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Integrated management of early blight of tomato with use of SAR chemicals, fungicides, bioagents and phytoextracts

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Abstract
Among the foliar diseases of tomato, early blight caused by *Alternaria solani* (Ellis and Martin) Jones and Grout, is one of the most destructive disease responsible for huge qualitative and quantitative losses. In recent years, the disease has assumed serious problems in tomato growing areas of Konkan region of Maharashtra. Therefore, with a view to reduce the losses in strategic manner integrated management of early blight of tomato with selective SAR chemicals, fungicides, bio-agents and phytoextracts is essential. Fungicides, SAR inducing chemicals, bio-agents and phytoextracts were significantly effective against early blight disease of tomato under natural epiphytotic conditions. Significantly least percent disease intensity (PDI) of 9.04% was observed due to seed treatment with captan @ 2 g/kg + 3 sprays of tebuconazole 50% + trifloxystrobin 25% WG @ 0.05 (T_9)with highest percent disease control over control by 79.95% followed by treatment T_{10} (seed treatment with captan @ 2 g/kg + 3 sprays of propiconazole (0.1%) and T_8 (seed treatment with captan @ 2 g/kg + 3 sprays of mancozeb (0.25%) with 14.45 and 16.72 PDI and 67.95% and 62.92% disease control over control, respectively. Highest yield (31.72 t/ ha.) and increase in yield over control (73.04%) was also recorded in treatment T_9 as against control (18.33 t/ ha.). Treatment T_{10} and T_8 were next best treatment with 29.28 t/ha. and 27.87 t/ha. fruit yield and 59.72 and 52.05 percent increase in yield over control, respectively. Seed biopriming with *P. fluorescens* + 2 sprays of *P. fluorescens* @ 1% recorded 18.26 PDI as against control with 59.51 percent disease reduction and yield of 24.20 t/ha. with 32.00% increase in yield. Next best treatment was seed biopriming with *T. viride* + 2 sprays of *T. viride* @ 1% with 22.72 PDI and 49.61 percent reduction in disease and 22.36 t/ha. and 21.97% increase in yield. Spraying of salicylic acid, benzoic acid and chitosan each @ 0.1% at two leaf stage in the nursery offered resistance to tomato plants against the pathogen up to 45 to 50 DAT, but there after there was slow development of the disease. Benzoic acid, salicylic acid and chitosan gave percent disease control over control to the tune of 34.47%, 39.75% and 23.86%, respectively. Among the phytoextracts evaluated, three sprays of neem leaf extract @ 10% recorded 26.48% disease severity.

Keywords: Early blight, *Alternaria solani*, SAR chemicals, biopriming, phytoextracts, fungicides

Introduction
Tomato (*Lycopersicon esculentum* Mill.) is one of the most popular and the second most important fruit vegetable crop after potato and is cultivated year round in tropical and subtropical regions of the world. Tomato is rich in vitamins and minerals with its anti-cancerous, antiseptic, antioxidant (Freeman and Reimers, 2010) [15] and anti-ageing properties and known to be one of the protective foods for the mankind. Tomato is native of Central and South America, was introduced in India by the Portuguese during 1700 (Kale and Kale, 1994) [20]. There are several factors responsible for low productivity of tomato, but diseases caused by biotic agents are the major one. Among the fungal diseases, early blight caused by *Alternaria solani* (Ellis and Martin) Jones and Grout, is the most important and destructive disease causing accountable qualitative and quantitative losses in tomato and resulting in less market value and economical monitory loss of farming community. Early blight was first recorded in epidemic form on tomatoes in Great Britain in 1944 by Glasscock and Ware. It was also reported from Morocco (Momento, 1938) [24], China (Wei and Chep, 1944) [44] and Mississippi (Neal and Barker, 1924) [26]. In India, Butler (1918) reported for the first time the prevalence of the disease in tomato.

It was also reported from Madras (Ramakrishnan *et al.*, 1971), Punjab (Bhatia *et al.*, 1972) [34, 7] and Madhya Pradesh (Agarwal *et al.*, 1959) [2]. In Maharashtra State, the disease was reported to be more severe during *Kharif* season, incurring yield losses to the tune of 78-80% (Datar and Mayee, 1981b) [12] moderate during *Rabi* and to a lesser extent during summer seasons.

Early blight of tomato is a three phase disease causing damping off of seedlings, leaf blight and stem canker. The characteristics symptoms of the disease are, initial dark brown to black spots which enlarge and develop concentric rings of raised and depressed necrotic tissue on foliage. As disease progress, affected leaves turn yellow with senescence and either dry up or fall off. Symptoms also appear on stem and fruits. Spots on fruit are sunken dry and may also have concentric ring pattern; on stem slightly sunken, circular or elongated, concentric dark spots with light coloured centre are developed and lesions may girdle the stem base killing or stunting the young plants, inducing wilting of older plants.

