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Farmer participatory evaluation of an IPM technology in the management of major pests and diseases of tomato (*Solanum lycopersicum*) in Uttarakhand

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ABSTRACT

Farmer participatory field trials were conducted for assessing the effects of an Integrated Pest Management (IPM) technology for the management of major pests of tomato (*Solanum lycopersicum* L.). The experiment was conducted during March to October, 2016 and 2017 at three locations, viz. Kota Kwanu, Majhgaon Kwanu and Malot Kwanu in Chakrata block of district Dehradun, Uttarakhand, India on two popular, bacterial wilt resistant tomato hybrids, viz. Abhinav and Heamsohna. The various treatments were as follows: T_1, seed treatment with *Trichoderma* + *Pseudomonas* @ 20 g/kg of seeds: T_2, use of FYM @ 100 Q/ha fortified with *Trichoderma* + *Pseudomonas*; T_3, planting of Abhinav and Heamsohna; T_4, weekly hand picking and destruction of leaves, shoots and fruits infected by late blight; T_5, staking of plants; T_6, four applications of *cymoxanil* + *mancozeb* @ 2 g/l at 30, 45, 60- and 75 days after planting; and T_7, application of chlorantraniliprole 18.5% SC @ 0.3 ml/l at 65-days. Incidence of diseases such as late blight and bacterial wilt, and pests such as fruit borer, *Helicoverpa armigera* was significantly high in the control plots. The severity of pest and diseases was comparatively more in 2017 than 2016 due to conducive climatic conditions. Maximum yield (410 q and 400 q/ha) was recorded during 2016 and 2017, respectively due to IPM practices combining all possible components as compared to other treatments or control. As a result of enhanced fruit yield, the gross (₹ 615 000/ha and ₹ 800 000/ha) and net income (₹ 428 180/ha and ₹ 610 375/ha) were realized during 2016 and 2017, respectively. The cost benefit ratio was also maximum due to combination of all IPM components (1:2.3 and 1:3.22) both during 2016 and 2017, respectively. The IPM strategies combining all possible components proved significantly superior not only in effective management of major diseases and pests but also helped in realizing higher productivity and thereby enhanced income of tomato growers in remote tribal regions of Dehradun, Uttarakhand.

Key words: Bacterial wilt, Cost:benefit ratio, Fruit borer, IPM, Late blight, Tomato

Tomato (*Solanum lycopersicum* L.) (Solanaceae), is one of the commercially most important vegetable crops due to its varied uses. In India, tomato is grown in 0.774 million ha with a production of 18.732 million metric tonnes with an average productivity of 24.2 metric tonnes/ha and the area is on the increase (Anonymous 2017). With reference to Uttarakhand, the area, production and productivity figures are 8550.15 ha, 93223.49 metric tonnes and 10.9 metric tonnes/ha, respectively. Bestowed with excellent climatic conditions for cultivation of tomato during March to October, hilly regions of Uttarakhand produce excellent quality tomatoes during March to August with assured high net income to growers. With persistent demand, tomato is cultivated throughout the year in different parts of India. Although cultivation of tomato entail farmers with high cost of production, the premium price during May to August offset the same. In this regard, pest and diseases are the major constraints limiting the successful cultivation of tomato during March to August and also high temperature and heavy rains during March to August and July to August, respectively. In this regard, tomato hybrids 'Heamsohna' and 'Abhinav' are largely grown due to their high productivity, good fruit quality that fetches premium price. Heavy rains further compound the problem and make the management of a really difficult preposition for the farmers. Cost of chemical pesticides and labour further add to the woes. The major biotic factors that affect tomato cultivation in Uttarakhand are late blight and bacterial wilt and the fruit borer, *Helicoverpa armigera* (Tewari and Krishnamoorthy 1984, Sardana and Sabir 2007, Sardana and Bambawale 2011, and Singh *et al.* 2013. Majority of the farmers in Uttarakhand rely only on chemical pesticides for management of these diseases and pests due to lack of awareness on IPM. As a result, incidence of these pests has become one of the most important constraints in achieving the potential productivity of quality tomatoes. Farmers cultivate tomato in the month of February-March and harvesting starts from May onwards and during the same period, heavy rainfall is conducive for the incidence of late blight, bacterial wilt and fruit borer.

