	9.67	9.50	6.69
Year Effects									
Year Effects	9.72	9.42		567.50	574.00		210.20	212.60	
SE(d)±		0.12			8.31			3.08	
CD at 5%		0.26			NS			NS	

Table 13. Interaction effects of mulches and fertility levels (MxL) on number of fruits per plant in bell pepper hybrid cv. Bharath

Mulches	Fertility levels				SE(d) \pm		CD at 5%	
	L ₁	L ₂	L ₃	L ₄	A	B	A	B
1998								
M ₁	8.21	8.63	8.67	8.77				
M ₂	9.05	10.32	11.75	11.23	0.35	0.38	0.71	0.82
M ₃	10.79	10.67	11.57	11.97				
M ₄	7.94	8.30	8.44	9.25				
1999								
M ₁	8.27	8.83	8.48	8.90				
M ₂	9.11	10.35	11.37	10.99	0.46	0.33	NS	NS
M ₃	9.38	10.15	11.46	11.14				
M ₄	7.39	8.24	8.47	8.27				
Pooled								
M ₁	8.24	8.73	8.58	8.84				
M ₂	9.08	10.34	11.56	11.11	0.28	0.30	0.57	0.61
M ₃	10.08	10.41	11.51	11.56				
M ₄	7.66	8.27	8.46	8.76				

A=SE(d) \pm and CD at 5% for mulches at same fertility level

B=SE(d) \pm and CD at 5% for fertility level at same or different mulches

Table 14. Interaction effects of planting methods and fertility levels (PxL) on number of fruits per plant in bell pepper hybrid cv. Bharath

Planting methods	Fertility levels				SE(d) \pm		CD at 5%	
	L ₁	L ₂	L ₃	L ₄	A	B	A	B
1998								
P ₁	9.08	10.15	10.52	10.81				
P ₂	8.92	8.81	9.69	9.81	0.25	0.24	0.50	0.51
1999								
P ₁	8.89	9.86	10.43	10.67				
P ₂	8.18	8.92	9.46	8.98	0.32	0.37	NS	NS
Pooled								
P ₁	8.98	10.01	10.48	10.74	0.20	0.23	0.41	0.46
P ₂	8.55	8.87	9.58	9.39				

A=SE(d) \pm and CD at 5% for planting methods at same fertility level

B=SE(d) \pm and CD at 5%. for fertility levels at same or different planting methods

The second order interaction MxPxL had significant effect on this character during 1998 and in the pooled data, whereas in the second year of experimentation the interaction was found to be non-significant (Table 15). During 1998, maximum number of fruit (12.82) were obtained with the treatment $M_3P_1L_4$, which is at par with $M_2P_1L_3$ treatment (12.03). In pooled data similar trend was observed. However, minimum fruit numbers i.e. 7.24 and 7.32 were recorded with $M_4P_2L_3$ treatment in the year 1998 and in the pooled data respectively.

4.8 Fruit yield per plant (g)

Data pertaining to the main effects and interactions effects of various treatments under study with respect to fruit yield per plant have been tabulated in Tables 12, 16 and 17 (Appendix-II).

A perusal of the data revealed that all the treatments significantly affected the fruit yield (g/plant). M_3 produced highest fruit yield (690.70 g/plant), which was superior to M_1 and M_2 in the pooled data. Similar results were obtained during both the years. P_1 gave significantly higher yield than P_2 during both cropping years and in pooled data. With the increase in fertility level from L_1 to L_3 there was a corresponding increase in fruit yield per plant in bell pepper. The yield declined at L_4 level but it was statistically at par with L_3 during both years and in pooled data.

Among the first order interactions only MxL interaction exhibited significant effect in the year 1998 and in pooled data. Maximum fruit yield per plant (730.20 and 738.90 g) was obtained in the year 1998 and in pooled data.

Amongst the MxPxL interaction, the significant increase in yields were there during the year 1999 and in pooled data. Maximum fruit yield (790.90 g/plant) was obtained with the $M_3P_1L_3$ treatment combination being at par with $M_2P_1L_3$. Whereas,

Table 15. Interaction effects of mulches, planting methods and fertility levels (M₁X₁X₁L) on number of fruits per plant in bell pepper hybrid cv. Dnyanesh

Treatment	P ₁				P ₂				SE(d) _±			CD at 5%		
	L ₁	L ₂	L ₃	L ₄	L ₁	L ₂	L ₃	L ₄	A	B	C	A	B	C
1998														
M ₁	8.99	9.59	9.03	9.08	7.43	7.67	8.32	8.46						
M ₂	8.58	10.86	12.03	11.89	9.52	9.77	11.47	10.57						
M ₃	10.61	10.77	11.79	12.82	10.96	10.57	11.34	11.13	0.50	0.48	0.51	1.00	0.99	1.08
M ₄	8.11	9.37	9.23	9.44	7.76	7.24	7.67	9.06						
1999														
M ₁	9.11	9.17	8.88	9.58	7.43	8.49	8.08	8.22						
M ₂	8.67	10.43	11.60	11.47	9.55	10.28	11.15	10.50						
M ₃	10.11	10.79	11.77	12.60	8.64	9.52	11.15	9.67	0.65	0.77	0.72	NS	NS	NS
M ₄	7.67	9.05	9.48	9.02	7.11	7.42	7.46	7.52						
Pooled														
M ₁	9.06	9.38	8.95	9.33	7.42	8.08	8.20	8.34						
M ₂	8.62	10.65	11.81	11.68	9.54	10.02	11.31	10.53						
M ₃	10.36	10.78	11.78	12.71	9.80	10.04	11.24	10.40	0.40	0.46	0.44	0.81	0.93	0.90
M ₄	7.89	9.21	9.36	9.23	7.43	7.32	7.56	8.29						

A=SE(d)_± and CD at 5% for two mulches at same combination of planting methods and fertility levels

B=SE(d)_± and CD at 5% for two planting methods at same combination of mulches and fertility levels

C=SE(d)_± and CD at 5% for two fertility levels at same combination of mulches and planting methods

Table 16. Interaction effects of mulches and fertility levels (MxL) on fruit yield (g/plant) of bell pepper hybrid cv. Bharath

Mulches	Fertility levels				SE(d) \pm		CD at 5%	
	L ₁	L ₂	L ₃	L ₄	A	B	A	B
1998								
M ₁	455.30	480.50	505.40	527.10				
M ₂	532.90	617.20	710.30	672.30	25.97	28.35	52.24	61.60
M ₃	660.50	680.00	730.20	715.50				
M ₄	408.10	441.60	462.00	482.00				
1999								
M ₁	478.20	507.00	519.10	532.80				
M ₂	550.60	640.40	718.90	685.20	25.51	27.26	NS	NS
M ₃	617.70	667.10	747.60	707.30				
M ₄	403.40	459.40	479.60	469.70				
Pooled								
M ₁	466.70	493.70	512.30	530.00				
M ₂	541.80	628.80	714.60	678.70	18.20	19.66	36.13	40.39
M ₃	639.10	673.50	738.90	711.40				
M ₄	405.70	450.50	470.80	475.90				

A=SE(d) \pm and CD at 5% for mulches at same fertility level

B=SE(d) \pm and CD at 5% for fertility levels at same or different mulches

Table 17. Interaction effects of mulches, planting methods and fertility levels (MxPxL) on fruit yield (g/plant) of bell pepper hybrid cv. Bharath

Treatment	P ₁				P ₂				SE(d) _±			CD at 5%		
	L ₁	L ₂	L ₃	L ₄	L ₁	L ₂	L ₃	L ₄	A	B	C	A	B	C
1998														
M ₁	493.50	534.60	526.90	546.80	417.10	426.30	483.90	507.30						
M ₂	513.60	653.80	731.60	720.40	552.30	580.60	689.00	624.10	37.72	39.22	39.66	NS	NS	NS
M ₃	697.00	713.30	777.30	757.40	624.00	646.60	683.00	673.60						
M ₄	443.90	513.80	526.90	497.90	372.20	369.40	397.00	466.00						
1999														
M ₁	530.90	548.10	545.80	552.80	425.40	466.00	492.40	512.90						
M ₂	523.10	663.20	740.50	730.20	578.20	617.70	697.30	640.10						
M ₃	709.00	719.50	804.50	789.30	526.40	614.70	690.70	625.30	36.08	43.13	40.91	72.55	92.78	88.17
M ₄	431.60	527.60	549.60	478.00	375.20	391.20	409.60	461.50						
Pooled														
M ₁	512.20	541.30	536.40	549.80	421.30	446.10	488.20	510.10						
M ₂	518.30	658.50	736.10	725.30	565.20	599.10	693.20	632.10	25.74	29.15	28.49	51.09	59.49	58.33
M ₃	703.00	716.40	790.90	773.30	575.20	630.60	686.90	649.50						
M ₄	437.80	520.70	538.30	487.90	373.70	380.30	403.30	463.80						

A=SE(d)_± and CD at 5% for two mulches at same combination of planting methods and fertility levels

B=SE(d)_± and CD at 5% for two planting methods at same combination of mulches and fertility levels

C=SE(d)_± and CD at 5% for two fertility levels at same combination of mulches and planting methods

the minimum fruit yield per plant (373.70 g) was obtained at $M_4P_2L_1$ (No mulch + Flat bed + Lowest fertility level) in the pooled data. Similar results were obtained during the year 1999.

4.9 Fruit yield per hectare (q)

An inquisition of the data (Table 12; Appendix-II) revealed that the main effects of all the treatments were found to be significant with respect to fruit yield ($q\ ha^{-1}$).

Pooled data showed that yield was increased significantly with the use of different mulch materials and the pine needle mulch (M_3) tended to produce highest fruit yield ($255.80\ q\ ha^{-1}$), which was statistically significant over M_2 ($237.40\ q\ ha^{-1}$) and M_1 ($185.40\ q\ ha^{-1}$). The percentage increase in yield of M_3 over M_1 and M_2 was 37.97 and 7.75 per cent, respectively in the pooled data. However, the percentage increase in yield over M_4 (No mulch) was 53.26 per cent. Similar trend was observed during both the years. The lowest yield was recorded at control or no mulch ($166.90\ q\ ha^{-1}$) treatment. Planting methods significantly increased the fruit yield when planting was done on ridges during both the years and in the pooled data. P_1 treatment produced more fruit yield ($225.60\ q\ ha^{-1}$) than the P_2 ($197.20\ q\ ha^{-1}$) which was 29.61 per cent more than P_2 in the pooled data. Fertility levels also influenced the fruit yield significantly during both the years and in pooled data. It was observed that fruit yield increased from L_1 to L_3 and then declined at L_4 treatment during both the years and in pooled data. The highest fruit yield ($225.60\ q\ ha^{-1}$) was obtained when NPK was applied @ 310:75:100 $kg\ ha^{-1}$ in the pooled data. Same results were obtained during both the years of investigations. However, minimum fruit yield ($190.10\ q\ ha^{-1}$) was produced at lowest fertility level (L_1). There were non-significant differences between the years, however, more fruit yield was obtained during 1999.

Amongst the first order interactions only MxL interaction was found to be significant during the year 1998 and in the pooled data (Table 18). Maximum fruit yield i.e. 270.40 q ha⁻¹ and 273.70 q ha⁻¹ were obtained when pine needle mulch (M₃) was applied in combination with NPK @ 310:75:100 kg ha⁻¹ during the year 1998 and in the pooled data.

Among MxPxL interactions, there was significant increase in yield during the second year and in the pooled data (Table 19). Highest fruit yield (297.90 and 292.90 q ha⁻¹) was obtained at M₃P₁L₃ combination during the year 1999 and in pooled data, respectively. However, minimum fruit yield was obtained with M₄P₂L₁ treatment in the second year as well as in the pooled analysis.

4.10 Harvest duration (days)

The data pertaining to harvest duration as affected by the main effects of mulches, planting method and fertilization are summarised in Table 16.

The perusal of the data indicated that significant effects have been produced by use of mulches and fertilization only, during both the years and in pooled data (Appendix-II). The use of mulches prolonged the harvest duration of bell pepper crop. Maximum harvest duration (53.35 days) was recorded with the use of pine needle mulch (M₃) in the pooled data, being statistically significant over M₁ and M₂. Similar results were obtained during 1998. However, M₁, M₂ and M₄ were statistically at par with each other but inferior to M₃. Fertilization affected the harvest duration significantly and more harvest days were registered at the highest level of fertilization during both the years and in pooled data.

All the first and second order interaction failed to exhibit any significant effect on harvest duration during both the years and in the pooled data.