The crop is susceptible to *Alternaria* blight at all the stages of crop growth. Considering heavy yield losses and regular occurrence of early blight disease of tomato in both *Rabi* and *Summer* seasons in recent past created interest to conduct the present investigation to find out the efficient disease management package with selective SAR chemicals, fungicides, bio-agents and phyto extracts.

Materials and Methods

The field experiment was laid out during *Rabi* 2016-17 and *Rabi* 2017-18 in Randomized Block Design (RBD) with 15 treatments and each treatment replicated thrice using tomato (Cv. Arka Alok) at the experimental farm of Department of Agronomy, College of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri (M.S.). Tomato seedlings were raised in the nursery one month before transplanting. The raised beds of size 3×1×0.15 m size were prepared. Seeds were sown 2-3 cm deep in the shallow furrow with row-row spacing of 10 cm. Sown seeds were covered with thin layer of the soil and then mulched with paddy straw for better germination followed by watering immediately after sowing. Seed beds were watered regularly. Separate beds were prepared for seed dressing of fungicide (captan), spraying of SAR inducing chemicals (at two leaf stage in the nursery) and bioprimed seeds as mentioned in the treatment details. The seedlings (at two leaf stage) on bed which was prepared for the SAR treatments were sprayed with SAR inducing chemicals 10 days after germination of the seeds in the nursery. All the recommended package of practices were followed during whole cropping season. The treatments were applied as per schedule given in the treatment details.

Treatment Details

Tr. No.	Treatment	Category
T_1	Spraying of salicylic acid @ 0.1%	SAR chemicals
T_2	Spraying of benzoic acid @ 0.1%	
T_3	Spraying of chitosan @ 0.1%	
T_4	Seed biopriming with *Trichoderma viride*	Bioagents liquid formulations
T_5	Seed biopriming with *T. viride* + 2 sprays of *T. viride*1%	
T_6	Seed biopriming with *Pseudomonas fluorescens*	
T_7	Seed biopriming with *P. fluorescens* + 2 sprays of *P. fluorescens* 1%	
T_8	Seed treatment with captan (@ 2 g/kg) + 3 sprays of mancozeb (0.25%)	Fungicides
T_9	Seed treatment with captan (@ 2 g/kg) + 3 sprays of tebuconazole 50% + trifloxystrobin 25% WG (0.05%)	
T_{10}	Seed treatment with captan (@ 2 g/kg) + 3 sprays of propiconazole (0.1%)	
T_{11}	Three sprays of marvel (0.5%)	Phytoextracts
T_{12}	Three sprays of soapnut extract (10%)	
T_{13}	Three sprays of neem leaf extract (10%)	
T_{14}	Three sprays of silica @ 2ml/lit	
T_{15}	Control	

Observations on early blight intensity were recorded applying 0-9 grade disease rating scale (Mayee and Datar, 1986) [23].

Rating/Scale	Leaf covered with the spots
0	Healthy (without spots)
1	<1% leaf area covered with spots
3	1-10% leaf area covered with spots
5	11-25% leaf area covered with spots
7	26-50% leaf area covered with spots
9	>75% leaf area covered with spots

Experimental Results

Terminal percent disease intensity/percent disease index (PDI)

Analyzed pooled data on percent disease severity/percent disease index (PDI) presented in Table 1 revealed that all the fungicides, SAR chemicals, bio-agents and phytoextracts evaluated were found significantly effective against early blight disease under natural epiphytotic conditions in the field. Among all the spray treatments, fungicides were found most effective against the disease and were followed by bio-agents. Least terminal percent disease intensity (PDI) was observed due to treatment T_9 (seed treatment with captan @ 2 g/kg + 3 sprays of tebuconazole 50% + trifloxystrobin 25% WG @ 0.05%) which showed 9.04 PDI as compared to control (45.09 PDI). This was followed by T_{10} (seed treatment with captan @ 2 g/kg + 3 sprays of propiconazole @ 0.1%) and T_8 (seed treatment with captan @ 2 g/kg + 3 sprays of mancozeb @ 0.25%) with 14.45 and 16.72 PDI, respectively. Treatment T_7 (seed biopriming with *P. fluorescens* + 2 sprays of *P. fluorescens* 1%) and T_{11} (three sprays of marvel (0.5%)) recorded 18.26 and 18.61 PDI as against control and were at par with each other and were followed by T_5 (seed biopriming with *T. viride* + 2 sprays of *T. viride*1%) with 22.72 percent disease index. It was also observed that use of bio-agents in the form of biopriming plus 2 sprays with same bio-agents were more effective than