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Therefore, farmer participatory field trial was conducted to demonstrate the utility of an IPM technology for the management of pest and diseases on tomato in the hilly regions of Dehradun, Uttarakhand.

MATERIALS AND METHODS

The field trial was carried out at three locations namely Kota Kwanu, Majhgaon Kwanu and Malot Kwanu in Chakrata block of Dehradun district of Uttarakhand during the year 2016 and 2017. The trials were conducted by Krishi Vigyan Kendra, Dhakrani, Dehradun under Govind Ballabh Pant University of Agriculture and Technology, Uttarakhand. The tomato hybrids Abhinav and Heamsohna (Syngenta Seeds) were raised in well prepared nursery beds at 15 cm row to row spacing and 5 cm seed to seed spacing during the second week of February in both years. Four weeks old seedlings were planted at 60 cm row to row and 50 cm plant to plant spacing during second week of March, 2016 and 2017. The size of each plot was 20 m^2 (5m × 4m). In all, there were seven treatments comprising all possible components of Integrated Pest Management in various combinations. The farmers' practice and unsprayed plots were also maintained to serve as control for comparison (Table 1). The crop was supplemented with uniform doses of farmyard manure (20 tonnes/ha) and nitrogen (120 kg/ha), phosphorus (60 kg/ha) and potassium (80 kg/ha). Farmyard manure was mixed well in the soil at the time of last ploughing and mixed well in the soil at 15 days before planting. Full amount of phosphorus was applied as basal dose and mixed in the soil just before planting. Nitrogen (as urea) was applied in three equal splits at 30, 60 and 90 DAT; whereas, potassium (as muriate of potash) was applied in two equal splits at 30 and 90 DAT. Three hand weedings at 30-, 60- and 90-DAT were done at the time of nitrogen application through top dressing followed by earthing up. Seed treatment, staking and other pest and disease management and other operation were followed as per the treatment specification (Table 1).

The trial were laid out in a randomized block design (RBD) with seven treatments including; five IPM packages,

Table 1 Components of IPM

Treatment	Treatment × Specification
Treatment 1 (T_1)	Planting of bacterial wilt tolerant hybrids of tomato (Abhinav and Heamsohna). Seed treatment with *Trichoderma* + *Pseudomonas* @ 20 g/kg of seeds. Use of *Trichoderma* + *Pseudomonas* fortified FYM @ 100 q/ha. Weekly hand picking and destruction of leaves, shoots and fruits infected with late blight disease. Providing support to plants by staking to facilitate ventilation and sunlight in the interiors of plants for alleviating micro-climate and discourage pest and disease severity and enhanced plant and fruit growth, Four (need based) applications of cymoxanil + mancozeb @ 2 g/l at 30, 45, 60 and 75 days after planting (DAP) for management of late blight, and Application of chlorantraniliprole 18.5% SC @ 0.3 ml/l at 65-days after planting for management of fruit borer
Treatment 2 (T_2)	Planting of bacterial wilt tolerant hybrids of tomato (Abhinav and Heamsohna). Spraying of mancozeb @ 2 g/l water at 30, 45, 60 and 75 DAP for management of late blight disease. Spraying of imidacloprid @ 0.5 ml/l at 65, 80 and 95 DAP for management of fruit borer.
Treatment 3 (T_3)	Planting of bacterial wilt tolerant hybrids of tomato (Abhinav and Heamsohna). Four (need based) applications of cymoxanil + mancozeb @ 2 g/l at 30, 45, 60 and 75 days after planting (DAP) for management of late blight. Spraying of indoxacarb @ 0.5 ml/l at 65, 80 and 95 DAP for management of fruit borer.
Treatment 4 (T_4)	Planting of bacterial wilt tolerant hybrids of tomato (Abhinav and Heamsohna). Spraying of copper oxychloride @ 3 g/l at 30, 45, 60 and 75 DAP for management of late blight disease. Spraying of cypermethrin @ 1 ml/l at 65, 80 and 95 DAP for management of fruit borer. Providing support to plants by staking to facilitate ventilation and sunlight in the interiors of plants for alleviating micro-climate and discourage pest and disease severity and enhanced plant and fruit growth,
Treatment 5 (T_5)	Planting of bacterial wilt tolerant hybrids of tomato (Abhinav and Heamsohna). Spraying of cholorothalonil @ 2 g/l at 30, 45, 60 and 75 DAP for management of late blight disease. Spraying of acetamiprid @ 0.5 ml/l at 65, 80 and 95 DAP for management of fruit borer.
Treatment 6 (Farmers practice) (T_6)	Planting of bacterial wilt tolerant hybrids of tomato (Abhinav and Heamsohna). Spraying of mancozeb @ 2 g/l at 40, 50, 60, 70, 80 and 90 DAP for management of late blight. Spraying of quinalphos @ 2 ml/l or imidacloprid @ 0.5 ml/l at 35, 45, 55, 65, 75 and 85 DAP for management of fruit borer. Drenching with copper oxychloride 3g/l + streptocycline sulphate 100 ppm at 25, 35, 45, 50 and 70 DAP for management of bacterial wilt.
Treatment 7 (Control) (T_7)	Planting of bacterial wilt tolerant hybrids of tomato (Abhinav and Heamsohna) without staking or adopting pest and disease management practice.