Table 18. Interaction effects of mulches and fertility levels (MxL) on fruit yield (q ha⁻¹) of bell pepper hybrid cv. Bharath

Mulches	Fertility levels				SE(d)±		CD at 5%	
	L ₁	L ₂	L ₃	L ₄	A	B	A	B
1998								
M ₁	168.60	177.90	187.20	195.20				
M ₂	197.40	228.60	263.10	249.00	9.61	10.50	19.34	22.81
M ₃	244.60	251.80	270.40	265.00				
M ₄	151.10	163.60	171.10	178.50				
1999								
M ₁	177.10	187.80	192.90	197.30				
M ₂	203.90	237.20	266.30	253.80	9.45	10.09	NS	NS
M ₃	228.80	247.10	276.90	262.00				
M ₄	149.40	170.20	177.60	174.00				
Pooled								
M ₁	172.90	182.90	189.70	196.30				
M ₂	200.70	232.90	264.70	251.40	6.74	7.28	13.38	14.96
M ₃	236.70	249.50	273.70	263.50				
M ₄	150.30	166.90	174.40	176.20				

A=SE(d)± and CD at 5% for mulches at same fertility level

B=SE(d)± and CD at 5% for fertility levels at same or different mulches

Table 19. Interaction effects of mulches, planting methods and fertility levels (MxPxL) on fruit yield (q ha-1) of bell pepper hybrid cv. Bharath

Treatment	P ₁				P ₂				SE(d) _±			CD at 5%		
	L ₁	L ₂	L ₃	L ₄	L ₁	L ₂	L ₃	L ₄	A	B	C	A	B	C
1998														
M ₁	182.80	198.00	195.20	202.50	154.50	157.90	179.20	187.90						
M ₂	190.20	242.20	271.00	266.80	204.50	215.00	255.20	231.20						
M ₃	258.10	264.20	287.90	280.50	231.10	239.05	253.00	249.50	13.60	14.53	14.69	NS	NS	NS
M ₄	164.40	190.30	195.10	184.40	137.90	136.80	147.00	172.60						
1999														
M ₁	196.60	203.00	202.20	204.70	157.60	172.60	182.40	190.00						
M ₂	193.70	245.60	274.30	270.50	214.10	228.80	258.30	237.10						
M ₃	262.60	266.50	297.90	292.30	195.00	227.70	255.80	231.60	13.36	15.98	15.15	30.81	34.37	32.65
M ₄	159.90	195.40	203.60	177.00	138.90	144.90	151.70	170.90						
Pooled														
M ₁	189.70	200.50	198.70	203.60	156.00	165.20	180.80	188.90						
M ₂	192.00	243.90	272.60	268.60	209.30	221.90	256.70	234.10						
M ₃	260.40	265.30	292.90	286.40	213.00	233.60	254.40	240.50	9.53	10.80	10.55	18.92	22.04	21.60
M ₄	162.10	192.90	199.40	180.70	138.40	140.90	149.40	171.80						

A=SE(d)_± and CD at 5% for two mulches at same combination of planting methods and fertility levels

B=SE(d)_± and CD at 5% for two planting methods at same combination of mulches and fertility levels

C=SE(d)_± and CD at 5% for two fertility levels at same combination of mulches and planting methods

4.11 Fruit rot incidence (%)

The results pertaining to the incidence of fruit rot, as influenced by main effects of mulches, planting methods and fertility levels, have been summarised in Table 20 and Appendix-II.

A perusal of the data indicated that the use of mulches tended to reduce the fruit rot incidence during both the years of experimentation and in the pooled data. The use of pine needle mulch (M_3) registered the lowest (4.04, 5.23 and 4.63% during 1998, 1999 and in pooled data, respectively) fruit rot incidence. M_3 proved significantly superior to M_1 and M_2 . However, M_1 was significantly at par with M_2 during both the years and in pooled analysis. Planting methods also influenced the fruit rot incidence significantly, during both the years and in pooled data and the lower incidence of fruit rot was recorded on ridge planted crop. It was observed that increasing levels of fertility, increased the fruit rot incidence from L_1 to L_4 level. At L_1 level fruit rot incidence was less and at L_4 it was highest. L_2 and L_3 were at par with each other. The year effects were found to be significant and the significantly lower disease incidence was recorded during the first year of experimentation.

Amongst the first order interaction, only $M \times L$ interaction was found to be significant during both the years and in pooled data (Table 21). Minimum percentage of fruit rot was recorded at M_3L_1 , M_3L_3 and M_3L_3 during the year 1998, 1999 and in pooled data.

4.12 Shoot biomass (kg ha^{-1})

Data on shoot biomass of bell pepper at final picking stage during both the years and pooled data are presented in Table 20 and their corresponding analysis of variance have been appended in Appendix-II.

Table 20. Effect of mulches, planting methods and fertility levels on harvest duration, fruit rot incidence and shoot biomass in bell pepper hybrid cv. Bharath

Treatments	Harvest duration(days)			Fruit rot incidence(%)			Shoot biomass(kg ha ⁻¹)		
	1998	1999	Pooled	1998	1999	Pooled	1998	1999	Pooled
Mulches									
Black polyethylene mulch (M ₁)	45.71	50.33	48.02	5.59 (2.35)	7.36 (2.71)	6.48 (2.53)	725.50	825.70	775.60
Transparent polyethylene mulch (M ₂)	46.12	50.50	48.31	5.62 (2.37)	7.32 (2.70)	6.47 (2.54)	886.30	1064.00	975.40
Pine needle mulch (M ₃)	51.37	55.33	53.35	4.04 (1.99)	5.23 (2.28)	4.63 (2.14)	1036.00	1179.00	1108.00
No mulch (M ₄)	45.54	50.54	48.04	7.53 (2.74)	10.07 (3.17)	8.80 (2.95)	653.00	777.20	715.10
SE(d) [±]	1.37	1.46	1.00	0.06	0.05	0.04	32.89	61.36	34.81
CD at 5%	3.36	3.57	2.18	0.13	0.11	0.07	80.49	150.15	75.85
Planting methods									
Ridge method (P ₁)	46.92	51.15	49.03	5.58 (2.34)	7.25 (2.67)	6.42 (2.51)	832.50	958.10	895.30
Flat bed method (P ₂)	47.46	52.21	49.83	5.81 (2.39)	7.73 (2.76)	6.77 (2.57)	818.10	965.20	891.70
SE(d) [±]	1.11	1.11	0.79	0.02	0.03	0.02	14.76	11.68	9.41
CD at 5%	NS	NS	NS	0.05	0.07	0.04	NS	NS	NS
Fertility levels(NPK kg ha⁻¹)									
190:45:50(L ₁)	44.67	49.21	46.94	5.03 (2.22)	6.88 (2.61)	5.96 (2.41)	783.20	903.40	843.30
250:60:75(L ₂)	46.21	50.54	48.37	5.67 (2.36)	7.33 (2.69)	6.50 (2.53)	803.10	946.00	874.60
310:75:100(L ₃)	48.50	52.83	50.67	5.75 (2.38)	7.44 (2.69)	6.59 (2.53)	846.90	1001.00	924.10
370:90:125(L ₄)	49.38	54.12	51.75	6.34 (2.51)	8.33 (2.87)	7.33 (2.69)	868.00	995.90	932.00
SE(d) [±]	1.40	1.27	0.95	0.04	0.03	0.02	31.84	26.59	20.74
CD at 5%	2.82	2.56	1.87	0.09	0.07	0.05	64.02	53.47	41.18
Year Effects	47.19	51.68		5.70 (2.36)	7.50 (2.71)		825.30	961.60	
SE(d) [±]		0.71			0.02			24.62	
CD at 5%		1.54			0.05			53.63	

*Figures within parentheses indicate transformed values

Table 21. Interaction effects of mulches and fertility levels (MxL) on fruit rot incidence (%) in bell pepper hybrid cv. Bharath

Mulches	Fertility levels				SE(d) \pm		CD at 5%	
	L ₁	L ₂	L ₃	L ₄	A	B	A	B
1998								
M ₁	4.25 (2.05)	5.75 (2.39)	5.97 (2.44)	6.42 (2.53)				
M ₂	5.38 (2.32)	5.57 (2.35)	5.65 (2.37)	5.90 (2.43)	0.09	0.09	0.18	0.20
M ₃	3.47 (1.85)	3.81 (1.95)	3.73 (1.92)	5.16 (2.26)				
M ₄	7.05 (2.65)	7.57 (2.75)	7.65 (2.76)	7.86 (2.80)				
1999								
M ₁	6.56 (2.56)	7.12 (2.67)	7.61 (2.76)	8.16 (2.86)				
M ₂	6.72 (2.59)	7.11 (2.66)	7.48 (2.73)	7.99 (2.82)	0.06	0.07	0.13	0.16
M ₃	5.20 (2.28)	5.34 (2.31)	4.23 (2.05)	6.13 (2.48)				
M ₄	9.04 (3.00)	9.76 (3.12)	10.42 (3.23)	11.05 (3.32)				
Pooled								
M ₁	5.40 (2.31)	6.44 (2.53)	6.79 (2.60)	7.29 (2.69)				
M ₂	6.05 (2.45)	6.34 (2.51)	6.57 (2.55)	6.94 (2.67)	0.05	0.06	0.11	0.12
M ₃	4.34 (2.07)	4.58 (2.13)	3.98 (1.99)	5.64 (2.37)				
M ₄	8.04 (2.83)	8.66 (2.94)	9.04 (3.00)	9.46 (3.06)				

A=SE(d) \pm and CD at 5% for mulches at same fertility level

B=SE(d) \pm and CD at 5% for fertility level at same or different mulches

*Figures within parentheses indicate transformed values

The use of mulches significantly increased the shoot biomass during both the years of experimentation and in the pooled data. During the course of investigation, it was observed that highest shoot biomass was recorded at M_3 and the lowest at M_4 (unmulched control). Planting methods failed to effect the shoot biomass during both the years and in pooled data. However, fertility levels significantly influenced the shoot biomass, and the maximum values were obtained at L_4 , L_3 and L_4 during 1998, 1999 and in pooled data, respectively. Differences between the years were found to be significant and more shoot biomass was produced during the second year of investigations.

Among the first order interaction, only MxP interaction exhibited significant influenced during the year 1998 and in pooled data (Table 22). M_3L_3 registered maximum shoot biomass in the pooled data and similar trend was observed in 1998.

4.13 Nitrogen content in bell pepper plant (%)

The results on N content in bell pepper leaves as affected by various treatments have been detailed in Table 23 and then pertinent analysis of variance have been presented in Appendix-II.

The use of different mulches significantly influenced the leaf N concentration in bell pepper plants and it was found that maximum leaf N content was recorded at M_3 during both the years of experimentation and in pooled data. There were significant differences between M_1 and M_2 , M_3 and M_2 , respectively in the pooled data. Similar trend was observed during both the years also. M_4 (No mulch) treatment registered lowest values, being statistically lower than all the mulches used. Planting method affected leaf N content during 1998 and in pooled data and higher respective values were obtained at P_1 . The concentration of leaf N increased with increase in fertility levels during both the years and in the pooled data. The highest N concentration (4.01%)

Table 22. Interaction effects of mulches and planting methods (MxP) on shoot biomass (kg ha⁻¹) of bell pepper hybrid cv. Bharath

Mulches	Planting methods		SE(d) _±		CD at 5%	
	P ₁	P ₂	A	B	A	B
1998						
M ₁	729.90	721.10				
M ₂	853.60	919.00	29.51	38.96	68.06	93.75
M ₃	1055.00	1018.00				
M ₄	692.00	614.10				
1999						
M ₁	828.50	822.80				
M ₂	1029.00	1100.00	23.36	63.54	NS	NS
M ₃	1199.00	1159.00				
M ₄	775.40	779.00				
Pooled						
M ₁	779.20	771.90				
M ₂	941.50	1009.00	18.82	37.27	39.91	80.91
M ₃	1127.00	1089.00				
M ₄	733.70	696.50				

A=SE(d)_± and CD at 5% for mulches at same planting method

B=SE(d)_± and CD at 5% for planting methods at same or different mulches

Table 23. Effect of mulches, planting methods and fertility levels on nitrogen, phosphorus and potassium content in bell pepper hybrid cv. Bharath

Treatments	Nitrogen content (%)			Phosphorus content (%)			Potassium content (%)		
	1998	1999	Pooled	1998	1999	Pooled	1998	1999	Pooled
Mulches									
Black polyethylene mulch (M ₁)	3.88	3.95	3.92	0.36	0.37	0.37	3.47	3.54	3.51
Transparent polyethylene mulch (M ₂)	3.54	3.91	3.73	0.35	0.36	0.36	3.23	3.27	3.25
Pine needle mulch (M ₃)	3.91	4.04	3.97	0.41	0.43	0.42	3.66	3.72	3.69
No mulch (M ₄)	3.65	3.70	3.68	0.32	0.33	0.33	3.17	3.23	3.20
SE(d)±	0.05	0.09	0.05	0.012	0.011	0.009	0.06	0.07	0.05
CD at 5%	0.13	0.22	0.11	0.030	0.028	0.019	0.15	0.18	0.11
Planting methods									
Ridge method (P ₁)	3.80	3.89	3.85	0.37	0.38	0.37	3.38	3.45	3.41
Flat bed method (P ₂)	3.68	3.91	3.79	0.35	0.37	0.36	3.39	3.44	3.41
SE(d)±	0.02	0.02	0.01	0.007	0.002	0.004	0.01	0.01	0.01
CD at 5%	0.04	NS	0.03	NS	0.004	0.008	NS	NS	NS
Fertility levels (NPK kg ha⁻¹)									
190:45:50 (L ₁)	3.60	3.74	3.67	0.33	0.34	0.34	3.31	3.37	3.34
250:60:75 (L ₂)	3.65	3.79	3.72	0.35	0.36	0.36	3.35	3.42	3.38
310:75:100 (L ₃)	3.81	3.95	3.88	0.37	0.39	0.38	3.42	3.48	3.45
370:90:125 (L ₄)	3.91	4.11	4.01	0.40	0.41	0.40	3.46	3.50	3.48
SE(d)±	0.03	0.03	0.02	0.011	0.003	0.006	0.02	0.01	0.01
CD at 5%	0.06	0.05	0.04	0.023	0.006	0.012	0.04	0.02	0.02
Year Effects									
Year Effects	3.74	3.90		0.36	0.38		3.39	3.44	
SE(d)±		0.04			0.006			0.038	
CD at 5%		0.08			0.013			NS	

was recorded with L_4 in the pooled data, though statistically at par with L_3 but superior to L_1 and L_2 treatment. Similar results were obtained during both the years. There were significant differences between the years and the higher N concentration was recorded during the year 1999.

Interaction effect studies showed that only MxP interaction was found to be significant during the year 1998 and in pooled data (Table 24; Appendix-II). Highest N concentration (3.94%) was recorded at M_3P_2 , being statistically significant over M_2P_2 , M_4P_1 and M_4P_2 but statistically at par with all other interactions. Similar trend was observed in pooled data.

4.14 Phosphorus content in bell pepper plant (%)

The main effects of mulches and fertility levels were found to be significant during both the years of experimentation and in the pooled data, however, the planting methods exhibited significant effects in the second year and in pooled data (Table 23; Appendix-II).

Different mulches affected the leaf P concentration in bell pepper plants and pooled data showed that maximum leaf P content (0.42%) was observed when pine needle mulch (M_3) was used being statistically significant over M_1 and M_2 . Similar results were obtained during both the years. Among the planting methods, P_1 registered the maximum P content during both the years and in pooled data. It was observed that, with the increase in fertility level there was a corresponding increase in P content of leaves during both the years and in pooled data. The maximum P content (0.40%) was observed at L_4 , being statistically significant over L_1 , L_2 and L_3 . Similar trend was observed during the individual year studies. Significant differences between the years were registered and more P content was recorded in the second year of investigations.