only biopriming with bio-agents. Only seed biopriming with *T. viride* and *P. fluorescens* showed 31.05% and 29.11% disease intensity, respectively. All the SAR inducing chemicals tested were found effective in effectively restricting the disease development up to 45 to 50 days after transplanting, but there after there was slow development of the disease in the treated plots. Among the SAR inducing chemicals used, benzoic acid (T_2) and salicylic acid (T_1) each @ 0.1% at two leaf stage in the nursery beds were found effective with 27.16 and 29.55 percent terminal disease index, respectively. As compare to these two, chitosan was found least effective with 34.33 PDI. Among the phytoextracts evaluated, three sprays of neem leaf extract @ 10% recorded 26.48% disease severity and was more effective than soapnut. Highest PDI (38.53) was recorded in three sprays of Silica @ 2ml/lit (T_{14}) followed by T_{12} (3 sprays of 10% soapnut rind extract) with 37.36 PDI.

Percent disease incidence (Terminal)

Analyzed pooled data presented in Table 2 revealed that least terminal (90 DAT) percent disease incidence was recorded in treatment T_9 (8.15%) and was significantly superior over rest of the treatments. This was followed by T_{10} (12.78%), T8 (15.29%), T_7 (16.76%), and T_{11} (17.26%) as compared to control (39.67%). Treatment T_5 (seed biopriming with *T. viride*+ 2 sprays of *T. viride* @ 1%) and T_{13} (Three sprays of neem leaf extract @ 10%) recorded 23.30 and 24.86 percent disease incidence and were at par. These were followed by T_2 (spraying of benzoic acid 0.1%) and T_6 (seed biopriming with *P. fluorescens*) which showed 25.83 and 27.63 percent disease incidence. Maximum percent disease incidence was recorded in T_{14} (34.56%) followed by T_{12} (34.15%) and were at par with each other. It was also observed that SAR inducing chemicals namely benzoic acid, salicylic acid and chitosan sprayed at two leaf stage in the nursery restricted the disease development at early stage of crop growth i.e. up to 45-50 DAT but later on there was steady disease development and recorded 25.83, 29.70 and 32.89 percent terminal disease incidence, respectively as compared to 39.67% in unsprayed control.

Percent disease control

Data (Table 2) also revealed that all the fungicides, SAR inducing chemicals, bio-agents and phytoextracts were effective in the early blight disease under field conditions. All the treatments were found significantly superior over unsprayed control. Highest percent disease control over control by 79.95% was recorded in treatment T_9 (seed treatment with captan (@ 2 g/kg) + 3 sprays of tebuconazole 50% + trifloxystrobin 25% WG (0.05%)). It was followed by T_{10} (seed treatment with captan (@ 2 g/kg) + 3 sprays of propiconazole (0.1%) and T_8 (seed treatment with captan (@ 2 g/kg) + 3 sprays of mancozeb (0.25%) with 67.95% and 62.92% disease control over control, respectively. Treatment T_7 (seed biopriming with *P. fluorescens* + 2 sprays of *P. fluorescens* 1%) and T_{11} (three sprays of marvel (0.5%) were also gave good control of the disease which recorded 59.51 and 58.74 percent disease reduction. T_5 (seed biopriming with *T. viride* + 2 sprays of *T. viride*1%) with 49.61% and T_{13} (three sprays of neem leaf extract @10%) with 41.27% reduction in the disease were also found effective under field conditions. Spraying of salicylic acid, benzoic acid and chitosan each @ 0.1% at two leaf stage in the nursery offered resistance against the pathogen up to 45 to 50 DAT and gave percent disease control over control to the tune of 34.47%, 39.75% and 23.86%, respectively. Least percent reduction in early blight disease was found in T_{14} (14.55%) and T_{12} (17.14%).

Effect of various treatments on yield of tomato

Analyzed pooled data (Table 3) revealed that fungicides were more effective in controlling early blight of tomato (Cv. Arka Alok) and increasing the yield over untreated control. Highest yield (31.72 t/ha.) and increase in yield over control (73.04%) was recorded in treatment T_9 (seed treatment with captan (@ 2 g/kg) + 3 sprays of tebuconazole 50% + trifloxystrobin 25% WG (0.05%) as against control (18.33 t/ha.). Treatment T_{10} (seed treatment with captan (@ 2 g/kg) + 3 sprays of propiconazole @ 0.1%) and T_8 (seed treatment with captan (@ 2 g/kg) + 3 sprays of mancozeb @ 0.25%) were next best treatment in order of merit with 29.28 t/ha. and 27.87 t/ha. fruit yield and 59.72 and 52.05 percent increase in yield over control, respectively. Among the SAR inducing chemicals, benzoic acid (T_2) recorded yield of 23.13 t/ha. with increase in yield of 26.21% over control and was followed by T_1 salicylic acid (22.03 t/ha. and 20.21%). Least yield (20.34 t/ha.) and increase in yield (10.99%) was recorded in T_{14} (three sprays of silica @ 2ml/lit) followed by T_{12} (20.52 t/ha. and 11.96%, respectively) and were at par with each other.

