5. SUMMARY AND CONCLUSIONS

The present investigations regarding the evaluation of various organic inputs and environmental factors affecting diseases coupled with an insight into developing ecofriendly management strategies were carried out and results obtained are summarized as follows.

Polyhouses of six districts namely Kangra, Hamirpur, Mandi, Una, Bilaspur and Kullu were surveyed and per cent disease incidence/severity of five major diseases viz., bacterial wilt, powdery mildew, Phytophthora blight, anthracnose and collar rot of bell pepper was recorded. Among these, bacterial wilt and powdery mildew were found to be prevalent and widely distributed in all the locations. Maximum incidence (83.3%) of bacterial wilt was recorded in Zmanabad followed by 70.5 per cent in Sai (Kangra) and 60.6 per cent in Sundernagar (Mandi). Powdery mildew was present in more severe form in district Kullu followed by Bilaspur, Una and Mandi, respectively. Phytophthora blight was observed maximum in Sundernagar i.e. 50.7 per cent and other diseases were minor in occurrence in all the areas surveyed.

Farmers’ polyhouses were selected at four locations viz., Rajol, Chauntra, Sungal and Palampur in Kangra district. Disease progress of two major diseases of bell pepper i.e. bacterial wilt and powdery mildew was recorded at weekly intervals during the cropping period. Increase in disease severity of powdery mildew was observed upto 11th week and after 12th week it became stable. While disease incidence of bacterial wilt was increased till 10th.

There was a positive correlation \([r = 0.802 \text{ (Rajol)}, 0.823 \text{ (Chauntra)} \text{ and } 0.929 \text{ (University Vegetable Farm)}]\) between disease severity of powdery mildew and maximum temperature. The correlation coefficients between minimum temperature and relative humidity were non significant. Multiple correlation coefficients between disease severity and all studied weather variables were
highly significant at all the three locations. Coefficient of determination revealed that all the weather variables contributed upto 74.3, 78.2 and 87.2 per cent towards disease severity at Rajol, Chauntra and University vegetable farm, respectively. Correlation coefficient \((r = 0.817, 0.916 \text{ and } -0.798)\) between disease incidence of bacterial wilt and maximum temperature was positive and highly significant at Rajol and University Vegetable Farm but negative and non significant at Sungal. Multiple correlation coefficients between disease incidence and all studied weather variables were highly significant at all the three locations. Coefficient of determination revealed that all the weather parameters contributed upto 81.2, 81.5 and 85.6 per cent towards disease incidence at Sungal, Rajol and University vegetable farm, respectively.

Six organic inputs namely vermiwash, fermented butter milk, biosol, panchgavya, biodynamic compost and matka khad were tested under \textit{in vitro} and \textit{in vivo} conditions against \textit{Ralstonia solanacearum} individually and in different combinations. \textit{In vitro} testing revealed that biodynamic compost tea provided maximum (95.6\%) inhibition of the bacterium followed by biosol at 4 per cent concentration. Under \textit{in vivo} conditions, the survivability of capsicum seedlings after 15, 30 minutes and one hour dipping in organic inputs was determined and the new formulation Orguard was found most effective against bacterial wilt.

\textit{In vitro} evaluation of five organic inputs (vermiwash, biosol, panchgavya, fermented butter milk and fermented cow urine) at different concentrations revealed that fermented cow urine is strongly inhibitory to all the fungal pathogens of capsicum (\textit{Sclerotium rolfsii, Fusarium oxysporum f.sp. capsici, F. solani, Colletotrichum capsici, Phytophthora nicotianae, Rhizoctonia solani} and \textit{Sclerotinia sclerotiorum}) followed by panchgavya and vermiwash, respectively. Fermented butter milk was found least effective against the test pathogens.

Organic inputs when spread on nutrient agar medium showed the presence of total 92 isolates, but only 12 isolates exhibited strong antifungal properties against test pathogens. These were identified on the basis of
morphological and biochemical characteristics as the species of *Bacillus*, *Pseudomonas*, *Serratia* and Actinomycetes. Based on *in vitro* evaluation, three isolates of *Bacillus* (AB8_{B2}, AP13_{B4} and AM15_{B5}), one each of *Serratia* (AP18_{S}) and Actinomycetes (AV10_{A2}) showed strong antifungal activity against pathogens of capsicum.