All the first as well as second order interactions were found to be non-significant with respect to P content in bell pepper leaves.

4.15 Potassium content in bell pepper plant (%)

Table 23 revealed that the use of pine needle mulch (M_3) produced the maximum K content as compared to other two mulches used. Highest value (3.69%) was registered at M_3 whereas lowest (3.20%) at M_4 (unmulched control) in the pooled data. Similar trend was observed during both the years of studies. Planting methods did not affect the K content significantly. Increase in fertility levels increased the K content of leaves and the maximum values were obtained at L_4 level during both the years and in pooled data. However, the highest K content (3.50%) was recorded at L_4 level during the year 1999 being statistically at par with L_3 .

All the interactions studied were found to be non-significant on this attribute (Appendix-II).

4.16 Weed density (number/0.25 m²)

Data pertaining to the main effects of various treatments under study with respect to weed density have been tabulated in Table 25.

A perusal of the data reveals that all the treatments significantly affected the number of weeds per 0.25 m² plot area (Appendix-II). Of the various mulches, the minimum number of weeds (13.06/0.25 m²) were found in M_1 which was statistically lower than all other treatments. M_3 (17.42/0.25 m²) and M_2 (18.06/0.25 m²) were statistically at par with each other but lower than the unmulched plots (33.35/0.25 m²). Same trend was observed during 1998 and 1999.

Planting methods also influenced the weed density and the lesser number of

Table 24. Interaction effects of mulches and planting methods (MxP) on nitrogen content (%) in bell pepper hybrid cv. Bharath

Mulches	Planting methods		SE(d) _±		CD at 5%	
	P ₁	P ₂	A	B	A	B
1998						
M ₁	3.89	3.87				
M ₂	3.82	3.25	0.031	0.058	0.071	0.142
M ₃	3.88	3.94				
M ₄	3.64	3.66				
1999						
M ₁	3.94	3.96				
M ₂	3.89	3.94	0.036	0.093	NS	NS
M ₃	4.05	4.03				
M ₄	3.70	3.69				
Pooled						
M ₁	3.91	3.92				
M ₂	3.86	3.59	0.023	0.003	0.047	0.006
M ₃	3.96	3.98				
M ₄	3.67	3.68				

A=SE(d)_± and CD at 5% for mulches at same planting method

B=SE(d)_± and CD at 5% for planting methods at same or different mulches

Table 25. Effect of mulches, planting methods and fertility levels on weed density, fresh weight and dry weight of weeds in bell pepper hybrid cv. Bharath at 60 days after transplanting

Treatments	Weed density (No./0.25 m ²)			Fresh weight (g/0.25 m ²)			Dry weight (g/0.25 m ²)		
	1998	1999	Pooled	1998	1999	Pooled	1998	1999	Pooled
Mulches									
Black polyethylene mulch (M ₁)	14.38	11.75	13.06	20.54	19.75	20.15	2.92	2.46	2.69
Transparent polyethylene mulch (M ₂)	19.67	16.46	18.06	42.12	39.83	40.98	5.38	5.29	5.33
Pine needle mulch (M ₃)	19.54	15.29	17.42	30.17	27.54	28.85	4.04	2.92	3.48
No mulch (M ₄)	40.00	36.71	35.35	75.08	69.33	72.21	11.96	10.17	11.06
SE(d)±	1.27	0.66	0.72	1.95	0.84	1.06	0.47	0.29	0.28
CD at 5%	3.12	1.61	1.56	4.77	2.06	2.32	1.16	0.72	0.61
Planting methods									
Ridge method (P ₁)	20.48	16.88	18.68	37.69	34.94	36.31	4.91	4.54	4.73
Flat bed method (P ₂)	26.31	20.33	23.27	46.27	43.29	44.78	7.23	5.88	6.55
SE(d)±	0.65	0.56	0.42	1.30	1.12	0.86	0.45	0.22	0.25
CD at 5%	1.50	1.26	0.90	2.99	2.59	1.82	1.03	0.51	0.53
Fertility levels (NPK kg ha⁻¹)									
190:45:50 (L ₁)	19.42	16.12	17.77	35.83	37.67	36.75	4.83	4.71	4.77
250:60:75 (L ₂)	22.37	17.42	19.90	41.88	39.75	40.81	5.58	4.83	5.21
310:75:100 (L ₃)	25.12	19.75	22.44	43.21	37.92	40.56	6.37	5.41	5.90
370:90:125 (L ₄)	26.67	20.92	23.79	47.00	41.12	44.06	7.50	5.88	6.69
SE(d)±	0.88	0.72	0.56	1.21	1.72	1.06	0.31	0.33	0.23
CD at 5%	1.76	1.45	1.12	2.45	NS	2.09	0.63	0.67	0.46
Year Effects									
Year Effects	23.40	18.55		41.98	39.11		6.07	5.21	
SE(d)±	0.51			0.75			0.19		
CD at 5%	1.11			1.64			0.42		

weeds were obtained in the ridge planted crop during both the years and in the pooled data. Number of weed per 0.25 m² increased from 17.77 to 23.79 per 0.25 m² plot area as the fertility level increased from L₁ to L₄ in the pooled analysis as well as in the individual years. Highest number of weeds (23.79/0.25 m²) were recorded at highest level of fertilization (L₄) which was statistically at par with L₃ but higher than L₁ and L₂. The year effects with respect to the weed density were also found to be significant and more number of weeds were recorded during the first year of investigation.

The first order interaction MxL was found to be significant during both the years and in pooled analysis (Table 27). MxP interaction was significant only during 1999 and in pooled analysis (Table 26). Highest number of weeds (41.83/0.25 m²) were observed in M₄L₄ and lowest (12.08/0.25 m²) in M₁L₁ treatments. Amongst the MxP interaction M₁P₁ suppressed the population of weeds to a greater extent and lowest number of weeds (10.75/0.25 m²) were recorded with this treatment combination during the year 1999. Same results obtained in pooled data.

Among second order interaction, MxPxL was found to be significant during both the years and in pooled analysis. Data in Table 28 revealed that the interaction M₁P₁L₁ registered the lowest number of weeds (9.83/0.25 m²), whereas highest number of weeds (46.83/0.25 m²) were recorded with M₄P₂L₄ interaction in the pooled analysis. Same trend was found in 1998. During the year 1999 the maximum number of weeds (41.67/0.25 m²) were observed at M₄P₂L₃ interaction.

4.17 Fresh weight of weeds (g/0.25 m²)

The main effects of various treatments on fresh weight of weeds has shown in Table 25 and pertinent analysis of variance in Appendix-II.

A perusal of the data revealed that M₁ (Black polyethylene mulch) treatment

Table 26. Interaction effects of mulches and planting methods (MxP) on weed density (No./0.25 m²) in bell pepper hybrid cv. Bharath

Mulches	Planting methods		SE(d) _±		CD at 5%	
	P ₁	P ₂	A	B	A	B
1998						
M ₁	12.33	16.42				
M ₂	17.75	21.58	1.29	1.57	NS	NS
M ₃	15.83	23.25				
M ₄	36.00	44.00				
1999						
M ₁	10.75	12.75				
M ₂	15.42	17.50	1.09	1.02	2.52	2.41
M ₃	14.08	16.50				
M ₄	27.25	34.17				
Pooled						
M ₁	11.54	14.58				
M ₂	16.58	19.54				
M ₃	14.96	19.87	0.85	0.94	1.80	2.02
M ₄	31.62	39.08				

A=SE(d)_± and CD at 5% for mulches at same planting method

B=SE(d)_± and CD at 5% for planting methods at same or different mulches

Table 27. Interaction effects of mulches and fertility levels (MxL) on weed density (No./0.25 m²) in bell pepper hybrid cv. Bharath

Mulches	Fertility levels				SE(d) \pm		CD at 5%	
	L ₁	L ₂	L ₃	L ₄	A	B	A	B
1998								
M ₁	13.83	13.50	14.50	15.67				
M ₂	17.33	18.00	21.00	22.33	1.75	1.98	3.53	4.34
M ₃	15.33	19.67	21.67	21.50				
M ₄	31.17	38.33	43.33	47.17				
1999								
M ₁	10.33	11.33	12.50	12.83				
M ₂	14.50	16.17	17.17	18.00	1.44	1.41	2.89	2.97
M ₃	14.83	14.67	15.33	16.33				
M ₄	24.83	27.50	34.00	36.50				
Pooled								
M ₁	12.08	12.42	13.50	14.25				
M ₂	15.92	17.08	19.08	20.17	1.13	1.22	2.25	2.49
M ₃	15.08	17.17	18.50	18.92				
M ₄	28.00	32.92	38.67	41.83				

A=SE(d) \pm and CD at 5% for mulches at same fertility level

B=SE(d) \pm and CD at 5% for fertility levels at same or different mulches

was effective in reducing the fresh weight of weeds during both the years of investigation and in the pooled analysis. Lowest fresh weight (20.15 g/0.25 m²) was recorded with M₁ and it was statistically lower than other two mulches applied. Similar results were obtained during both the years. Planting methods significantly suppressed the weed growth and the lowest fresh weight was obtained with P₁ treatment. Fresh weight of the weeds increased significantly during the year 1998 and in the pooled data. Minimum fresh weight (35.83 g/0.25 m²) was registered at L₁ level and the maximum (47.00/0.25 m²) with L₄ level. However, L₂ level was at par with L₃ level. Similar trend was observed in pooled analysis. The years effects were found to be significant and lesser fresh weight of weeds were observed during second year.

The first order interaction MxP was found significant during 1999 and in pooled analysis (Table 29), whereas MxL and PxL during the year 1998 only (Table 30 and 31). The data showed that the treatment M₁P₁ was best in suppressing weed growth, thus registered the lowest fresh weights 10.75 and 11.54 g/0.25 m² during the year 1999 and in pooled data, respectively. These values were significantly lower when different mulches were applied at P₁ treatment. In MxL interaction, the treatment M₁L₁ registered minimum fresh weight (19.50 g/0.25 m²) whereas in PxL interaction, P₁L₁ gave fresh weight of 33.50 g per 0.25 m² plot area. Second order interactions were found to be non-significant with respect to this aspect (Appendix-II).

4.18 Dry weight of weeds (g/0.25 m²)

Data recorded on this attribute are presented in Tables 25, 32 and 33 (Appendix-II).

The data revealed that the use of black polyethylene mulch (M₁) produced the minimum dry weight of weeds during both the years of experimentation and in the pooled data. Lowest dry weight (2.69 g/0.25 m²) was observed at M₁ in the pooled data

Table 28. Interaction effects of mulches, planting methods and fertility levels (MxPxL) on weed density (No./0.25 m²) in bell pepper hybrid cv. Bharath

Treatment	P ₁				P ₂				SE(d) _±			CD at 5%		
	L ₁	L ₂	L ₃	L ₄	L ₁	L ₂	L ₃	L ₄	A	B	C	A	B	C
1998														
M ₁	10.33	12.00	13.33	13.67	17.33	15.00	15.67	17.67						
M ₂	15.00	15.33	20.00	20.67	19.67	20.67	22.00	24.00	2.48	2.51	2.66	4.99	5.25	5.71
M ₃	14.33	15.33	16.33	17.33	16.33	24.00	27.00	25.67						
M ₄	30.00	35.67	38.33	40.00	32.33	41.00	48.33	54.33						
1999														
M ₁	9.33	10.67	11.33	11.67	11.33	12.00	13.67	14.00						
M ₂	14.33	14.67	16.33	16.35	14.67	17.67	18.00	19.67	2.04	2.07	2.03	4.09	4.33	4.27
M ₃	13.33	13.35	14.00	15.67	16.33	16.00	16.67	17.00						
M ₄	24.00	25.00	26.33	33.67	25.67	30.00	41.67	39.33						
Pooled														
M ₁	9.83	11.33	12.33	12.67	14.33	13.50	14.67	15.83						
M ₂	14.67	15.00	18.17	18.50	17.17	19.17	20.00	21.83	1.60	1.64	1.73	3.18	3.31	3.54
M ₃	13.83	14.33	15.17	16.50	16.33	20.00	21.83	21.33						
M ₄	27.00	30.33	32.33	36.83	29.00	35.50	45.00	46.83						

A=SE(d)_± and CD at 5% for two mulches at same combination of planting methods and fertility levels

B=SE(d)_± and CD at 5% for two planting methods at same combination of mulches and fertility levels

C=SE(d)_± and CD at 5% for two fertility levels at same combination of mulches and planting methods

Table 29. Interaction effects of mulches and planting methods (MxP) on fresh weight (g/0.25 m²) of weeds in bell pepper hybrid cv. Bharath

Mulches	Planting methods		SE(d) _±		CD at 5%	
	P ₁	P ₂	A	B	A	B
1998						
M ₁	15.67	25.42				
M ₂	37.92	46.33	2.59	2.67	NS	NS
M ₃	28.83	31.50				
M ₄	68.33	81.83				
1999						
M ₁	15.17	24.33				
M ₂	35.75	43.92	2.25	1.80	5.19	4.21
M ₃	27.25	27.83				
M ₄	61.58	77.08				
Pooled						
M ₁	15.42	24.87				
M ₂	36.83	45.12	1.72	1.61	3.64	3.45
M ₃	28.04	29.67				
M ₄	64.96	79.46				

A=SE(d)_± and CD at 5% for mulches at same planting method

B=SE(d)_± and CD at 5% for planting methods at same or different mulches

being statistically lower to M_3 and M_2 . Same trend was observed during 1998. However, in 1999 M_1 was at par with M_3 but significantly lower than M_2 . Maximum dry weight of weeds was recorded in unmulched treatment during both years and in pooled data. Among the planting method, P_1 reduced the weed growth and registered lower weed dry weight than P_2 . An increase in the dry weight of weeds was recorded when fertility level increased from L_1 to L_4 . The lowest weed dry weight (4.77 g/0.25 m²) was observed at lowest fertility level (L_1) in the pooled data and similar results were obtained during both the years of experimentation.

There were significant differences between the years with regard to dry weight of weeds and lower dry weight was registered during the second cropping year.