Incremental cost: benefit ratio (ICBR)

Pooled data (Table 4) on incremental cost: benefit ratio (ICBR) in respect of various spray treatments revealed that all the treatments significantly reduced the percent disease intensity and thereby increased the fruit yield of tomato (Cv. Arka Alok) with significantly maximum gross returns and additional returns with better ICBR over unsprayed control. Fungicides were emerged as most effective in reducing the severity of early blight, increasing the fruit yield, gross and additional returns with maximum ICBR as against unsprayed control. Treatment T_9 (seed treatment with captan (@ 2 g/kg) + 3 sprays of tebuconazole 50% + trifloxystrobin 25% WG (0.05%) was found most effective which recorded highest gross returns (Rs. 6,34,400/-) with additional income of Rs. 2,67,800/- and with highest ICBR (1.43). The next best treatments based on ICBR were T_{10} (seed treatment with captan (@ 2 g/kg) + 3 sprays of propiconazole @ 0.1%) and T_8 (seed treatment with captan (@ 2 g/kg) + 3 sprays of mancozeb @ 0.25%) which recorded gross returns of Rs. 5,85,600/- and 5,57,400/- with additional income of Rs. 2,19,000/- and 1,90,800/-, respectively with ICBR of 1.19 and 1.04, respectively. These were followed by T_7 (seed biopriming with *P. fluorescens* + 2 sprays of *P. fluorescens* 1%), T_{11} (three sprays of marvel (0.5%), T_{13} (three sprays of neem leaf extract (10%) and T_2 (spraying of benzoic acid @ 0.1%) which recorded the additional income of Rs. 1,17,400/-, 1,15,200/-, 98,000/- and 74,000/-, with ICBR of 0.65, 0.62, 0.54 and 0.53, respectively. Least additional returns of Rs. 40,200/- & 43,800/- were recorded due to three sprays each of silica and soapnut with ICBR of 0.22 & 0.24, respectively.

Discussion

The experimental results of present field study revealed that all the fungicides, SAR inducing chemicals, bio-agents and phytoextracts were significantly effective against early

blight disease of tomato under natural epiphytotic conditions in the field. Among all the treatments, fungicides were emerged as most effective against the disease and were followed by bio-agents. Significantly least terminal percent disease intensity (PDI) of 9.04%was observed due to seed treatment with captan @ 2 g/kg + 3 sprays of tebuconazole 50% + trifloxystrobin 25% WG @ 0.05% (T_9) as compared to control (45.09 PDI) and with highest percent disease control over control by 79.95%. This was followed by treatment T_{10} (seed treatment with captan @ 2 g/kg + 3 sprays of propiconazole (0.1%) and T_8 (seed treatment with captan @ 2 g/kg + 3 sprays of mancozeb (0.25%) with 14.45 and 16.72 PDI and 67.95% and 62.92% disease control over control, respectively. The results obtained also revealed that least terminal percent disease incidence was recorded in treatment T_9 (8.15%) and was significantly superior over rest of the treatments. This was followed by T_{10} (12.78%) and T_8 (15.29%).

Highest yield (31.72 t/ha) and increase in yield over control (73.04%) was also recorded in treatment T_9 as against control (18.33 t/ha.). Treatment T_{10} and T_8 were next best treatment in order of merit with 29.28 t/ha. and 27.87 t/ha. fruit yield and 59.72 and 52.05 percent increase in yield over control, respectively.

