5. SUMMARY AND CONCLUSIONS

The present investigations on organic management of buckeye rot of tomato caused by *Phytophthora nicotianae* var *parasitica* were conducted. Various organic inputs and antagonists were evaluated against buckeye rot in order to develop integrated organic disease management schedule. Since the disease has become a limiting factor in the cultivation of tomato in Himachal Pradesh. Bioagents and organic inputs were tested against the pathogen under *in vitro* conditions and the best ones were employed against the disease under field conditions by using them as seedling-dip, soil treatment and sprays along with recommended cultural practices such as raised seed-bed, mulch and staking.

Sixteen sites at three different locations were surveyed around Mandi and Palampur tomato growing areas and samples were collected. Isolations were made, pure cultures developed and the pathogenicity was proved. The pathogen associated was identified to be *Phytophthora nicotianae* var *parasitica* on the basis of microscopic, cultural and molecular characteristics.

Out of seven different media evaluated, potato dextrose agar was selected for further studies on the basis of mycelial growth characteristics and sporangial formation. Sixteen fungal and bacterial cultures isolated from tomato phyllosphere were evaluated *in vitro* but none of these showed complete inhibition of buckeye rot pathogen.

Forty three bacterial strains were isolated from various ITK based organic inputs and were evaluated against buckeye rot pathogen *in vitro*. Sixteen isolates inhibited the growth of the pathogen completely which were further evaluated against the disease under laboratory conditions following three methods a). Fruit dip followed by inoculation (M1) b). Fruit dip – injury - inoculation (M2) and c). Injury - fruit dip- inoculation. All thirteen isolates except KBmB$_1$, KBfuB$_2$, KScB resulted in complete control of the disease compared to 50 per cent disease in control. In M2 treatments only one strain i.e. KLCuB$_3$ completely controlled the disease and isolates KBmB$_1$, KCmB$_1$, KCmB$_3$, and KJbB$_2$ resulted in 16.67, 16.67, 33.34 and 33.34 per cent disease, respectively. In all
other treatments, the disease level was less than 20 per cent. No disease development took place when bacterial strains KLCuB<sub>3</sub> and KJbB<sub>2</sub> was tested by M3 method. Four strains namely KBfuB<sub>2</sub>, KCuB, KJbB<sub>2</sub> and KScB resulted in less than 20 per cent disease.

Four organic inputs viz., himsol, matkakhad, panchgavya and vermiwash were tested in vitro against the pathogen at different concentrations under sterilized and unsterilized conditions respectively by 'Poison Food Technique'. Complete inhibition of the pathogen growth was recorded, when the products were used without autoclaving, whereas after sterilization, maximum inhibition percentage was recorded only at 10 per cent concentration which was 12.41, 17.77, 100 and 19.81 per cent with himsol, matkakhad, panchgavya and vermiwash respectively. Panchgavya resulted in complete inhibition of pathogen growth and was selected for further investigations.

Fresh and fermented desi cow products namely butter milk, cow milk and cow urine were evaluated against the pathogen and complete inhibition was recorded at all the concentrations, when the products were tested without autoclaving. Cow urine was found to be most effective when used as fresh, 70 per cent inhibition of the pathogen was recorded while after fermentation 100 per cent inhibition was recorded at both 8 and 10 per cent concentration. Fresh buttermilk and cow milk at all concentrations promoted the growth of pathogen from 15.9-46.44 per cent and from 15.72-33.33 per cent, respectively at 1-10 per cent concentration whereas when both the products were fermented, inhibited the growth of the test pathogen to the tune of 25.29-35.01 and 12.84-26.07 per cent, respectively at all the concentrations evaluated.