Interaction studies showed that MxL and PxL interactions were found to be significant during the year 1998 only. Lowest dry weight was observed at M_1L_1 being statistically at par with M_1L_2 , M_1L_3 and M_1L_4 . Similarly, P_1L_1 treatment suppressed the weed growth and registered lowest dry weight (4.08 g/0.25 m²) of weeds. However, P_1L_1 was at par with P_1L_2 and P_2L_2 .

4.19 Available nitrogen (kg ha⁻¹)

Data on available nitrogen in soil after the harvest of the crop as affected by various treatments during the year 1998 and 1999 are detailed in Table 34 and their corresponding analysis of variance in Appendix-II.

A reference to the data in Table 29 indicates that all the mulch treatments differed significantly among themselves in the pooled data. However, maximum available nitrogen was there in the soil during second cropping season. The data further reveals that the maximum value with respect to the planting methods were obtained when planting was done on ridges (P_1). With the increase in fertility level there is corresponding

Table 30. Interaction effects of mulches and fertility levels (MxL) on fresh weight (g/0.25 m²) of weeds in bell pepper hybrid cv. Bharath

Mulches	Fertility levels				SE(d) _±		CD at 5%	
	L ₁	L ₂	L ₃	L ₄	A	B	A	B
1998								
M ₁	19.50	21.00	19.67	22.00				
M ₂	36.17	41.00	43.83	47.50	2.43	2.87	4.91	6.35
M ₃	24.50	29.83	32.50	33.83				
M ₄	63.17	75.67	76.83	84.67				
1999								
M ₁	19.30	20.00	18.33	21.17				
M ₂	37.00	39.00	40.00	43.33	3.45	1.92	NS	NS
M ₃	23.17	28.83	27.50	30.67				
M ₄	71.00	71.17	65.83	69.33				
Pooled								
M ₁	19.40	20.50	19.00	21.58				
M ₂	36.58	40.00	41.92	45.42	2.11	1.49	NS	NS
M ₃	23.83	29.33	30.00	32.25				
M ₄	67.08	73.42	71.33	77.00				

A=SE(d)_± and CD at 5% for mulches at same fertility level

B=SE(d)_± and CD at 5% for fertility levels at same or different mulches

Table 31. Interaction effects of planting methods and fertility levels (P×L) on fresh weight (g/0.25 m²) of weeds in bell pepper hybrid cv. Bharath

Planting methods	Fertility levels				SE(d) _±		CD at 5%	
	L ₁	L ₂	L ₃	L ₄	A	B	A	B
1998								
P ₁	33.50	37.42	38.67	41.17				
P ₂	38.17	46.33	47.75	52.83	1.72	1.98	3.47	4.23
1999								
P ₁	32.08	35.25	34.75	37.67				
P ₂	43.25	44.25	41.08	44.58	2.44	2.39	NS	NS
Pooled								
P ₁	32.79	36.33	36.7	39.42				
P ₂	40.71	45.29	44.42	48.71	1.49	1.55	NS	NS

A=SE(d)_± and CD at 5% for planting methods at same fertility level

B=SE(d)_± and CD at 5% for fertility levels at same or different planting methods

Table 32. Interaction effects of mulches and fertility levels (MxL) on dry weight (g/0.25 m²) of weeds in bell pepper hybrid cv. Bharath

Mulches	Fertility levels				SE(d) _±		CD at 5%	
	L ₁	L ₂	L ₃	L ₄	A	B	A	B
1998								
M ₁	2.33	2.50	3.17	3.67				
M ₂	4.67	5.00	5.50	6.33	0.63	0.73	1.28	1.60
M ₃	3.00	3.67	4.33	5.17				
M ₄	9.33	11.17	12.50	14.83				
1999								
M ₁	1.83	2.33	2.50	3.17				
M ₂	4.33	4.50	5.83	6.50	0.66	0.44	NS	NS
M ₃	2.33	2.83	3.17	3.33				
M ₄	10.33	9.67	10.17	10.50				
Pooled								
M ₁	2.08	2.42	2.83	3.42				
M ₂	4.50	4.75	5.67	6.42	0.46	0.36	NS	NS
M ₃	2.67	3.25	3.75	4.25				
M ₄	9.83	10.42	11.33	12.67				

A=SE(d)_± and CD at 5% for mulches at same fertility level

B=SE(d)_± and CD at 5% for fertility levels at same or different mulches

Table 33. Interaction effects of planting methods and fertility levels (P×L) on dry weight (g/0.25 m²) of weeds in bell pepper hybrid cv. Bharath

Planting methods	Fertility levels				SE(d)±		CD at 5%	
	L ₁	L ₂	L ₃	L ₄	A	B	A	B
1998								
P ₁	4.08	4.67	5.25	5.67				
P ₂	5.58	6.50	7.50	9.33	0.45	0.59	0.90	1.29
1999								
P ₁	3.91	4.00	5.00	5.25				
P ₂	5.50	5.67	5.83	6.50	0.47	0.47	NS	NS
Pooled								
P ₁	4.00	4.33	5.13	5.46				
P ₂	5.54	6.08	6.67	7.92	0.32	0.38	NS	NS

A=SE(d)± and CD at 5% for planting methods at same fertility level

B=SE(d)± and CD at 5% for fertility levels at same or different planting methods

Table 34. Effect of mulches, planting methods and fertility levels on available NPK in the surface soil (0-15 cm) at final harvesting of crop

Treatments	Available N (kg ha ⁻¹)			Available P ₂ O ₅ (kg ha ⁻¹)			Available K ₂ O (kg ha ⁻¹)		
	1998	1999	Pooled	1998	1999	Pooled	1998	1999	Pooled
Mulches									
Black polyethylene mulch (M ₁)	351.40	355.80	353.10	36.21	37.83	37.02	275.70	277.20	276.50
Transparent polyethylene mulch (M ₂)	354.80	364.20	359.50	37.71	40.71	39.21	277.00	280.09	278.50
Pine needle mulch (M ₃)	364.50	368.50	366.50	40.75	42.79	41.77	280.00	285.10	282.60
No mulch (M ₄)	340.00	350.40	345.70	35.21	36.41	35.71	273.10	276.50	274.80
SE(d)±	4.06	3.26	2.60	0.73	0.97	0.61	0.52	0.54	0.37
CD at 5%	9.93	7.99	5.67	1.78	2.37	1.32	1.28	1.31	0.81
Planting methods									
Ridge method (P ₁)	353.90	360.40	357.20	37.92	39.87	38.90	277.10	280.40	278.70
Flat bed method (P ₂)	351.40	359.00	355.20	37.02	38.90	37.96	275.90	279.05	277.40
SE(d)±	1.15	1.26	0.86	0.39	0.46	0.30	0.47	0.55	0.36
CD at 5%	2.48	NS	1.82	0.89	NS	0.64	1.07	1.27	0.77
Fertility levels (NPK kg ha⁻¹)									
190:45:50 (L ₁)	347.70	355.80	351.80	35.92	37.75	36.83	274.50	277.40	276.00
250:60:75 (L ₂)	350.50	357.70	354.10	37.25	39.12	38.19	276.00	279.00	277.50
310:75:100 (L ₃)	355.00	361.70	358.40	38.08	29.92	39.00	277.60	281.01	279.40
370:90:125 (L ₄)	357.40	363.70	360.50	38.68	40.75	39.69	277.70	281.40	279.50
SE(d)±	0.81	0.73	0.55	0.34	0.36	0.25	0.48	0.54	0.36
CD at 5%	1.64	1.47	1.09	0.69	0.73	0.49	0.97	1.09	0.72
Year Effects									
Year Effects	352.70	359.70		37.47	39.39		276.50	279.70	
SE(d)±	1.84			0.43			0.26		
CD at 5%	4.01			0.93			0.58		

increase in the available N content in the soil and maximum N (kg ha^{-1}) was obtained at highest fertility level L_4 . Interaction $M \times L$ was found to be highly significant during both the years and in pooled data with respect to available N content in soil (Table 35). Highest values were registered when pine needle mulch (M_3) was applied at L_4 level during both the years of studies and in the pooled analysis. All other interactions were found to be non-significant.

4.20 Available phosphorus (kg ha^{-1})

The data reveals that the application of mulch in respect of available P after harvest was found to be significant during both the years and in the pooled data (Table 34 and Appendix-II). M_3 recorded maximum (41.77 kg ha^{-1}) P content being significant over M_1 and M_2 . Planting methods were found to be significant during 1998 and in the pooled data. Ridge method of planting gave the highest values of P content in soil. Fertilization significantly affected the P content in the soil and maximum available P was recorded at highest fertility level (L_4). All the interaction effects studied were found to be non-significant with respect to available phosphorus content.

4.21 Available potassium (kg ha^{-1})

A perusal of the data in Table 34 revealed that available K content in soil increased significantly when pine needle mulch (M_3) was applied being significant over M_1 and M_2 . M_2 registered significantly higher value than the M_1 in the pooled analysis. Similar trend was observed during both the years. However, available K content was lowest in the non-mulched (M_4) treatment. Higher K content with respect to planting methods were obtained when the planting was done on ridges during both the years of investigations. Fertilization also had a significant effect on available K content in the soil. K content increased as the fertility levels increased from L_1 to L_4 . Highest values were obtained at L_4 level during both the cropping seasons and in the pooled data. All

Table 35. Interaction effects of mulches and fertility levels (MxL) on available nitrogen (kg ha⁻¹) in the soil after harvest

Mulches	Fertility levels				SE(d) _±		CD at 5%	
	L ₁	L ₂	L ₃	L ₄	A	B	A	B
1998								
M ₁	346.50	349.20	353.70	356.30				
M ₂	350.30	350.70	358.00	360.20	1.63	4.29	3.28	10.29
M ₃	361.80	364.70	365.20	366.30				
M ₄	332.30	337.70	343.20	346.70				
1999								
M ₁	350.50	350.70	358.00	360.20				
M ₂	361.80	363.50	365.20	366.30	1.46	3.49	2.93	8.34
M ₃	364.50	367.30	370.20	371.80				
M ₄	346.50	349.20	353.70	356.30				
Pooled								
M ₁	348.50	349.90	355.80	358.20				
M ₂	356.10	357.10	361.60	363.20	1.09	2.77	2.17	5.97
M ₃	363.20	366.00	367.70	369.10				
M ₄	339.40	343.40	348.40	351.50				

A=SE(d)_± and CD at 5% for mulches at same fertility level

B=SE(d)_± and CD at 5% for fertility levels at same or different mulches

Table 36. Effect of mulches on soil moisture content (%) and soil temperature (°C) during the year 1998 and 1999

Date	Treatments									
	Soil moisture					Soil temperature				
	M ₁	M ₂	M ₃	M ₄	Mean	M ₁	M ₂	M ₃	M ₄	Mean
1998										
24.05.98(D ₁)	18.23	18.92	20.24	16.54	18.48	31.33	27.33	24.33	26.33	27.33
08.06.98(D ₂)	18.42	19.44	20.82	17.24	18.98	32.67	28.33	25.33	29.33	28.92
23.06.98(D ₃)	20.77	21.32	22.44	19.37	20.97	35.33	33.33	27.00	30.33	31.50
08.07.98(D ₄)	21.44	22.27	23.80	20.25	21.94	34.00	31.67	25.33	28.67	29.92
23.07.98(D ₅)	20.91	21.91	23.35	19.95	21.53	31.00	29.00	24.67	26.67	27.83
07.08.98(D ₆)	20.55	21.64	23.22	19.64	21.26	31.33	28.00	24.33	26.67	27.58
22.08.98(D ₇)	20.82	22.54	24.16	20.16	21.92	30.00	27.33	23.33	25.67	26.58
06.09.98(D ₈)	21.74	23.47	24.37	20.49	22.52	29.33	26.67	22.67	24.67	25.83
21.09.98(D ₉)	22.68	24.28	25.36	21.50	23.46	28.00	25.33	20.67	23.33	24.33
Mean	20.62	21.74	23.08	19.46		31.44	28.56	24.19	26.85	
	SE(d) _±		CD at 5%			SE(d) _±		CD at 5%		
Mulch (M)	0.18		0.35			0.29		0.59		
Date (D)	0.27		0.53			0.44		0.88		
MxD	0.53		NS			0.88		NS		
1999										
10.05.99(D ₁)	18.89	20.38	22.03	16.86	19.54	28.67	24.67	20.67	22.00	24.00
26.05.99(D ₂)	20.15	21.10	22.54	18.43	20.56	29.67	25.33	21.67	22.67	24.83
10.06.99(D ₃)	18.67	19.62	22.00	17.11	19.35	30.67	26.67	22.67	23.33	25.83
25.06.99(D ₄)	20.40	21.26	22.15	18.79	20.65	33.33	30.67	23.33	24.67	28.00
10.07.99(D ₅)	22.13	23.41	24.54	21.17	22.81	31.67	29.67	22.67	27.00	27.75
25.07.99(D ₆)	21.33	23.74	24.82	20.89	22.69	29.33	27.33	23.33	24.00	26.00
09.08.99(D ₇)	21.81	23.94	25.11	20.82	22.92	28.67	26.67	23.00	24.67	25.75
24.08.99(D ₈)	21.32	24.26	24.78	20.73	22.77	27.33	24.67	22.67	24.00	24.67
08.09.99(D ₉)	20.57	23.72	24.37	19.83	22.12	26.33	23.33	21.33	22.67	23.42
Mean	20.59	22.38	23.59	19.40		29.52	26.56	22.37	23.89	
	SE(d) _±		CD at 5%			SE(d) _±		CD at 5%		
Mulch (M)	0.23		0.46			0.29		0.59		
Date (D)	0.34		0.69			0.45		0.89		
MxD	0.69		NS			0.89		1.78		

the first and second order interaction were found to be non-significant regarding the K content in the soil (Appendix-II).

4.22 Soil moisture content (%)

The data pertaining to the effect of mulches on soil moisture content have been represented in Table 36 during the year 1998 and 1999, respectively and their analysis of variance given in Appendix-III.