one farmers practice and one untreated control; each replicated thrice. Spraying of chemical pesticides was done as per the treatment specification with knapsack sprayer using 600 l of spray solution per ha. Observations were recorded at weekly interval started 30 DAT on three leaves from top, middle and bottom portion of plants for incidence of late blight disease at all the three locations. Observations on per cent fruit borer infestation were recorded at 5, 10 and 15 days of each spray from ten randomly selected plants of each plot. For per cent fruit damage, the number of infested and healthy as well as weight of healthy and infested fruits from ten observational plants was recorded at each picking. The total weight of healthy and infested fruits for all picking was pooled and total yield per plot computed and converted into quintals per hectare. The data on incidence of bacterial wilt were also recorded at weekly intervals starting 20 days after transplanting. The number of infected plant was counted during each observation and finally the total infected plants with bacterial wilt per plot recorded and averages worked out for all the seven treatments at all the three locations. The economics of all the treatments was estimated and profit and cost: benefit ratio worked out.

RESULTS AND DISCUSSION

The observations recorded on incidence of major diseases such as late blight and bacterial wilt and, insect-pest such as fruit borer during 2016 and 2017 are summarized in Table 2 and Table 3. It is evident from data that the incidence of diseases such as late blight and bacterial wilt and the severity of insect-pest such as fruit borer on tomato were significantly influenced due to different treatments.

Incidence of diseases

The incidence of late blight varied from 3.71 to 49.48% during 2016 while it was 4.08 to 68.85 in 2017. The observations revealed that T_1 combining all possible components of Integrated Pest and Disease Management (IPDM) schedules such as (i) seed treatment with *Trichoderma* + *Pseudomonas* @ 20 g/kg of seeds, (ii) use of FYM @ 100 q/ha fortified with *Trichoderma* + *Pseudomonas*, (iii) planting of bacterial wilt tolerant tomato varieties such

Table 2 Effect of different treatments on pest and disease management and yield of tomato during 2016