These findings are in close conformity with those of Mondal *et al.* (2007) [25]. According to them Nativo (tebuconazole 50% + trifloxystrobin 25% WG) has proved to be most effective against *A. brassicae* disease of rapeseed. Similarly, Kumar (2015) [22] reported tebuconazole 50% + trifloxystrobin 25% WS, effective against early blight of tomato caused by *Alternaria solani.* Kumar *et al*. (2010) [21] reported the maximum disease control with lowest PDI in the propiconazole (0.1%) treated plots followed by pyraclostrobin (0.2%). However, least fruit infection was recorded in 0.1% propiconazole sprayed plots (1.0%) followed by 0.2% mancozeb (1.4%). Also, Amaresh (2000) [3] reported propiconazole as effective fungicide against *A. helianthi* in sunflower. Present findings are also in agreement to earlier reports of Arunakumar (2010) [5] and Bhaskar and Lukose (2012) [6]. Teerdhala (2015) [42] found mancozeb and propiconazole, the effective fungicides against *A. solani* causing early blight which gave 55.7% and 32.1% reduction in disease with 19.88 and 17.96 t/ha. fruit yield, respectively. Sali *et al*. (2010) [35] reported that two sprays of mancozeb (0.3%) or propiconazole (0.05%) at an interval of 15 days were effective for reducing disease intensity of early blight of tomato. Three sprays of mancozeb 75 WP at 0.2 percent gave significantly better control of early blight caused by *A. solani*and stabilized higher marketable yield with reducing incidence of *Alternaria* fruit rot. Likewise, the highest yields of tomato with greater financial benefits obtained in chlorothalonil or mancozeb at 7 and 10 days interval treatments was primarily due to suppression of *Alternaria* and other fruit rot (Dillard *et al*., 1997) [14]. Singh *et al*. (2000) reported that the disease appearance was delayed by seed treatment and foliar spray of fungicides. Maximum disease control (75.27%) with highest fruit yield (375.50 q/ha) was reported when mancozeb (0.2%) was sprayed. The present findings are also in accordance with those of Gondal *et al*. (2012) [18] and Nikam *et al.* (2013) [27].

Treatment T_7 (seed biopriming with *P. fluorescens* + 2 sprays of *P. fluorescens* 1%) recorded 18.26 PDI, 16.76% disease incidence as against control with 59.51 percent disease reduction over control. Next best treatment was T_5 (seed biopriming with *T. viride* + 2 sprays of *T. viride* @ 1%) with 22.72 percent disease index, 23.30% disease incidence and 49.61 percent reduction in disease as against unsprayed control. It was also observed that use of bio-agents in the form of seed biopriming plus 2 sprays with same bio-agents at 15 days interval were more effective than only seed biopriming with bio-agents. Only seed biopriming with *T. viride* and *P. fluorescens* showed 31.05% and 29.11% disease intensity, respectively. Treatment T_7 (seed biopriming with *P. fluorescens* + 2 sprays of *P. fluorescens* 1%) recorded highest yield of 24.20 t/ha. with 32.00% increase in yield and was followed by T_5 (seed biopriming with *T. viride* + 2 sprays of *T. viride* @ 1%) with 22.36 t/ha. and 21.97% increase in yield.

Pseudomonas fluorescens and *Trichoderma viride* were reported as potential bio-agents for effective management of early blight of tomato incited by *A. solani* (Bhattiprolu, 2010; Patel and Choudhary, 2010; Chaudhary *et al.*, 2011; Ganie *et al.*, 2013 and Abdalla *et al.*, 2014) [8, 29, 9, 16, 1]. Similarly, Teerdhala (2015) [42] also proved the effectiveness of *Trichoderma viride* against early blight of tomato by reducing the disease intensity to the tune of 50.7 percent. Under glass house conditions *Trichoderma* sp. exhibited a similar efficacy with a percent disease control ranging from 82.6 - 91.3 (Singh *et al.*, 2015) [38].

It is evident from the data obtained that spraying of salicylic acid, benzoic acid and chitosan each @ 0.1% at two leaf stage in the nursery offered resistance to tomato plants against the pathogen up to 45 to 50 DAT, but thereafter there was slow development of the disease in the treated plots. Benzoic acid (T_2), salicylic acid (T_1) and chitosan (T_3) showed 27.16, 29.55 and 34.33 percent disease severity and gave percent disease control over control to the tune of 34.47%, 39.75% and 23.86%, respectively. Among the SAR inducing chemicals, benzoic acid (T_2) recorded yield of 23.13 t/ha with increase in yield of 26.21% over control and was followed by 22.03 t/ha and 20.21%, respectively due to salicylic acid (T_1). Earlier, Sathiyabama *et al.* (2014) [37] reported that chitosan was able to induce the level of chitinase activity and new isoforms of chitinase, resulting in the reduction of early blight disease severity in tomato leaves. These results suggested the role of chitosan in activation of defense responses as well as protecting tomato plants from *A. solani* infection.Hardrami *et al.* (2010) stated that chitosan elicits activities leading to a variety of defense responses in host plants in response to microbial infections. Singh and Singh (2006) [40] reported effectiveness of benzoic acid against *Alternaria* blight of linseed caused by *Alternaria lini*. Similarly Splentzer and Enyedi (1999) [41] found that application of salicylic acid helps in reducing *Alternaria* blight of tomato caused by *A. solani* by 77% as compared to control.