The antagonistic bacterial isolates also exhibited plant growth promoting traits such as phosphate solubilization, IAA production, siderophore production, proteolytic activity, nitrogenase enzyme activity and ammonia production. Among these, species of *Bacillus* and *Serratia* possessed maximum number of probiotic characteristics.

Aqueous and organic extracts and cow urine distillates of five botanicals viz., *Ranunculus muricatus*, *Melia azedarach*, *Vitex negundo*, *Eupatorium* sp. and *Murraya koenigii* were evaluated against *Sclerotium rolfsii*, *Fusarium oxysporum* f.sp. *capsici*, *F. solani*, *Colletotrichum capsici*, *Phytophthora nicotianae*, *Rhizoctonia solani* and *Sclerotinia sclerotiorum* at different concentrations. Out of these, distillates of *Vitex negundo* and *Murraya koenigii* provided the complete inhibition (100%) of all the test pathogens at 10 per cent concentration. Although the aqueous extracts were comparatively more inhibitory than organic extracts and aqueous extracts of *M. koenigii* and *V. negundo* showed more than 90 per cent mycelial inhibition of test pathogens at 100 per cent concentration.

Trials on the management of diseases of bell pepper under protected cultivation were conducted at four locations viz., Rajol, Sungal, Chauntra (farmers’ polyhouses) and University Vegetable Farm. Effectiveness of organic inputs individually and in combinations was evaluated at all the locations in integrated manner. Twelve treatments were tested in two varieties (US-181 and Peppera Pepper) at Sungal for the management of bacterial wilt of capsicum and drench of the new formulation i.e. Orguard at 15 days interval provided 85 per cent control of bacterial wilt in both the varieties. Similar treatments were evaluated at Rajol and University vegetable farm on four (Indra, Bharat, Rv-1049-
09 and Rv-824-09) and two varieties (Mekong and Peppera Pepper), respectively against bacterial wilt, Phytophthora blight, anthracnose and powdery mildew and results obtained revealed that the drench of Orguard at 15 days interval gave maximum control of bacterial wilt followed by Phytophthora blight and anthracnose in variety Indra and Peppera Pepper while it was least effective against powdery mildew. Effect of organic inputs was tested against powdery mildew at three locations (Chauntra, Rajol and University vegetable farm) and spray of milk in combination with asafoetida and sulphur showed more than 80 per cent disease control.

Conclusions

- Bacterial wilt and powdery mildew are two major pathological constraints in capsicum under protected cultivation in Himachal Pradesh.

- Maximum daily temperature was found to have positive correlation between severity of powdery mildew and bacterial wilt. However, negative correlation was observed with minimum temperature and relative humidity on the diseases of capsicum.

- The growth of all capsicum pathogens viz., Sclerotium rolfsii, Fusarium oxysporum f.sp. capsici, F. solani, Colletotrichum capsici, Phytophthora nicotianae, Sclerotinia sclerotiorum, Rhizoctonia solani and Ralstonia solanacearum is inhibited by various organic inputs namely fermented cow urine, panchgavya, vermiwash, biosol and fermented butter milk to the tune of 90-100 per cent.

- Ninety two microbes were isolated from organic inputs. Out of which, twelve showed antifungal activity against all the pathogens of capsicum. These isolates also exhibited probiotic characteristics like phosphate solubilization, IAA production, siderophore production, lytic enzyme activity, nitrogenase activity and ammonia production.

- Effective combinations of organic inputs as identified under in vitro experiments were evaluated under farmers’ polyhouses at four locations.
A combination of five organic inputs was found most effective in the management of capsicum diseases.

- New formulation “ORGUARD” was designed using an unique combination of organic inputs which provided more than 85 per cent control of soil borne diseases caused by *Ralstonia solanacearum*, *Sclerotium rolfsii*, *Fusarium oxysporum* f.sp. *capsici*, *F. Solani*, *Rhizoctonia solani* and *Sclerotinia sclerotiorum* when applied as drench at 15 days interval under protected cultivation.

- Spray of milk in combination with asafoetida and sulfur was found effective for the management of powdery mildew of capsicum under protected cultivation.