Treatment	Incidence of late blight disease (%)		Incidence of bacterial wilt (%)	Infestation of fruit borer (%)	Yield (q/ha)**	Cost of cultivation (₹/ ha)	Gross income (₹/ha)*	Net income (₹/ha)	C:B ratio
	Plants	Fruits							
T_1	3.71 (2.05)	2.08 (1.61)	3.82 (2.08)	1.18 (1.30)	410.00	186820	615000	428180	2.30
T_2	36.24 (6.06)	17.60 (4.25)	12.53 (3.61)	18.70 (4.38)	284.14	136670	426210	289540	2.12
T_3	29.86 (5.51)	22.52 (4.80)	10.87 (3.37)	16.24 (4.09)	280.30	148340	420450	272110	1.83
T_4	27.92 (5.33)	19.55 (4.48)	13.10 (3.69)	14.62 (3.89)	272.26	146265	408390	262125	1.80
T_5	31.39 (5.65)	20.70 (4.60)	11.86 (3.52)	16.08 (4.07)	265.82	148948	398730	249782	1.68
T_6	33.06 (5.79)	22.45 (4.79)	12.38 (3.59)	17.88 (4.29)	260.00	145642	390000	244358	1.68
T_7 (Control)	49.48 (7.07)	44.96 (6.74)	38.58 (6.25)	34.89 (5.95)	159.88	108647	239820	131173	1.21
SEm±	0.461	0.503	NS	0.616	0.458				
CD (P=0.05)	1.006	1.098	NS	1.343	0.999				

*Sales rate @ ₹1500/q, **Mean yield of two hybrdis, viz. Abhinav and Heamsohna.

Table 3 Effect of different treatments on pest and disease management and yield of tomato during 2017

Treatment	Incidence of late blight disease (%)		Incidence of bacterial wilt (%)	Infestation of fruit borer (%)	Yield (q/ha)**	Cost of cultivation (₹/ha)	Gross income (₹/ha)*	Net Income (₹/ha)	C:B ratio
	Plants	Fruits							
T_1	4.08 (2.14)	3.20 (1.92)	4.46 (2.23)	1.60 (1.45)	400.00	189625	800000	610375	3.22
T_2	48.16 (6.98)	38.10 (6.21)	10.46 (3.31)	14.82 (3.91)	241.46	138580	482920	344340	2.49
T_3	44.32 (6.69)	35.44 (5.99)	11.43 (3.45)	17.68 (4.26)	240.72	149880	481440	331560	2.21
T_4	43.89 (6.66)	33.56 (5.84)	12.08 (3.55)	13.05 (3.68)	230.00	148890	460000	311110	2.10
T_5	49.68 (7.08)	41.03 (6.44)	13.45 (3.73)	17.16 (4.20)	220.86	150245	441720	291475	1.94
T_6	47.76 (6.95)	36.96 (6.12)	10.59 (3.33)	15.80 (4.04)	200.33	147335	400660	253325	1.78
T_7 (Control)	68.85 (8.33)	59.08 (7.72)	42.62 (6.57)	39.66 (6.34)	131.35	110210	262700	152490	1.38
SEm±	0.333	0.168	NS	0.208	0.176				
CD (P=0.05)	0.726	0.367	NS	0.454	0.384				

*Sales rate @ ₹ 2000/q, **Mean yield of two hybrdis, viz. Abhinav and Heamsohna

as hybrid Abhinav and Heamsohna, (iv) weekly hand picking and destruction of leaves, shoots and fruits from plants infected by late blight, (v) providing support to plants by staking to facilitate ventilation and sunlight in the interiors of plants for alleviating micro-climate and discourage pest and disease severity and enhanced plant and fruit growth, (vi) four (need based) applications of cymoxanil + mancozeb @ 2 g/l at 30, 45, 60 and 75 days after planting for management of late blight, and (vii) application of chlorantraniliprole 18.5% SC @ 0.3 ml/l at 65 DAP for management of fruit borers; was significantly superior over all other treatments in management of late blight disease on foliage and fruits of tomato hybrids during both the years, 2016 and 2017 (Table 2). Significantly minimum incidence of late blight disease on tomato plants was observed due to T_1 (3.71 and 4.08% during 2016 and 2017, respectively, followed by T_4 (27.92 and 43.89% during 2016 and 2017, respectively), and T_3 (29.86 and 44.32% during 2016 and 2017, respectively) and T_2 (36.24 and 48.16% during 2016 and 2017, respectively) and farmers practice. Significantly maximum (49.48 and 68.85% during 2016 and 2017, respectively) incidence of late blight on foliage was recorded due to T_7 (Control).