Among the phytoextracts evaluated, three sprays of neem leaf extract @ 10% at 15 days interval recorded 26.48% disease severity and was more effective than soapnut. Three sprays of marvel (0.5%) (T_{11}) recorded 18.61 PDI with 58.74 percent disease reduction over control with 17.26% disease incidence as compared to 39.67% in control. Earlier, Chhabra *et al.* (1999) [10] reported that five sprays of Bioneem (*A. indica*) significantly controlled the early blight (*A. solani*) disease incidence (60.39%) in tomato and recorded maximum increase in yield (57.29%). The findings are also in agreement with findings of Patil *et al.* (2001) [30] who found that the plant products namely neem seed extract

(19.75 PDI) and neem leaf extract (20.35 PDI) were effective in reducing disease incidence and increasing the fruit yield. Antifungal potential of the neem leaf extract (@ 10%) was reported against many species of *Alternaria* including *A. solani*, causing blights and leaf spots in many crops (Raja, 2010; Pattnaik *et al.*, 2012; Chourasiya *et al.*, 2013 and Deepti Sadana and Nidhi Didwania, 2015) [32, 31, 11, 13]. Highest PDI (38.53) was recorded in three sprays of silica @ 2ml/lit (T_{14}) followed by T_{12} (3 sprays of 10% soapnut rind extract) with 37.36 PDI which showed only 14.55 and 17.14 percent reduction in control over unsprayed control, respectively. Least yield (20.34 t/ ha.) and increase in yield (10.99%) was recorded in T_{14} followed by T_{12} with 20.52 t/ha. and 11.96%, respectively.

Based on incremental cost: benefit ratio (ICBR) it is evident that all the treatments significantly reduced percent disease severity and thereby increased the fruit yield of tomato (Cv. Arka Alok) with significantly maximum gross returns and additional returns with better ICBR over unsprayed control. Fungicides were emerged as most effective in reducing the severity of early blight, increasing the fruit yield, gross and additional returns with maximum ICBR. Seed treatment with captan (@ 2 g/kg) + 3 sprays of tebuconazole 50% + trifloxystrobin 25% WG (0.05%) was found most effective which recorded highest gross returns (Rs. 6,34,400/-), additional income of Rs. 2,67,800/- and with highest ICBR of 1.43. The next best treatments based on ICBR were T_{10} (seed treatment with captan (@ 2 g/kg) + 3 sprays of propiconazole @ 0.1%) and T_8 (seed treatment with captan (@ 2 g/kg) + 3 sprays of mancozeb @ 0.25%) which recorded gross returns of Rs. 5,85,600/- and 5,57,400/- with additional income of Rs. 2,19,000/- and 1,90,800/-, respectively with ICBR of 1.19 and 1.04, respectively. These were followed by T_7 (seed biopriming with *P. fluorescens* + 2 sprays of *P. fluorescens* 1%), T_{11} (three sprays of marvel (0.5%), T_{13} (three sprays of neem leaf extract (10%) and T_2 (spraying of benzoic acid @ 0.1%) which recorded the additional income of Rs. 1,17,400/-, 1,15,200/-, 98,000/- and 74,000/- with ICBR of 0.65, 0.62, 0.54 and 0.53, respectively. Least additional returns (Rs. 40,200/-& 43,800/-) were recorded due to three sprays each of silica and soapnut with ICBR of 0.22 & 0.24, respectively.

Results of the present study obtained on integrated management of tomato early blight incited by *A. solani* with SAR chemicals, fungicides, bioagents and phytoextracts which effectively managed the disease with significant increase in fruit yield and better ICBR are on the same line with the findings of those reported earlier by Datar and Mayee (1981b) [12], Bhattiprolu (2010) [8], Patel and Chaudhary (2010) [29], Samanta *et al.* (2012) [36] and Teerdhala (2015) [42].

Thus, on the basis of ICBR, the most effective treatments for management of early blight disease of tomato caused by *Alternaria solani* and to get higher returns were T_9 (seed treatment with captan (@ 2 g/kg) + 3 sprays of tebuconazole 50% + trifloxystrobin 25% WG (0.05%)), T_{10} (seed treatment with captan (@ 2 g/kg) + 3 sprays of propiconazole @ 0.1%),T_8 (seed treatment with captan (@ 2 g/kg) + 3 sprays of mancozeb @ 0.25%), T_7 (seed biopriming with *P. fluorescens* + 2 sprays of *P. fluorescens* 1%), T_{11} (three sprays of marvel (0.5%), T_{13} (three sprays of neem leaf extract (10%),T_2 (spraying of benzoic acid @ 0.1%) and T_5 (seed biopriming with *T. viride* + 2 sprays of *T. viride*1%).