The urines collected from different cow groups viz. buffalo, desi cow, Jersey bull, Jersey cow, local bull and she-calf of local cow were compared in vitro both under sterilized and unsterilized conditions by Poison Food Technique. Complete inhibition was recorded when urine of desi cow and she-calf was tested without autoclaving at all the concentrations (1, 2, 4, 6, 8 and 10 %) whereas urine of Jersey bull at 2 per cent and above and local bull at 4 per cent and higher concentration completely inhibited the growth of test pathogen. In case of buffalo urine, maximum inhibition was recorded up to 76.67 per cent at 10 per cent concentration.
The standard bioagents (obtained from the Department of Plant Pathology, CSKHPKV, Palampur) were evaluated against the pathogen and *Trichoderma koningii* (*DMA-8*) resulted in highest per cent inhibition i.e. 51.93 per cent followed by *T. koningii* (*JMA-11*), *T. harzianum* (*SMA-5*) and *Trichoderma harzianum* (*JMA-4*) resulting in 44.58, 39.53 and 9.53 per cent inhibition, respectively.

Aqueous extract of marigold leaves completely inhibited the growth of the pathogen followed by turmeric, black pepper, garlic (lyophilized powder) and garlic (oven dried powder) which inhibited the pathogen growth by 50.34, 31.93, 11.09 and 8.87 per cent, respectively. Crude extracts obtained from *Eupatorium adenophorum* @ 0.5 per cent and *Melia azedarach* @1 per cent without sterilization completely inhibited the mycelial growth of the pathogen. On the other hand, when crude extract was sterilized, complete inhibition of the pathogen was recorded at 2 and 2.5 per cent concentration, respectively.

Amongst water soluble oils, pine oil at 1-10 per cent concentrations with and without sterilization resulted in complete inhibition of the pathogen. The range of inhibition in case of neem oil varied from 20.92-82.22 per cent after autoclaving while it ranged between 41.67 to 76.11 per cent without autoclaving. The tree spray oil was least effective causing 28 and 60 per cent inhibition with and without autoclaving respectively.

Different Panchgavya (Pg) formulations were prepared in order to reduce the cost of 'Panchgavya' by substituting ghee with different oils (apricot oil, castor oil, linseed oil and sesame/til oil) and were evaluated *in vitro* both fresh and after 20 days of fermentation under sterilized and unsterilized conditions. All such formulations completely inhibited the mycelial growth of pathogen at 1 per cent concentration under unsterilized conditions. Standard Panchgavya inhibited the growth of the pathogen completely at 10 per cent concentration when sterilized. In case of castor oil and linseed oil substituted formulations, complete inhibition was recorded at 6 and 8 per cent concentration, respectively. Maximum mycelial growth inhibition i.e. 75.37 and 58.89 per cent was recorded in case of apricot and sesame oil substituted formulations, respectively at 10 per cent conc. Out of various formulations castor oil substituted formulation was found to be most effective followed by linseed oil, desi ghee, apricot oil
and sesame oil respectively. After fermentation, all the formulations resulted in higher inhibition percentage compared to unfermented ones. Standard and linseed substituted panchgavya were found at par in inhibiting the pathogen growth.

In case of organic inputs, all the products except butter milk resulted in complete control of the disease in case of M1 method. *Eupatorium*, pine oil, panchgavya substituted with linseed oil and *Trichoderma* (DMA-8) completely controlled the disease whereas biospray, butter milk and cow urine resulted in 16.67 per cent disease in all the cases. In treatment M3 also, butter milk, biospray and cow urine resulted in less than 50 per cent disease. The disease severity in various treatments varied from 0-16.67 per cent compared to 50 per cent disease in control in case of M1 method whereas it varied from 0-100 per cent and 0-66.68 per cent respectively in M2 and M3 methods. *Eupatorium*, pineoil, panchgavya and *Trichoderma* (DMA-8) completely controlled the disease incidence, under all three methods of inoculation.

Amongst six commercial products, sumona and *T. viride* resulted in complete control of the disease and less than 20 per cent disease incidence was recorded in case of bio sanjivni, biomycin and sun supreme compared to 50 per cent disease in control in M1 method. *T. viride* and Su-Mona resulted in less than 50 per cent disease incidence in case of M2 method. No disease appeared when the fruits were dipped in Su-Mona suspension after injury and then inoculated with the pathogen. Biomycin, sun supreme and *T. viride* resulted in less than 20 per cent disease incidence in this treatment. Disease severity varied from 0-33.34 per cent compared to 50 per cent disease in control in case of M1 method of treatment while in M2 and M3 methods, the disease severity varied from 16.67-100 per cent and 0-83.35 per cent, respectively. No commercially available product completely checked the disease.