The incidence of late blight disease on fruits of both the tomato hybrids, viz. Abhinav and Heamsohna ranged from 2.08 to 44.96 and from 3.2 to 59.08% during 2016 and 2017, respectively. Significantly minimum incidence (2.08 and 3.2% during 2016 and 2017, respectivey) of late blight disease was recorded due to comprising Integrated Pest and Disease management schedule having all possible components such as (i) seed treatment with *Trichoderma* + *Pseudomonas* @ 20 g/kg of seeds, (ii) use of FYM @ 100 q/ha fortified with *Trichoderma* + *Pseudomonas*, (iii) planting of bacterial wilt tolerant tomato varieties such as hybrid Abhinav and Heamsohna, (iv) weekly hand picking and destruction of leaves, shoots and fruits from plants infected by late blight, (v) providing support to plants by staking to facilitate ventilation and sunlight in the interiors of plants for alleviating micro-climate and discourage pest and disease severity and enhanced plant and fruit growth, (vi) four (need based) applications of cymoxanil + mancozeb @ 2g/l at 30, 45, 60 and 75 days after planting for management of late blight, and (vii) application of chlorantraniliprole 18.5% SC @ 0.3 ml/l at 65 DAP for management of fruit borers. It was followed by T_4, T_3 or T_2 all being superior to farmers practice or control. The incidence of bacterial wilt ranged from 3.82% to 38.58% in 2016 while it was 4.46% to 42.62% during 2017. Although there were differential reactions with respect to incidence of bacterial wilt due to various IPDM schedules but these were at par. This could be attributed to selection of bacterial wilt tolerant tomato hybrids in trial.

The data on infestation of fruit borer was observed to vary from 1.18 to 34.89% during 2016 and from 1.6 to 39.66% during 2017, respectively. It is evident that the infestation of fruit borer was significantly minimum due to treatment-1 comprising Integrated Pest and Disease management schedule having all possible components such as (i) seed treatment with *Trichoderma* + *Pseudomonas* @ 20g/kg of seeds, (ii) use of FYM @ 100 Q/ha fortified with *Trichoderma* + *Pseudomonas*, (iii) planting of bacterial wilt tolerant tomato varieties such as hybrid Abhinav and Heamsohna, (iv) weekly hand picking and destruction of leaves, shoots and fruits from plants infected by late blight, (v) providing support to plants by staking to facilitate ventilation and sunlight in the interiors of plants for alleviating micro-climate and discourage pest and disease severity and enhanced plant and fruit growth, (vi) four (need based) applications of cymoxanil + mancozeb @ 2 g/l at 30-, 45-, 60- and 75- days after planting for management of late blight, and (vii) application of chlorantraniliprole 18.5% SC @ 0.3 ml/l at 65 DAP for management of fruit borers followed by other IPDM schedules such as T_4, T_3 or T_2, all being superior to farmers practice or control.

Effects on yield

The data on yield of tomato hybrids as influenced due to different IPM treatments during 2016 and 2017 are summarized in Table 2 and Table 3, respectively. It is evident that the fruit yield of tomato hybrids differed significantly among various treatments and ranged from 159.88 q/ha to 410 q/ha during 2016 and, from 131.35 q/ha to 400 q/ha during 2017. Significantly maximum (410 q/ha & 400 q/ha during 2016 & 2017, respectively) fruit yield was recorded due to T_1 comprising Integrated Pest and Disease management schedule having all possible components such as (i) seed treatment with *Trichoderma* + *Pseudomonas* @ 20g/kg of seeds, (ii) use of FYM @ 100 q/ha fortified with *Trichoderma* + *Pseudomonas,* (iii) planting of bacterial wilt tolerant tomato varieties such as hybrid Abhinav and Heamsohna, (iv) weekly hand picking and destruction of leaves, shoots and fruits from plants infected by late blight, (v) providing support to plants by staking to facilitate ventilation and sunlight in the interiors of plants for alleviating micro-climate and discourage pest and disease severity and enhanced plant and fruit growth, (vi) four (need based) applications of cymoxanil + mancozeb @ 2 g/l at 30, 45, 60 and 75 days after planting for management of late blight, and (vii) application of chlorantraniliprole 18.5% SC @ 0.3 ml/l at 65-DAP for management of fruit borers followed by other IPDM schedules; all being superior to farmers practice and control.