From the data, it is evident that the mulch application had a significant effect on soil moisture content during both the years of investigations. Among the different mulches maximum soil moisture content was recorded under the pine needle mulch (M_3), which was significantly more than other two mulches i.e. black polyethylene mulch (M_1) and transparent mulch (M_2). All the mulch treatments were statistically different to each other. Minimum soil moisture content was recorded when no mulch was applied during both the years.

Among the different dates, maximum soil moisture was recorded at the end of the growing season during first year and first fortnight of August during second year whereas minimum was observed during the second fortnight of May in 1998 and in the first fortnight of June in 1999. The mulch and date interaction ($M \times D$) with respect to soil moisture content were found to be non-significant; however, maximum soil moisture was recorded under pine needle mulch on 21st September and 25th July in the year 1998 and 1999, respectively, while minimum was observed with the application of black polyethylene mulch on May 24, and 10th June in the first and second years, respectively.

4.23 Soil temperature (°C)

Data regarding to the effect of mulches on soil temperature are presented in Table 36 (Appendix-III) during the year 1998 and 1999, respectively.

Table 37. Economics of bell pepper hybrid production

Sr No	Treatment	Fruit yield (q ha ⁻¹)	Gross returns (Rs. ha ⁻¹)	Expenditure/treatment	Net returns (Rs. ha ⁻¹)	Benefit-cost ratio (Rs. ha ⁻¹)
1.	M ₁ P ₁ L ₁	189.70	189700.00	72230.81	117469.19	1.63
2.	M ₁ P ₁ L ₂	200.50	200500.00	73659.96	126840.04	1.72
3.	M ₁ P ₁ L ₃	198.70	198700.00	75089.11	123610.89	1.65
4.	M ₁ P ₁ L ₄	203.60	203600.00	76518.26	127081.74	1.66
5.	M ₁ P ₂ L ₁	156.00	156000.00	69485.81	86514.19	1.25
6.	M ₁ P ₂ L ₂	165.20	165200.00	70914.96	94285.04	1.33
7.	M ₁ P ₂ L ₃	180.80	180800.00	72344.11	108455.89	1.50
8.	M ₁ P ₂ L ₄	188.90	188900.00	73773.26	115126.74	1.56
9.	M ₂ P ₁ L ₁	192.00	192000.00	72230.81	119769.19	1.66
10.	M ₂ P ₁ L ₂	243.90	243900.00	73659.96	170240.04	2.31
11.	M ₂ P ₁ L ₃	272.60	272600.00	75089.11	197510.89	2.63
12.	M ₂ P ₁ L ₄	268.60	268600.00	76518.26	192081.74	2.51
13.	M ₂ P ₂ L ₁	209.30	209300.00	69485.81	139814.19	2.01
14.	M ₂ P ₂ L ₂	221.90	221900.00	70914.96	150985.04	2.13
15.	M ₂ P ₂ L ₃	256.70	256700.00	72344.11	184355.89	2.55
16.	M ₂ P ₂ L ₄	234.10	234100.00	73773.26	160326.74	2.17
17.	M ₃ P ₁ L ₁	260.40	260400.00	66914.81	193485.19	2.89
18.	M ₃ P ₁ L ₂	265.30	265300.00	68343.96	196956.04	2.88
19.	M ₃ P ₁ L ₃	292.90	292900.00	69773.11	223126.89	3.20
20.	M ₃ P ₁ L ₄	286.40	286400.00	71202.26	215197.74	3.02
21.	M ₃ P ₂ L ₁	213.00	213000.00	64169.81	148830.19	2.32
22.	M ₃ P ₂ L ₂	233.60	233600.00	65598.96	168001.04	2.56
23.	M ₃ P ₂ L ₃	254.40	254400.00	67028.11	187371.89	2.80
24.	M ₃ P ₂ L ₄	240.50	240500.00	68457.26	172042.74	2.51
25.	M ₄ P ₁ L ₁	162.10	162100.00	62470.81	99629.19	1.59
26.	M ₄ P ₁ L ₂	192.90	192900.00	63899.96	129000.04	2.01
27.	M ₄ P ₁ L ₃	199.40	199400.00	65329.11	134070.89	2.05
28.	M ₄ P ₁ L ₄	180.70	180700.00	66758.26	113941.74	1.70
29.	M ₄ P ₂ L ₁	138.40	138400.00	59725.81	78674.19	1.31
30.	M ₄ P ₂ L ₂	140.90	140900.00	61154.96	79745.04	1.30
31.	M ₄ P ₂ L ₃	149.40	149400.00	62584.11	86815.89	1.39
32.	M ₄ P ₂ L ₄	171.80	171800.00	64013.26	107786.74	1.68

The details are in Appendix-IV
 Sale price of bell pepper fruit = Rs. 1000 q⁻¹

The perusal of the data reveals that the treatment M_1 (Black polyethylene mulch) recorded highest temperatures whereas pine needle mulch had the lowest soil temperatures throughout the growing seasons during both the years of investigations. All the treatments M_1 , M_2 , M_3 and M_4 were significantly different to each other. The average soil temperature increased gradually from May to the second fortnight of June and then there was gradual decrease in soil temperature upto the end of growing seasons during both the years. During the year 1998 highest soil temperature (35.33°C) was recorded under black polyethylene mulch on 23rd June, while it was maximum (33.33°C) on 25th June, 1999. The minimum soil temperatures were recorded under pine needle mulch on 21st September, 1998 and 10th May, 1999 respectively. However, interaction effects of mulch and dates (MxD) were found to be non-significant during the first year of investigations.

4.24 Economics

The economics of bell pepper hybrid production, as affected by various treatments of this study was worked out on the basis of pooled fruit yield data of two years and the benefit-cost ratios are presented in Table 37 and cost of cultivation in Appendix-IV.

The maximum fruit yield of 292.90 q ha^{-1} was recorded at $M_3P_1L_3$ (Pine needle Mulch + Ridge Method + $310:75:100 \text{ kg NPK ha}^{-1}$). This involved the expenditure of Rs.69773.11 and the net returns were to the tune of Rs.223126.89 with Rs.3.20 returns per rupee investment. However, the minimum fruit yield of 138.40 q ha^{-1} was recorded with $M_4P_2L_1$ (No mulch + Flat bed + $190:45:50 \text{ kg NPK ha}^{-1}$) involving cost of production of Rs.59725.81 with lowest net returns of 78674.19 and Rs.1.31 return per rupee investment.

Chapter-5

DISCUSSION

The experimental results obtained from the present field investigations entitled “Response of bell pepper hybrid cv. Bharath to cultural practices” conducted during the Kharif seasons of 1998 and 1999 to assess the effect of various mulches, planting methods and fertilization on bell pepper hybrid ^{cv. Bharath} have been described in preceding chapter.

An attempt, however, ^{has} ~~have~~ been made in this chapter to interpret the significant effects of various treatments on different parameters recorded during this study on scientific basis to establish cause and effect relationship in the light of available evidences.

In general, each management treatment influences yield by affecting one or more factors of growth and development and relative effects of all treatments usually explain yield differences detected in field trials. The effects are not consistent and frequently change ^{due to} during growth condition in the field and hence crop responses can not be reproduced exactly year-wise and as a result, the basis of yield differences may vary from year to year. Differences caused in various attributes by the application of mulches, planting methods, fertilizers and their interactions are discussed in this chapter in their respective section with respect to growth and yield parameters of the crop under study.

The higher respective yields were obtained in second cropping season i.e. 1999 than the first crop season i.e. 1998. This may be attributed to the weather conditions which were more conducive for the overall growth and development of the crop during 1999. Hence, the factors like temperature, rainfall, humidity, water supply and various other cultural and management practices exert a strong influence on the performance of vegetable crops.

5.1 Effect of mulch material

Application of mulches have resulted in better vegetative growth and ultimately enhanced the bell pepper fruit yield during both years of investigations. Flowering was advanced by 6-8 days with the application of different mulches. The use of black polyethylene mulch resulted in early flowering as compared to other mulches during both the years of experimentation (Table 3). The early flowering recorded due to mulching could be attributed to improved crop growth resulting from warming effect and better soil moisture retention by the mulches. These findings are in conformity with the reports of VanDerwerken and Wilcox (1988).

Plant height was significantly higher in the mulched plots than in the unmulched control. Numerically higher plant height (60.99 cm) was recorded in pine needle mulched plot (M_3), which was at par with M_1 (Black polyethylene mulch) in pooled data. The possible reasons for better plant height by the use of mulches may be attributed to more available soil moisture and better weed control which resulted in conditions favourable for good crop growth. These results are in conformity with the findings of Decoteau *et al.* (1990), Castellane *et al.* (1992), Gollifer (1993), Vos and Sumarni (1997) and Flores and Ibarra (1998).

The present investigations showed that application of different mulches significantly enhanced the fruit breadth during the first year of experimentation and in

the pooled data (Table 10). Similar observations were observed by Flores and Ibarra (1998) in case of bell pepper.

Average fruit weight was significantly increased in the mulched plots than in the unmulched control (M_4) and the highest fruit weights were obtained with the use of pine needle mulch (M_3) during both the years of studies. Increased fruit weight could be attributed to higher soil moisture levels and favourable soil temperature for good crop health. These results are in agreement with Stephen and Stewart (1987).

The use of mulches exhibited promotive effect on number of fruits per plant which is evident from the fact that highest number of fruits were obtained with the application of pine needle mulch. This may be because of increased plant height, more number of branches per plant which ultimately resulted in more number of fruits per plant. Similar results have been obtained by Stephen and Stewart (1987), Siti *et al.* (1994) and Flores and Ibarra (1998).

The different growth and yield parameters like increased plant height, number of fruits per plant along with more fruit breadth and fruit weight due to the application of different mulches demonstrated their cumulative effect in influencing the bell pepper fruit yield per plant and per hectares. It was interesting to note that fruit yield was maximum (690.70 g/plant and 255.80 q ha⁻¹) with the application of pine needle mulch (M_3), being significantly higher than transparent and black polyethylene mulch application. Although use of black polyethylene resulted the lowest fruit yield among the various mulched treatments but it was significantly higher than the unmulched control. The low fruit yield from the black plastic mulch may have been due to the higher soil temperature and less soil moisture during both the years of investigations. Similar results were obtained by Roberts and Anderson (1994). However, increased fruit yields in mulched plots attributes to better weed control, less nutrient loss through

leaching, more conservation of soil moisture, favourable soil temperature, less incidence of fruit rot, prolonged harvest duration and enhanced activities of microorganisms in the soil resulting in increased availability of nutrients. These results are in agreement with those of Locascio and Fiskell (1979), Szabo (1979), Crespo (1988), VanDerwerken and Wilcox (1988), Wivutvongvana *et al.* (1991), Roe *et al.* (1994), Siti *et al.* (1994), Borosic *et al.* (1998) and Flores and Ibarra (1998) who have reported higher yields of bell pepper with the application of various mulch materials.

The harvest duration of bell pepper was prolonged by the use of mulches and maximum harvest duration was recorded with the application of pine needle mulch during both the years of investigations. Prolonged harvest duration may be attributed to more available soil moisture and nutrients which resulted in favourable plant growth conditions.

The present studies indicate that fruit rot incidence was reduced to a greater extent with the use of different mulches (Table 20). The minimum incidence of fruit rot occurred in the pine needle mulched treatment during both the years of studies. Disease incidence was reduced to the extent of 46-48 per cent by the use of pine needle mulch than the unmulched control. This may be due to the fact that mulches mitigate the harmful effects of soil borne fungi and create a barrier for the pathogen which cause the disease. These results are in conformity with the findings of Brown *et al.* (1989).

Shoot biomass of bell pepper plant was greatly influenced by the application of mulches and the maximum shoot biomass was recorded with pine needle mulch (M₁) during both cropping seasons and in the pooled data. This might be attributed to enhanced root growth under the pine needle mulch which contributed more absorption of nutrients. Similar observations were recorded by Decoteau *et al.* (1990) and Gollifer (1993).

Mulches affected NPK concentration of bell pepper leaves during both the years of experimentation (Table 23). Relatively higher values of N contents were recorded with the application of pine needle mulch being statistically at par with the black polyethylene mulch. Similarly the P and K contents were significantly higher in pine needle mulched plants than the other two mulches used. In general, mulched plants had higher nutrient content than unmulched plants. These results are in agreement with those of Siti *et al.* (1994) and Vos and Sumarni (1997).

In the present investigations weed studies indicated that weed density was significantly lesser under black polyethylene mulch, followed by pine needle and transparent mulch than the unmulched control. Black polyethylene was comparatively more efficient in control of weeds than the other two mulches used. Lowest weed fresh and dry weights were recorded under black polyethylene mulch, being statistically lower than pine needle and transparent plastic mulch. Unmulched control plots recorded higher weed density and more fresh and dry weights of weeds. During the course of experimentation it was observed that black polyethylene was very efficient in suppressing weed growth as it absorbs large quantum of sunrays due to its colour and increase soil temperature. Exclusion of sunlight in black plastic mulched area resulted in elimination of photosynthesis to weeds, which suppressed weed population resulting in reduced fresh and dry matter production of weeds. The results are in conformity with the reports of Kwon *et al.* (1988), Carter and Johnson (1988), Putnam (1990), Asiegbu (1991) and Russo *et al.* (1997).

Application of different mulches significantly influenced the available NPK content of soil at final harvesting of the crop during both the cropping seasons and maximum available NPK contents were recorded with the application of pine needle mulch. This may be because of the more conservation of soil moisture, reduced leaching of nitrogen, and increased activity of microorganisms in the soil resulting in larger

availability of nutrients. These results are in line with the observation of Vos and Sumarni (1997).

The use of different mulch materials significantly affected the soil moisture and temperature during both the year of investigations (Table 36). Soil moisture content varied with types of mulching. Without mulches, soil moisture was lower than that with mulches. Soil moisture under pine needle mulch was 18.6 per cent and 12 per cent higher than that without mulches and black polyethylene mulches, respectively. Almost similar trend was observed during the second year studies. Soil temperatures were higher under black and transparent polyethylene mulches than the pine needle mulch and bare ground. Lowest soil temperature was recorded under pine needle mulch. The higher moisture level may be attributed to reduced evaporation under the pine needle mulch thereby increasing the usable water reserves. These findings are in agreement with Porter and Etzel (1982), Ashworth and Harrison (1983), Siti *et al.* (1994), Roberts and Anderson (1994) and Vos and Sumarni (1997).