Table 1: Efficacy of SAR chemicals, fungicides, bio-agents and phytoextracts on percent disease intensity of early blight of tomato (Pooled)

Tr. No.	Treatments	*Percent Disease Intensity (PDI)					Percent Disease Control
		30 DAT	45 DAT	60 DAT	75 DAT	90 DAT	
T_1	Spraying of salicylic acid @ 0.1%	0.00 (0.00)**	0.00 (0.00)	9.38 (17.81)	18.47 (25.45)	29.55 (32.93)	34.47
T_2	Spraying of benzoic acid @ 0.1%	0.00 (0.00)	0.64 (4.50)	7.25 (15.58)	17.65 (24.83)	27.16 (31.41)	39.76
T_3	Spraying of chitosan @ 0.1%	0.70 (4.79)	4.04 (11.56)	11.29 (19.62)	24.89 (29.90)	34.33 (35.87)	23.86
T_4	Seed biopriming with *Trichoderma viride*	0.61 (3.21)	5.28 (13.20)	14.89 (22.69)	22.13 (28.06)	31.05 (33.86)	31.14
T_5	Seed biopriming with *T. viride* + 2 sprays of *T. viride* 1%	0.41 (3.63)	5.36 (13.36)	11.74 (20.03)	17.61 (24.81)	22.72 (28.47)	49.61
T_6	Seed biopriming with *Pseudomonas fluorescens*	0.16 (2.18)	3.72 (11.10)	11.81 (20.09)	19.67 (26.33)	29.11 (32.65)	35.44
T_7	Seed biopriming with *P. fluorescens* + 2 sprays of *P. fluorescens* 1%	0.15 (2.06)	3.11 (10.10)	9.58 (18.01)	13.94 (21.92)	18.26 (25.29)	59.51
T_8	Seed treatment with captan (@ 2 g/kg) + 3 sprays of mancozeb (0.25%)	0.00 (0.00)	7.57 (15.92)	12.52 (20.71)	14.04 (22.00)	16.72 (24.12)	62.92
T_9	Seed treatment with captan (@ 2 g/kg) + 3 sprays of tebuconazole 50% + trifloxystrobin 25% WG (0.05%)	0.00 (0.00)	3.43 (10.65)	6.71 (15.01)	7.88 (16.29)	9.04 (17.49)	79.95
T_{10}	Seed treatment with captan (@ 2 g/kg) + 3 sprays of propiconazole (0.1%)	0.03 (0.60)	7.35 (15.72)	9.87 (18.31)	12.36 (20.58)	14.45 (22.34)	67.95
T_{11}	Three sprays of marvel (0.5%)	3.55 (10.83)	9.03 (17.47)	12.66 (20.84)	16.76 (24.15)	18.61 (25.53)	58.74
T_{12}	Three sprays of soapnut extract (10%)	4.14 (11.79)	11.64 (19.95)	20.44 (26.88)	29.18 (32.69)	37.36 (37.68)	17.14
T_{13}	Three sprays of neem leaf extract (10%)	4.95 (12.84)	10.03 (18.41)	15.78 (23.40)	22.87 (28.56)	26.48 (30.97)	41.27
T_{14}	Three sprays of silica @ 2ml/lit	4.20 (11.76)	12.34 (20.56)	23.78 (29.19)	31.24 (33.98)	38.53 (38.36)	14.55
T_{15}	Control	4.32 (12.00)	13.73 (21.75)	28.72 (32.40)	37.19 (37.57)	45.09 (42.18)	-
	S. Em±	0.69	0.62	0.45	0.49	0.49	
	C. D at 5%	2.01	1.81	1.29	1.41	1.43	

*Mean of three replications

** Values in parenthesis are arc-sin transformed values

Table 2: Efficacy of SAR chemicals, fungicides, bio-agents and phytoextracts on disease incidence of early blight of tomato (Pooled)