Cost: benefit ratio

The estimated gross income, net income and C:B ratio as influenced due to various IPM treatments during 2016 and 2017 are summarized in Table 2 and Table 3, respectively. It is evident that the gross return was greatly influenced due to productivity. The maximum gross income (₹ 800 000 during 2017 and ₹ 615 000 during 2016) was estimated due to treatment-1 comprising Integrated Pest and Disease management schedule having all possible components such as (i) seed treatment with *Trichoderma* + *Pseudomonas* @ 20 g/kg of seeds, (ii) use of FYM @

100 q/ha fortified with *Trichoderma* + *Pseudomonas*, (iii) planting of bacterial wilt tolerant tomato varieties such as hybrid Abhinav and Heamsohna, (iv) weekly hand picking and destruction of leaves, shoots and fruits from plants infected by late blight, (v) providing support to plants by staking to facilitate ventilation and sunlight in the interiors of plants for alleviating micro-climate and discourage pest and disease severity and enhanced plant and fruit growth, (vi) four (need based) applications of cymoxanil + mancozeb @ 2 g/l at 30, 45, 60 and 75 days after planting for management of late blight, and (vii) application of chlorantraniliprole 18.5% SC @ 0.3 ml/l at 65 DAP for management of fruit borers followed by other IPDM treatments; all being superior to farmers practice and control. Minimum gross return was reported due to control (₹ 239 820/ha and ₹ 262 700/ha during 2016 and 2017, respectively). Similarly, maximum net income (₹ 428 180/ ha and ₹ 610 375/ha during 2016 and 2017, respectively) was estimated due to treatment with combination of all possible components of IPDM followed by other IPDM schedules; all being superior to farmers practice and control. The results of trials proved efficiacy and superiority of IPDM schedules in enhancing the cost:benefit ratio as compared to farmers practice or control mainly contributed by enhanced yield of marketable tomato fruits which ranged from 1:1.21 to 1:2.30 during 2016 and, from 1:1.38 to 1:3.22 during 2017.

Farmer oriented field validation and economic analysis of IPM technology in tomato at Meerut, Uttar Pradesh has proved the successful adoption of IPM technology resulting in significant reduction in incidence of all the insect-pests and diseases (Sardana *et al*. 2014). The field trials conducted by Singh *et al*. (2014) also revealed that application of cymoxanil + mancozeb against late blight disease, chlorantraniliprole for management of fruit borer and *Trichoderma* + *Pseudomonas* against bacterial wilt and other diseases worked very effectively if applied in judicious manner. Earlier studies laid out by Sardana and Naved Sabir (2007), Sardana and Bambawale (2011), Singh *et al.* (2012), Singh *et al*. (2014), Singh (2012), Singh and Singh (2006) and Singh and Singh (2006) also supported that various strategies in tomato crop based on IPM schedules including judicious use of chemical pesticides played an important role in keeping the pest and disease population below the economic threshold level and thereby enhanced fruit yield and profitability in tomato cultivation. The farmers participatory trials on Farm Evaluation of IPM Technology at all the three locations revealed that the yield of tomato was significantly improved due to IPDM practices and was largely helpful in enhanced income to growers and also supplemented by high price during the lean season. The observations further proved that if IPM approaches are integrated with the off-season production system of tomato in hilly regions, then the production of tomato can be enhanced by 2-3 times.

Hence, realistic IPM tools comprising suitable varieties supplemented with seed treatments, integrated crop management and need based use of selective and safer chemical pesticides need to be promoted for large scale adoption to reduce the losses and improve the productivity of quality tomatoes.

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