5.2 Effect of planting methods

The studies reveals that the ridge method of planting recorded earlier flowering and more plant height than the flat bed method. This may be because of better plant stand during the initial stages of growth. These results are in line with those of VanDerwerken and Wilcox (1988). Planting the bell pepper seedlings on ridges also produced significantly higher fruit weight, more number of fruits per plant, fruit yield per plant and per hectare during both the years of investigations. Further, it was observed that 14 per cent more yield was obtained on ridge planted crop than flat bed method of planting. This may be attributed to better soil drainage and aeration, increased soil temperature in the root zone and hence more proliferation of roots resulting in vigorous plant growth and more fruit yield. These results are in conformity with the findings of Velez (1973), Ramaiah and Lal (1987) and Caverro *et al.* (1996). The present studies

showed that the fruit rot incidence, weed density and fresh and dry weight of weeds were reduced when ridge method of planting was adopted. This may be because of the healthy and vigorous plant stand which restricts the attack of pathogen and suppress the weed growth effectively. Further, it was observed that the leaf N and P content were significantly increased in the year 1999 and 1998, respectively, whereas available N and P content of soil increased significantly during the first year of investigations, and available K content during both the years of studies when the bell pepper crop was planted on ridges. This increase may be attributed to the better soil microbial activities resulting in larger availability of nutrients and hence leading to higher fruit yield.

5.3 Effect of fertilization

Macronutrients play a major role in modifying the various characters related to growth and yield in bell pepper as it requires heavy fertilization for successful cultivation, so as to get maximum yield. The studies revealed that application of NPK exhibited significant effect on days to 50 per cent flowering and it was delayed at highest fertility level, perhaps due to diversion of photosynthates for the vegetative growth of plants. Similar results were obtained by Srivastava (1996).

Plant height was recorded maximum at L_4 level i.e. NPK @ 370:90:125 kg ha⁻¹, being at par with L_3 . This suggests that increasing levels of fertilizers enhance the vegetative growth of plant as a result of higher photosynthetic activities. Similar results have been reported by Srinivas and Prabhakar (1982), Doikova *et al.* (1984), Medhi *et al.* (1990) and Chailloux *et al.* (1992) in case of bell pepper.

The number of fruits per plant progressively increased with every additional dose of NPK fertilizers applied resulting in maximum number of fruits per plant (10.06) at 370:90:125 kg NPK ha⁻¹. This may be because of higher synthesis of photosynthates and their translocation to fruiting branches. These results are in conformity with the

findings of Gill *et al.* (1994), Mishriky and Alphonse (1994) and Srivastava (1996).

Significant response of NPK fertilization was observed with respect to fruit yield per plant and per hectare. It was observed during the course of these studies that the fruit yield per plant and per hectare increased upto L₃ level (NPK @ 310:75:100 kg ha⁻¹) and then it declined at highest fertility level. The highest fruit yield recorded per plant and per hectare was 609.10 g and 255.60 q, respectively. These results suggested that the requirement for highest fruit yield are met at 310:75:100 kg NPK ha⁻¹ and thus confirms that once the requirements of plants are met, further increase in quantity of NPK may have adverse effect on fruit yield as higher material concentrations upsets the normal fruiting of the plant growth processes. These findings are in agreement with Flores and Ibana (1998) who reported reduced capsicum yields at highest level of NPK (200:100:100 kg ha⁻¹). However, increase in fruit yield of bell pepper have been reported by Ludilov and Ludilova (1975), Chougule and Mahajan (1979), Doikova *et al.* (1984), Osman and George (1984), Frontela and Morejon (1987), Belichki (1988), Surlikov and Rankov (1989), Russo (1996) and Srivastava (1996) at increasing levels of NPK.

The prolonged harvest durations were observed with increasing levels of NPK and fruits were available for maximum days (51.75 days) at highest fertility level i.e. NPK @ 370:90:125 kg ha⁻¹. This may be attributed to the more availability of nutrients for the growth and development of the plants at the later phase of plant growth. Bell pepper shoot biomass increased as the fertilizer doses were increased and the maximum values with respect to this attribute was obtained at highest fertility level i.e. NPK @ 370:90:125 kg ha⁻¹. This may be because of the extensive vegetative growth due to higher fertilization. Khan and Suryanarayana (1978) have also recorded increased shoot biomass at higher NPK levels.

Fruit rot incidence was increased with the increase in fertility levels and the maximum fruit rot incidence (7.33%) occurred at highest level of NPK whereas minimum incidence of fruit rot (5.96%) was recorded at lowest level of fertility. This may be attributed to the more tenderness of the crop at higher doses of NPK which make the plants vulnerable to the disease causing pathogen.

The number of weeds per 0.25 m² plot area significantly influenced by the fertility levels at 60 days after transplanting and the number of weeds tended to increase with the corresponding increase in the fertility levels and the maximum number of weeds (23.79/0.25 m²) were recorded at L₄ level i.e. NPK @ 370:90:125 kg ha⁻¹. This might be due to the more availability of the nutrients resulting in faster growth and multiplication of the weeds. Similarly, the fresh and dry weight of weeds were recorded maximum at highest level of fertility during the course of investigations, however, minimum values with respect to these attributes are recorded at lowest fertility level. This may be attributed to the reasons as discussed earlier in case of weed density.

In the present studies it was found that NPK content of bell pepper leaves increased with the increase in NPK rates. The increase in NPK content may be because of the increased nutrient supply, which render more nutrients available to the plants, and their efficient translocation could have resulted in their accumulation in leaves. Similar observations were put forth by Somos *et al.* (1973) and Roe *et al.* (1997) who observed that rising NPK supply raised the nutrient content of stem and leaves in capsicum plants.

Chemical fertilizers play a vital role in physiological activities of the plants. Especially nitrogen is responsible for formation of protoplasm, cell division, energy metabolism and for activation of various enzymes. There were significant differences for availability of N, P and K elements with the increasing levels of fertilizers. The

higher application of NPK showed an increase in the availability of these nutrients in the soil after harvest of the crop as expected. These results are in agreement with Hegde (1987b).

5.4 Interactions

Amongst different interactions studied, the complimentary effect of mulches and fertility levels (MxL) seemed to be most consistent and significantly manifested in different characters under study. It was observed that application of pine needle mulch along with NPK @ 310:75:100 kg ha⁻¹ resulted in highest fruit yield per hectare (273.70 q). This may be because of the fact that all the related characters like plant height, number of branches and fruits per plant, fruit yield per plant were recorded significantly higher at M₃L₃ (Pine needle Mulch + 310:75:100 kg NPK kg ha⁻¹). Similar conclusions have been drawn by Locascio and Fiskell (1977) and Siti *et al.* (1994). On the other hand less fruit rot incidence was also recorded with this treatment combination thus supporting the higher fruit yield. Further, it was found that the weed density was maximum when the black polyethylene mulch was applied along with NPK @ 190:45:50 kg ha⁻¹. Similarly, this treatment combination suppressed the weed growth thereby reducing the fresh and dry weight of weeds during the course of experimentation. Similar conclusions have been drawn by Putnam (1990) and Gollifer (1993). It was also reported that the soil available nitrogen was highest when pine needle mulch was applied along with the highest fertility level (NPK @ 370:90:125 kg ha⁻¹). This may be attributed to the more available soil moisture under pine needle mulch and reduction in leaching of the nutrients. The beneficial effect of mulch x planting method interaction (MxP) was also exhibited with respect to plant height, shoot biomass, nitrogen content in bell pepper leaves, weed density and fresh weight of weeds. Maximum plant height and shoot biomass was recorded at M₃P₁ (Pine needle mulch + Ridge method) treatment. This may be because of the enhanced vegetative growth of bell pepper plants on ridges

mulched with pine needle. However, the maximum N content of leaves was observed at M_3P_2 (Pine needle mulch + Flat bed method) treatment. On the other hand, minimum weed density and fresh weight of weeds was recorded when black polyethylene mulch was applied on the ridge planted bell pepper crop. Similar observations were made by VanDerwerken and Wilcox (1988). Plant height, number of fruits per plant and fresh and dry weight of weeds had shown significant effects with planting methods x fertility levels (PxL) interactions. Maximum values with respect to plant height and fruit number per plant were recorded when ridge method of planting was adopted and the NPK was administered @ 310:75:100 and 370:90:125 kg ha⁻¹. In contrast, the fresh and dry weight of weeds was minimum at lowest level of NPK i.e. 190:45:50 kg ha⁻¹ on ridge planted crop.

The combined effect of mulches, planting methods and fertility levels was found significant with respect to fruit yield per hectare which was recorded highest at the treatment combination of $M_3P_1L_3$ (Pine needle mulch + Ridge method + NPK @ 310:70:100 kg ha⁻¹). The increased fruit yield at this treatment may be attributed to the fact that all the characters associated with higher fruit yield viz. plant height, number of branches and fruits per plant and fruit yield per plant were also recorded significantly higher values at $M_3P_1L_3$. However, significantly minimum weed population was observed at $M_1P_1L_1$ (Black polyethylene + Ridge method + NPK @ 190:45:50 kg ha⁻¹) treatment combination. Thus, keeping in view the findings of the present investigations, it can be concluded that the treatment combination of $M_3P_1L_3$ (Pine needle mulch + Ridge method + NPK @ 310:70:100 kg ha⁻¹) may be suggested for the mid hill conditions of Himachal Pradesh for obtaining the maximum yields of bell pepper hybrid cv. Bharath.

5.5 Economics

The economics of the bell pepper production as affected by various treatments of this study revealed that the maximum net returns (Rs.223126.89 ha⁻¹) and benefit-

cost ratio of 3.20 were obtained by planting the bell pepper crop on ridges and using the pine needle mulch along with NPK @ 310:75:100 kg ha⁻¹. Thus, it can be concluded that for obtaining higher bell pepper yields and thus obtaining higher net returns, this combination may be recommended for the commercial cultivation of bell pepper hybrid Bharath in mid hills of Himachal Pradesh.

Chapter-6

SUMMARY

The present investigations entitled “Response of bell pepper hybrid cv. Bharath to cultural practices”, were carried out under mid hill conditions of Himachal Pradesh during the Kharif seasons of 1998 and 1999 at research farm of the Department of Vegetable Crops, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.). There were four mulch treatments (M_1 -Black polyethylene mulch; M_2 -Transparent polyethylene mulch; M_3 -Pine needle mulch and M_4 -Control or no mulch), two planting methods (P_1 -Ridge method and P_2 -Flat bed method) and four levels of NPK (L_1 -190:45:50 kg NPK ha⁻¹; L_2 -250:60:75 kg NPK ha⁻¹; L_3 -310:75:100 kg NPK ha⁻¹ and L_4 -370:90:125 kg NPK ha⁻¹). The experiment was laid out in split-split plot design, keeping mulches in main plots, planting methods in sub plots and fertility levels in sub-sub plots with three replications. The initial status of the soil was high in organic carbon and available potassium and medium in available nitrogen and phosphorus.

The observations were recorded on days to 50 per cent flowering, plant height, number of branches per plant, fruit length, fruit breadth, fruit weight, fruits per plant, fruit yield per plant and per hectare, harvest duration, fruit rot incidence, shoot biomass, weed density, fresh and dry weight of weeds, soil moisture, soil temperature, NPK content of leaves and available soil NPK after harvest.

The salient findings of the experiments have been summarised here under:

Among the different mulch materials in general the use of pine needle mulch (M_3) proved to be most efficacious treatment to promote the plant height, fruit breadth, fruit length, number of fruits per plant, fruit yield per plant and per hectare, harvest duration, shoot biomass, NPK content of bell pepper leaves and available NPK content of soil at final harvest. Pine needle mulch application was also found to be very effective in reducing the fruit rot incidence as lowest number of diseased fruits were recorded in pine needle mulched plots. Maximum soil moisture content and minimum soil temperature was recorded when pine needle mulch was applied, however, black polyethylene mulch advanced the flowering of bell pepper hybrid Bharath and proved to be most effective in controlling the weeds as minimum number of weeds and minimum fresh and dry weight of weeds were observed with this treatment.

Most of the characters like plant height, fruit weight, number of fruit per plant and fruit yield per plant and per hectare, N and P content of leaves, available NPK content of soil recorded maximum values when planting was done on ridges. Flowering was earliest on ridge planted crop. Ridge method was most effective in controlling the disease and weed incidence in bell pepper crop as the lowest values with respect to fruit rot incidence, weed density, fresh and dry weight of weeds were registered with this treatment.

The different fertility levels exhibited pronounced effect in improving the various characteristics of bell pepper. Minimum days to 50 per cent flowering were observed at initial fertility levels during both the years and in pooled data. Plant height increased with successive increase in fertility levels and the maximum plant height was obtained at highest fertility level (NPK @ 370:90:125 kg ha⁻¹). The yield contributing characters like number of fruits per plant, fruit yield per plant and per hectare increased with

corresponding increase in fertility levels upto L_3 level (NPK @ 310:75:100 kg ha⁻¹) and then declined at L_4 level. Other characters like harvest duration, fruit rot incidence, shoot biomass, NPK content of bell pepper leaves, weed density, fresh and dry weight of weeds and available NPK content of soil were significantly affected with the application of NPK fertilizers. Highest values with respect to these characters were registered at the highest fertility level (L_4) i.e. 370:90:125 kg NPK ha⁻¹, though the values were at par with L_3 level in most of the cases.