Studies on susceptibility of fruits at various stages indicated that as the fruit stage progresses, the susceptibility decreases. Upto 70 days of fruit development, 100 per cent disease occurred under artificial inoculation whereas 80.58, 52.42 and 39.04 per cent disease developed after 71-75, 76-80 and 81-85 days of fruit development, respectively. In case of ripe fruits, lowest disease i.e. 31.15 per cent disease was recorded irrespective of fruit size.
Fruits from sixteen germplasm lines were evaluated against the buckeye rot disease under lab conditions both under normal and injured conditions. None of the lines screened was found resistant to the disease. However, Ptom resulted in the least infection (< 20%) without injury whereas the disease level increased up to 30% after injury. Palam Pride, BT-18, Arka Saurab, Hybrid 7704 and CLN 2123-A-1 Red showed 21-40% disease without injury but after injury only BT-18 and Palam Pride resulted in < 50% disease. All other lines screened resulted in more than 40% disease without injury which was further aggravated to > 50% when injured.

The tomato plants were sprayed with BTH (Benzo (1,2,3)-thiadiazole-7-carbothioic acid S-methyl ester) @ 200 mg/l to study the development of resistance development. The disease appeared after 14, 18 and 20 days of inoculation when the fruits were harvested after 2nd, 4th and 6th days of spray, respectively whereas in control the disease appeared on 8th day, indicating the role of BTH spray in inducing resistance in the tomato plant against the disease. Cent per cent fruit infection was recorded after 26 days of inoculation in case of fruits harvested after 2 days of spray while this level appeared on 30th day when fruits were harvested after 4th and 6th day of spray.

No disease developed on fruits placed after injury on soil either sterilized or drenched with panchgavya, neemastra, jeevamrit, ghniri extract and akshwan @10 per cent concentration while in all other cases the disease developed on fruits.

In the field experiment, organic sprays viz. *Eupatorium*, cow urine, panchgavya substituted with linseed oil (PgLO), biospray, DMA8 (*Trichderma* suspension), pine oil along with ridomil were tested to check the disease incidence and spread. Spray with the DMA8 resulted in minimum disease i.e. 15.68 per cent compared to 71.03 per cent disease in control. Other sprays viz. *Eupatorium*, ridomil, cow urine, PgLO, biospray and pine oil resulted to 17.10, 17.69, 22.25, 24.88, 25.34 and 31.88 per cent disease incidence and 68.40, 67.31, 58.09, 54.03, 53.18 and 41.65 per cent disease control, respectively. DMA8, *Eupatorium* and ridomil were found effective significantly in disease management whereas cow urine, PgLO and biospray are also at par with each other. Pine oil spray was found to be least effective.

The observation w.r.t per cent fruit infection after various organic sprays was recorded from the initiation of the disease till crop harvest. The AUDPC was calculated which shows that *Eupatorium* with 226.77 AUDPC was found to be best organic spray
followed by *Trichoderma* (DMA8), biospray, ridomil, cow urine, PgLO and pine oil which resulted in AUDPC as 408.54, 409.58, 409.68, 440.63, 502.31 and 521.49 respectively.

Minimum buckeye rot incidence i.e. 4.26 per cent was observed in case of plastic mulch +soil treatment with *Trichoderma* resulting in maximum 82.86 per cent disease control. Whereas other treatments i.e. M+SD+ST, M, SD+ST ,SD, M+SD, ST resulted in 8.33, 9.4, 11.11, 14.36, 16.13 and 18.01 per cent disease and 66.48, 62.17, 55.29, 42.21, 35.09 and 27.53 per cent disease control, respectively. M+ST was found significantly effective compared to M+SD+ST, M, SD+ST, which are at par with each other followed by SD, M+SD, ST. The observation w.r.t per cent fruit infection after various treatments was recorded from the initiation of the disease till crop harvest. The AUDPC was calculated which shows that M+SD+ST was found to be best treatment followed by M+ST, M+SD, SD, SD+ST, ST and M.

Correlation of weather parameters with disease severity indicates that relative humidity was positively correlated with disease development than temperature.