During the course of investigations it was observed that among the first order interaction, mulches x fertility levels (MxL) interaction influenced most of the characters under study whereas mulches x planting methods (MxP) and planting methods x fertility levels (PxL) had significant effects on few of them. Application of pine needle mulch on ridges gave the maximum plant height and shoot biomass of bell pepper hybrid. However, maximum N content of leaves was observed when pine needle mulch was applied on flat bed. On the other hand, application of black polyethylene mulch on ridges significantly suppressed the weed growth in bell pepper field and minimum weed population and fresh weight of weeds were recorded with this treatment combination. MxL interaction significantly influenced plant height, number of branches per plant, number of fruits per plant, fruit yield per plant and per hectare, fruit rot incidence, weed density, fresh and dry weight of weeds and available nitrogen in the soil after harvest. Maximum plant height, number of branches per plant, fruit yield per plant and per hectare were obtained when pine needle mulch was applied along with NPK @ 310:75:100 kg ha⁻¹. However, fruit rot incidence was minimum at this treatment combination. Minimum weed density, fresh and dry weight of weeds were recorded when black polyethylene mulch was applied in combination with NPK @ 190:45:50 kg ha⁻¹. However, maximum available soil nitrogen was recorded when pine needle mulch was applied at highest fertility level. Similarly, in PxL interaction, ridge method of

planting + NPK @ 310:75:100 kg ha⁻¹ recorded maximum plant height, fruit weight and number of fruits in bell pepper, whereas ridge method + NPK @ 190:45:50 kg ha⁻¹ produced minimum fresh and dry weight of weeds. In MxPxL interaction, the combination of pine needle mulch + ridge method + NPK @ 310:75:100 kg ha⁻¹ recorded maximum fruit yield per plant (790.90 g) and per hectare (297.90 q). However, the characters like plant height, number of branches per plant, fruits per plant and weed density were also influenced significantly with this interaction.

Maximum net returns of Rs.223 126.89 ha⁻¹ were obtained from treatment M₃P₁L₃ (Pine needle mulch + ridge method + NPK @ 310:75:100 kg ha⁻¹) with net returns of Rs.3.20 per rupee investment.

Conclusion

These studies conclusively demonstrated that:

1. The use of different mulches significantly increased the growth, yield and yield contributing components and reduced the weed and disease incidence effectively. However, pine needle mulch was found best among the mulches.
2. The planting of bell pepper seedlings on ridges at transplanting time proved to be beneficial as the plants grow vigorously on ridges and produced maximum fruit yield during the course of investigations.
3. The optimum dose worked out for obtaining high fruit yield was NPK @ 310:75:100 kg ha⁻¹.
4. The present studies have clearly demonstrated that for achieving higher fruit yields with maximum net returns per unit area in bell pepper hybrid under mid hill conditions of Himachal Pradesh the crop should be planted on ridges and pine needle mulch should be applied along with NPK @ 310:75:100 kg ha⁻¹.

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Appendix-I

Mean weekly meteorological data during experimental seasons (April 98 to September 98 and April 99 to September 99)

Month	Week days	Temperature (°C)		Relative humidity (%)	Rainfall (mm)
		Maximum	Minimum		
1998					
April	06-12	27.1	8.9	45.4	-
	13-19	28.0	9.9	42.5	-
	20-26	31.7	13.6	58.0	20.4
May	27-3	30.3	14.3	44.5	-
	04-10	29.0	13.6	46.2	21.4
	11-17	31.2	13.4	50.1	-
	18-24	33.3	16.3	49.9	41.6
	25-31	35.9	19.0	40.6	-
June	01-07	35.1	17.9	37.2	3.4
	08-14	29.8	17.1	57.6	125.0
	15-21	29.3	17.8	67.1	50.3
	22-28	32.4	20.1	61.2	-
July	29-05	28.8	21.1	84.0	60.2
	06-12	29.5	20.5	84.6	72.0
	13-19	28.5	20.2	84.2	33.0
	20-26	29.6	19.5	69.8	2.8
August	27-02	30.4	21.1	77.8	44.0
	03-09	29.4	19.6	80.7	1.0
	10-16	28.8	21.0	85.2	33.0
	17-23	26.0	20.3	85.3	39.2
	24-30	28.3	19.7	85.1	27.6
September	31-06	29.2	17.7	72.7	-
	07-13	28.6	17.9	80.8	18.6
	14-20	26.1	18.6	85.8	10.6
	21-27	24.3	17.2	86.6	170.5
	28-04	28.0	16.0	74.8	-
1999					
April	02-08	30.5	11.8	28.4	-
	09-15	31.7	13.0	27.8	-
	16-22	32.3	13.2	30.4	-
	23-29	34.4	15.7	38.1	-
May	30-06	35.6	18.6	31.0	-
	07-13	31.3	15.7	45.1	32.4
	14-20	30.8	16.3	47.6	3.7
	21-27	28.9	16.6	66.0	155.2
June	28-03	30.7	15.4	42.9	9.4
	04-10	30.5	16.4	52.6	22.0
	11-17	31.5	18.8	60.6	22.5
	18-24	29.3	19.1	67.8	18.5
	25-01	30.6	19.8	74.0	92.2
July	02-08	29.6	19.2	74.0	82.9
	09-15	28.7	19.7	76.0	40.3
	16-22	25.6	20.1	91.6	282.2
	23-29	28.4	20.5	81.9	15.1
August	30-05	28.7	20.5	83.0	32.5
	06-12	27.0	19.9	88.2	56.3
	13-19	28.7	18.4	73.6	38.3
	20-26	27.6	20.0	75.6	23.6
September	27-02	29.6	17.1	73.5	-
	03-09	27.5	18.4	81.4	28.0
	10-16	28.1	16.1	79.6	30.0
	17-23	27.2	18.2	81.3	79.0
	24-30	27.8	16.2	81.3	12.4

Source: Meteorological Observatory, Department of Soil Science and Water Management, Dr YS Parmar University of Horticulture and Forestry, Solan 173 230

Appendix-II

Analysis of variance (ANOVA) for various characters in bell pepper hybrid Bharath

Source of variation	df	Mean sum of squares																				
		Days to 50% flowering	Plant height (cm)	Number of branches (g)	Fruit length (cm)	Fruit breadth (cm)	Fruit weight (g)	No. of fruits/plant	Fruit yield/plant (g)	Fruit yield (q/ha)	Harvest duration (days)	Fruit rot incidence (%)	Shoot biomass (kg/ha)	N-content (%)	P-content (%)	K-content (%)	Weed density (No./0.25m ²)	Fresh weight of weed (g/0.25m ²)	Dry weight of weed (g/0.25m ²)	Available N (kg/ha)	Available P ₂ O ₅ (kg/ha)	Available K ₂ O (kg/ha)
1998																						
Replication(R)	2	43.72	112.93*	0.082	3.49	2.77	54.05	0.30	1316.70	180.62	55.50	0.002	21981.00	0.039	0.004	0.051	39.39	270.29	18.76*	134.20	1.97	22.16*
Mtch (M)	3	268.36*	328.85*	1.133	3.00	3.84*	380.12*	47.45*	326690.00*	44813.00*	188.49*	2.217*	703660.00*	0.785*	0.032*	1.191*	3086.7*	13560.00*	393.70*	2460.90*	140.18*	200.20
Error (A)	6	10.12	11.67	0.603	1.52	0.59	24.28	0.61	3578.00	490.80	22.61	0.036	12985.00	0.036	0.002	0.045	19.57	45.65	2.70	197.56	6.34	3.27
Planting methods (P)	1	37.50*	91.39*	0.005	0.22	0.84	153.67*	16.53*	121050.00*	16605.00*	7.04	0.064*	4960.40	0.382*	0.005	0.002	816.67*	1768.20*	128.34*	150.00*	19.26*	36.26*
MxP	3	7.19	83.46*	0.289	0.59	0.50	27.96	0.85	2808.60	385.26	26.04	0.019	21817.00*	0.543*	0.002	0.003	28.53	121.14	5.26	47.25	1.95	1.93
Error (B)	8	4.27	16.73	0.141	2.30	0.95	17.26	0.31	3164.10	434.04	29.67	0.009	5227.8	0.006	0.001	0.003	10.13	40.46	4.78	32.16	3.81	5.19
Fertility levels (L)	3	11.86*	17.97	0.145	0.06	0.66	19.96	8.61*	41570.00*	5702.30*	11057*	0.334*	36431.00*	0.500*	0.021*	0.100*	244.51*	51601*	31.23*	450.42*	33.37*	55.46*
MxL	9	0.66	40.16*	0.326*	0.77	0.20	13.66	1.45*	4160.50*	583.27*	11.38	0.057*	3141.70	0.222	0.002	0.001	44.63*	68.75*	3.83*	25.98*	0.79	1.31
PdL	3	0.53	67.87*	0.223	1.31	0.58	12.74	1.48*	2984.02	409.36	2.07	0.014	14981.00	0.024	0.001	0.001	12.75	50.42*	5.45*	1.58	0.37	3.51
MxPdL	9	0.66	19.34*	0.240*	0.87	0.35	7.66	0.99*	2701.04	370.56	5.96	0.009	4598.00	0.009	0.001	0.004	19.91*	89.72	2.29	9.54	0.44	0.95
Error (C)	48	2.80	6.80	0.081	0.81	0.28	13.97	0.37	2023.80	277.61	23.63	0.023	12168.00	0.011	0.002	0.006	9.23	17.84	1.21	7.97	1.45	2.80
1999																						
Replication(R)	2	164.14*	83.18	0.356	2.26	1.50	31.77	0.53	1868.00	256.25	14.26	0.014	77710.00	0.188	0.011*	0.038	3.17	21.76	7.32*	414.51	4.26	7.17
Mtch (M)	3	264.90*	244.85*	0.610	0.54	0.31	352.30*	37.72*	293770.00*	40298.00*	142.79*	3.179*	883460.00*	0.501*	0.043*	0.130*	1672.50*	11381.00*	299.25*	1514.60*	206.84*	366.04*
Error (A)	6	18.08	42.113	0.604	0.85	0.38	64.27	0.71	3059.30	419.66	25.58	0.025	45183.00	0.097	0.002	0.067	5.19	8.54	1.03	127.84	11.30	3.44
Planting methods (P)	1	135.37*	73.55	0.003	1.32	0.06	80.78*	27.92*	163130.00*	22378.00*	27.09	0.179*	1201.00	0.002	0.002*	0.003	270.01*	1675.00*	42.67*	48.17	23.01	49.59*
MxP	3	9.63	117.73	0.081	0.27	0.19	14.77	2.38	12583.00	1726.10	23.98	0.016	12642.00	0.005	0.0001	0.001	34.04*	224.29*	3.19	19.86	3.65	11.43
Error (B)	8	13.28	30.75	0.140	0.48	0.42	13.81	1.69	5307.00	727.98	29.67	0.020	3276.10	0.008	0.0001	0.001	7.19	30.34	1.19	38.28	5.02	7.31
Fertility levels (L)	3	26.07	34.92*	0.250	0.17	0.18	16.09	9.77*	49739.00*	6822.90*	117.70*	0.291*	51069.00*	0.670*	0.016*	0.082*	113.65*	63.82	7.03*	31215*	39.09*	83.21*
MxL	9	11.26	31.32*	0.317*	1.28	0.19	9.05	1.15	3632.90	498.34	9.22	0.055*	1573.90	0.013	0.0001	0.002	29.84*	28.13	1.11	13.22*	0.90	5.26
PdL	3	12.85	4.90	0.253	0.73	0.20	59.54*	1.08	492.24	67.52	8.68	0.004	12892.00	0.002	0.0001	0.005	14.68	28.96	0.86	0.50	0.18	2.48
MxPdL	9	12.43	25.49*	0.099	0.49	0.36	19.71	0.72	4722.60*	647.82*	8.16	0.007	5384.50	0.003	0.0001	0.001	13.71*	24.86	1.28	5.97	0.93	1.98
Error (C)	48	12.35	5.27	0.111	0.72	0.30	18.21	0.63	1951.90	267.75	19.39	0.013	8487.80	0.008	0.0001	0.001	6.21	35.72	1.34	6.38	1.57	3.55
Pooled																						
Replication(R)	2	174.13*	192.44*	0.38	0.27	0.10	4.74	0.04	1209.80	165.95	60.32	0.007	48552.00	0.197	0.013*	0.076	25.63	208.23*	24.19*	509.76	0.26	26.72*
Year (Y)	1	581.02*	616.38*	5.23*	8.47*	8.86*	334.44*	4.26*	2005.70	275.13	967.51*	5.840*	892000.00*	1.181*	0.011*	0.159	1126.20*	393.88*	35.88*	2394.20*	176.33*	500.52*
Mtches (M)	3	526.95*	501.98*	1.60	1.13	2.72*	725.79*	83.83*	618340.00*	84820.00*	328.98*	5.351*	1574100.00*	1.007*	0.074*	2.493*	4648.20*	24889.00*	686.14*	3784.30*	338.56*	539.68*
Y x M	3	6.31	71.72	0.14	2.41	4.17*	6.62	1.33	2117.80	290.42	2.30	0.043	12979.00	0.279*	0.0004	0.002	110.94*	52.05	6.81*	191.17	8.46	26.56*
Y x R	2	33.72	3.67	0.06	5.48*	1.44	81.08	0.79	1975.00	270.92	9.44	0.009	51139.00	0.030	0.002	0.012	16.92	83.82	1.89	38.95	5.97	2.59
Error (A)	12	14.10	26.89	0.60	1.19	0.48	44.28	0.66	3318.60	455.23	24.09	0.031	29084.00	0.066	0.002	0.056	12.38	27.09	1.87	162.70	8.82	3.36
Planting methods (P)	1	157.69*	164.45*	0.008	0.23	0.68	228.64*	43.70*	282620.00*	38768.00*	30.88	0.229*	639.91	0.162*	0.007*	0.00005	1012.90*	3442.50*	159.51*	184.08*	42.19*	85.33*
Y x P	1	15.19	0.48	0.28	1.31	0.22	5.81	0.74	1566.70	214.91	3.26	0.014	5521.4	0.223*	0.0005	0.005	73.76*	0.63	11.50	14.08	0.08	0.52
MxP	3	8.48	175.65*	0.0002	0.48	0.63	35.50	2.12	11871.00	1628.40	42.89	0.027	29625.00*	0.231*	0.0007	0.0007	53.58*	336.89*	7.94	25.13	2.09	7.59
Y x M x P	3	8.34	25.53	0.09	0.38	0.07	7.23	1.12	3520.60	482.93	7.13	0.008	4833.40	0.317*	0.001	0.003	8.99	8.53	0.52	41.99	3.51	5.76
Error (B)	16	8.78	23.74	0.14	1.39	0.72	15.53	1.00	4235.60	581.01	29.67	0.015	4252.00	0.007	0.0007	0.002	8.66	35.40	2.98	35.22	4.42	6.26
Fertility levels (L)	3	33.59*	45.90	0.26	0.01	0.16	34.49	17.88*	90391.00*	12399.00*	227.80*	0.612*	84678.00*	1.162*	0.036*	0.180*	344.06*	429.55*	33.67*	755.62*	72.23	136.60*
Y x L	3	4.34	6.98	0.13	0.22	0.67	1.56	0.49	917.11	125.80	0.48	0.014	2821.40	0.009	0.0002	0.002	14.10	150.28*	4.59*	6.95	0.24	2.06
MxL	9	6.58	58.51*	0.56*	1.25	0.32	17.93	2.17*	6925.20*	949.96*	18.23	0.077	3184.00	0.019	0.0009	0.004	66.54	36.16	1.13	23.21*	0.60	2.07
PdL	3	8.45	31.75*	0.46	0.10	0.25	59.92*	1.84*	2924.20	401.13	3.30	0.014	22306.00	0.011	0.0006	0.002	20.94	7.19	2.27	0.85	0.23	5.93
Y x M x L	9	5.33	12.97*	0.08	0.81	0.08	4.77	0.43	668.14	91.651	7.45	0.035	1531.60	0.014	0.0007	0.0009	7.94	60.71	3.82*	15.99*	1.08	4.49
Y x PdL	3	4.92	41.03*	0.01	1.97	0.53	12.36	0.72	552.24	75.753	2.38	0.003	5566.10	0.014	0.0009	0.003	6.49	72.17*	4.05*	1.24	0.32	0.06
MxPdL	9	6.48	33.86*	0.24*	0.96	0.53	19.91	1.51*	6984.30*	958.06*	10.98	0.007	7048.00	0.009	0.0008	0.003	21.22	50.34	1.22	4.94	0.78	0.88
Y x M x PdL	9	6.61	10.96	0.09	0.39	0.18	7.46	0.21	439.71	60.32	3.14	0.008	2934.60	0.002	0.0008	0.001	12.39	64.24*	2.36	10.57	0.58	2.06
Error (C)	96	7.58	6.03	0.09	0.76	0.29	16.09	0.50	1987.90	272.68	21.51	0.018	10328.00	0.009	0.0008	0.003	7.72	26.78	1.27	7.17	1.51	3.17

*Significant at 5 per cent level

Appendix-III

ANOVA for soil moisture and temperature as influenced by different mulches

Source of variation	df	Mean sum of square			
		Soil moisture		Soil temperature	
		1998	1999	1998	1999
Replication (R)	2	0.12	0.06	2.26	1.44
Mulches (M)	3	64.99*	93.46*	250.31*	266.63*
Dates (D)	8	30.55*	25.88*	55.55*	29.10*
MxD	24	0.19	0.64	1.29	3.79*
Error	70	0.42	0.71	1.18	1.20

*Significant at 5% level

Appendix-IV

Cost of cultivation (Rs.ha⁻¹)

A. Fixed Inputs

a) Nursery management

i)	Cost of 250 g seed @ 50000 kg ⁻¹	12500.00
ii)	Soil fumigation with 40% formation (1): water (9)	820.00
	Quantity required for 1 bed = 10 L For 10 bed = 100 L (10:90) Cost of 1 L = Rs.82.00	
iii)	FYM = 25 kg per bed and for 10 beds = 250 kg @ Rs.28 q ⁻¹	70.00
iv)	Single superphosphate (SSP) 200 g per for 10 beds 2 kg @ Rs.2.85 kg ⁻¹	5.70
v)	CAN 200 g per bed and for 10 beds 2 kg @ Rs.4.08 kg ⁻¹	8.16
vi)	Fungicide (Dithane M-45) 20 g per bed and for 10 beds 200 g @ Rs.225 kg ⁻¹	45.00
vii)	Insecticide 20 g/bed and for 10 beds 200 g @ Rs.20 kg ⁻¹	4.00
viii)	Labour charges for preparation of beds, soil fumigation and nursery care, 20 labourers @ Rs.45.75/day	915.00

b) Preparatory tillage

i)	3 ploughings @ Rs.500	1500.00
ii)	3 plankings @ Rs.150	450.00
iii)	Preparation of beds and channels 30 labourers @ Rs.45.75 per day	1372.50

c) Transplanting and mulching

	60 labourers @ Rs.45.75/day	2745.00
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d)	Watering of seedlings for 7 days 2 labourers per day = 14 labourers @ Rs.45.75/day	640.50
e)	Manuring: 20 tonnes FYM @ Rs.28 q ⁻¹	5600.00
f)	Labour charges on carriage and application of FYM and fertilizers 25 labourers @ Rs.45.75/day	1143.75
g)	Cultural operations	2745.00
	i) Weeding, hoeing and gap filling 60 labourers @ Rs.45.75	
	ii) 4 irrigations including worker charges	915.00
h)	Plant protection measures	
	i) Cost of insecticides/fungicides	2000.00
	ii) 4 sprays (12 labourers @ Rs.45.75/day)	549.00
i)	Harvesting	
	i) Picking (5 pickings) 75 labourers @ Rs.45.75 per day	3431.25
	ii) Transportation	6000.00
j)	Miscellaneous charges (Land revenue, interes on capital depreciation)	12000.00
	Grand Total	55458.86

B. Variable inputs

a)	Cost of fertilizers	
	i) Fertilizer level (L ₁)	
	N 760 kg CAN	3100.80
	P 281.25 kg SSP	798.75
	K 83.50 kg MOP	367.40
		4266.95
	ii) Fertilizer level (L ₂)	
	N 1000 kg CAN	4080.00

	P 375 kg SSP	1065.00
	K 125.25 kg MOP	551.10
		5696.10
iii)	Fertilizer level (L_3)	
	N 1240 kg CAN	5059.20
	P 468.75 kg SSP	1331.25
	K 167.00 kg MOP	734.80
		7125.25
iv)	Fertilizer level (L_4)	
	N 1480 kg CAN	6038.40
	P 562.50 kg SSP	1597.50
	K 208.75 kg MOP	918.50
		8554.40
b)	Cost of planting methods	
i)	Raised beds (P_1)	2745.00
	60 labourers @ Rs.45.75/day	
ii)	Flat beds (P_2)	-
C.	Cost of mulches	
i)	Black polyethylene (M_1)	
	60% coverage. Use two times.	
	Resale @ Rs. 10 kg ⁻¹	
	Polyethylene loss 5% per year	
	@ 289 g/plot (5.40 m ²)	9760.00
ii)	Transparent polyethylene (M_2)	
	60% coverage. Use two times.	
	Resale @ Rs. 10 kg ⁻¹	
	Polyethylene loss 5% per year	
	@ 289 g/plot (5.40 m ²)	9760.00
iii)	Pine needle mulch (M_3)	
	@ 4 kg/plot (60% coverage)	4444.00
iv)	No mulch (M_4)	-

Price:

CAN	@ Rs. 4.08 kg ⁻¹
SSP	@ Rs. 2.84 kg ⁻¹
MOP	@ Rs. 4.40 kg ⁻¹
Polyethylene	@ Rs. 80.00 kg ⁻¹
Pine needle mulch	@ Rs.100 q ⁻¹

Treatment cost

1.	M ₁ P ₁ L ₁	9760+2745+4266.95	16771.95
2.	M ₁ P ₁ L ₂	9760+2745+5696.10	18201.10
3.	M ₁ P ₁ L ₃	9760+2745+7125.25	19630.25
4.	M ₁ P ₁ L ₄	9760+2745+8554.40	21059.40
5.	M ₁ P ₂ L ₁	9760+0 +4266.95	14026.95
6.	M ₁ P ₂ L ₂	9760+0 +5696.10	15456.10
7.	M ₁ P ₂ L ₃	9760+0 +7125.25	16885.25
8.	M ₁ P ₂ L ₄	9760+0 +8554.40	18314.40
9.	M ₂ P ₁ L ₁	9760+2745+4266.95	16771.95
10.	M ₂ P ₁ L ₂	9760+2745+5696.10	18201.10
11.	M ₂ P ₁ L ₃	9760+2745+7125.25	19630.25
12.	M ₂ P ₁ L ₄	9760+2745+8554.40	21059.40
13.	M ₂ P ₂ L ₁	9760+0 +4266.95	14026.95
14.	M ₂ P ₂ L ₂	9760+0 +5696.10	15456.10
15.	M ₂ P ₂ L ₃	9760+0 +7125.25	16885.25
16.	M ₂ P ₂ L ₄	9760+0 +8554.40	18314.40
17.	M ₃ P ₁ L ₁	4444+2745+4266.95	11455.95
18.	M ₃ P ₁ L ₂	4444+2745+5696.10	12885.10
19.	M ₃ P ₁ L ₃	4444+2745+7125.25	14314.25
20.	M ₃ P ₁ L ₄	4444+2745+8554.40	15743.40
21.	M ₃ P ₂ L ₁	4444+0 +4266.96	8710.95
22.	M ₃ P ₂ L ₂	4444+0 +5696.10	10140.10
23.	M ₃ P ₂ L ₃	4444+0 +7125.25	11569.25
24.	M ₃ P ₂ L ₄	4444+0 +8554.40	12998.40
25.	M ₄ P ₁ L ₁	0+2745+4266.95	7011.95
26.	M ₄ P ₁ L ₂	0+2745+5696.10	8441.10
27.	M ₄ P ₁ L ₃	0+2745+7125.25	9870.25
28.	M ₄ P ₁ L ₄	0+2745+8554.40	11299.40
29.	M ₄ P ₂ L ₁	0+0 +4266.95	4266.95
30.	M ₄ P ₂ L ₂	0+0 +5696.10	5696.10
31.	M ₄ P ₂ L ₃	0+0 +7125.25	7125.25
32.	M ₄ P ₂ L ₄	0+0 +8554.40	8554.40

Curriculum Vitae

Name Kuldeep Singh Thakur
Father's Name Sh N R Thakur
Date of birth 28.02.1969
Sex Male
Marital status Married
Nationality Indian

Educational qualifications

Certificate/ Degree	Class/ Grade	Board/University	Year
10+2	First	Himachal Pradesh Board of School Education	1989
B.Sc.(Hort)	First	Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, HP	1993
M.Sc.(Hort) Vegetable Crops	First	Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, HP	1996

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

Scholarship/stipend/fellowship/any other financial assistance received during

- | | |
|------------|------------------------------|
| i) 10+2 | Merit Scholarship |
| ii) B.Sc. | University Merit Scholarship |
| iii) M.Sc. | University Stipend |
| iv) Ph.D. | University Stipend |

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Title of the Thesis : "Response of bell pepper hybrid cv. Bharath to cultural practices"
 Name of the Student : Kuldeep Singh Thakur
 Admission Number : H-96-16-D
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 Degree awarded : Ph. D. Horticulture (Vegetable Crops)
 Year of Award of Degree : 2000
 Total pages in Thesis : 95 + ix + VIII
 Number of words in abstract : 519

ABSTRACT

The field experiments were conducted at Research Farm of the Department of Vegetable Crops, Dr. YS Parmar University of Horticulture & Forestry, Nauni, Solan (HP) during the kharif seasons of 1998 and 1999 on a well drained sandy loam soil. There were four mulch treatments (M_1 -Black polyethylene mulch; M_2 -Transparent polyethylene mulch; M_3 - Pine needle mulch and M_4 -control or no mulch), two planting methods (P_1 -Ridge method and P_2 -Flat bed method) and four levels of NPK (L_1 -190:45:50 kg NPK ha⁻¹; L_2 -250:60:75 Kg NPK ha⁻¹; L_3 -310:75:100 kg NPK ha⁻¹ and L_4 370:90:125 kg ha⁻¹). The trials were laid out in Split-Split plot design keeping mulches in main plots, planting methods in sub-plots and fertility levels in sub-sub plots with three replications. The seedlings of bell pepper hybrid cv. Bharath were spaced at 60x45 cm. The observations were recorded on days to 50 per cent flowering, plant height, number of branches per plant, fruit length, breadth and weight, fruits per plant, fruit yield per plant and per hectare, harvest duration, fruit rot incidence, shoot biomass, weed density, fresh and dry weight of weeds, soil moisture content, soil temperature, NPK content of leaves, available soil NPK after harvest and economics of the crop. Amongst the mulch materials the use of pine needle mulch proved to be most effective to promote the plant height, number of fruits per plant, harvest duration, shoot biomass and NPK content of bell pepper leaves. Maximum fruit yield (255.80 q ha⁻¹) was obtained with the application of this mulch as it helped in conserving the soil moisture, provided favourable soil temperature for the proper growth and development of the crop and reduced the fruit rot incidence. However, the black polyethylene mulch proved to be the best in controlling the weed population. Ridge method of planting was most effective in advancing the flowering in bell pepper and reducing the disease and weed incidence and hence produced significantly higher fruit yield in comparison to flat bed method thus ensuring the proper drainage for good crop health. The fertility levels significantly influenced the plant height, number of fruits per plant and fruit yield per plant and per hectare. The maximum fruit yield (225.60 q ha⁻¹) was obtained with the application of NPK @ 310:75:100 Kg ha⁻¹. Among the first order interactions, mulch x fertility levels (MxL) interaction influenced most of the characters under study whereas, mulches x planting methods (MxP) and planting methods x fertility levels (PxL) interaction had significant effect on few of them. The maximum fruit yield was obtained when pine needle mulch was applied along with NPK @ 310:75:100 Kg ha⁻¹ during both the years of investigations. The interaction effects of mulches, planting methods and fertility levels also exhibited significant influence on growth and fruit yield of bell pepper hybrid as the maximum fruit yield (297.90 q ha⁻¹) was obtained with a treatment combination of pine needle mulch + ridge method + NPK @ 310:75:100 kg ha⁻¹ with a maximum returns and benefit cost ratio to the tune of Rs. 223126.89 ha⁻¹ and 3.20, respectively.

Signature of Chairman *B. S. Mehta*
 27.6.2000

Signature of Student *K. S. Thakur*
 27.6.2000

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