Tr. No.	Treatment	*Disease Incidence (%)					Percent Disease Control
		30 DAT	45 DAT	60 DAT	75 DAT	90 DAT	
T_1	Spraying of Salicylic acid @ 0.1%	0.00 (0.00)**	0.00 (0.00)	7.91 (16.33)	19.10 (25.91)	29.70 (33.02)	25.14
T_2	Spraying of Benzoic acid @ 0.1%	0.00 (0.00)	0.61 (4.40)	6.65 (14.93)	16.88 (24.25)	25.83 (30.55)	34.89
T_3	Spraying of Chitosan @ 0.1%	2.52 (9.11)	4.05 (11.59)	9.36 (17.79)	23.17 (28.77)	32.89 (34.99)	17.10
T_4	Seed biopriming with *Trichoderma viride*	1.11 (5.39)	6.00 (14.13)	13.42 (21.47)	22.89 (28.58)	31.87 (34.37)	19.66
T_5	Seed biopriming with *T. viride* + 2 sprays of *T. viride*1%	2.35 (8.82)	5.19 (13.16)	11.07 (19.41)	16.21 (23.74)	23.30 (28.84)	41.27
T_6	Seed biopriming with *Pseudomonas fluorescens*	0.87 (5.14)	4.39 (12.06)	11.05 (19.41)	21.02 (27.29)	27.63 (31.71)	30.35
T_7	Seed biopriming with *P. fluorescens* + 2 sprays of *P. fluorescens* 1%	0.80 (4.80)	3.62 (10.95)	8.54 (16.98)	12.91 (21.04)	16.76 (24.16)	57.75
T_8	Seed treatment with Captan (@ 2 g/kg) + 3 sprays of Mancozeb (0.25%)	0.00 (0.00)	6.71 (14.92)	12.59 (20.77)	13.49 (21.55)	15.29 (23.01)	61.47
T_9	Seed treatment with Captan (@ 2 g/kg) + 3 sprays of tebuconazole 50% + Trifloxystrobin 25% WG (0.05%)	0.00 (0.00)	4.19 (11.79)	5.93 (14.08)	7.26 (15.62)	8.15 (16.58)	79.46
T_{10}	Seed treatment with Captan (@ 2 g/kg) + 3 sprays of Propiconazole (0.1%)	0.64 (3.70)	6.65 (14.93)	8.59 (17.04)	10.31 (18.73)	12.78 (20.94)	67.78
T_{11}	Three sprays of Marvel (0.5%)	4.48) (12.18)	9.16 (17.61)	12.08 (20.34)	15.14 (22.90)	17.26 (24.55)	56.49
T_{12}	Three sprays of soapnut extract (10%)	5.28 (13.27)	11.85 (20.13)	17.63 (24.83)	26.74 (31.13)	34.15 (35.76)	13.93
T_{13}	Three sprays of Neem leaf extract (10%)	6.41 (14.64)	9.82 (18.25)	14.43 (22.32)	21.93 (27.92)	24.86 (29.90)	37.35
T_{14}	Three sprays of Silica @ 2ml/lit	5.22 (13.18)	12.80 (20.95)	20.66 (27.03)	27.68 (31.74)	34.56 (36.00)	12.89
T_{15}	Control	6.02 (14.18)	14.09 (22.03)	25.51 (30.33)	32.76 (34.91)	39.67 (39.04)	-
	S.Em±	0.84	0.59	0.48	0.33	0.37	
	C.D at 5%	2.42	1.70	1.39	0.95	1.07	

*Mean of three replications
** Values in parenthesis are arc-sin transformed values

Table 3: Effect of various treatments on yield of tomato (Cv. Arka Alok)

Tr. No.	Treatment	*Rabi*, 2016-17		*Rabi*, 2017-18		Pooled	
		*Yield (t/ha.)	% increase over control	*Yield (t/ha.)	% increase over control	*Yield (t/ha.)	% increase over control
T_1	Spraying of salicylic acid @ 0.1%	22.98	20.46	21.09	19.33	22.03	20.21
T_2	Spraying of benzoic acid @ 0.1%	24.17	26.71	22.10	25.66	23.13	26.21
T_3	Spraying of chitosan @ 0.1%	22.56	18.24	20.43	16.17	21.49	17.25
T_4	Seed biopriming with *Trichoderma viride*	21.96	15.12	19.91	13.20	20.93	14.20
T_5	Seed biopriming with *T. viride* + 2 sprays of *T. viride*1%	23.33	22.32	21.38	21.58	22.36	21.97
T_6	Seed biopriming with *Pseudomonas fluorescens*	23.14	21.29	21.15	20.21	22.14	20.77
T_7	Seed biopriming with *P. fluorescens* + 2 sprays of *P. fluorescens* 1%	25.06	31.38	23.33	32.68	24.20	32.00
T_8	Seed treatment with captan (@ 2 g/kg) + 3 sprays of mancozeb (0.25%)	29.06	52.34	26.69	51.74	27.87	52.05
T_9	Seed treatment with captan (@ 2 g/kg) + 3 sprays of tebuconazole 50% + trifloxystrobin 25% WG (0.05%)	33.05	73.24	30.39	72.81	31.72	73.04
T_{10}	Seed treatment with captan (@ 2 g/kg) + 3 sprays of propiconazole (0.1%)	30.78	61.36	27.77	57.93	29.28	59.72
T_{11}	Three sprays of marvel (0.5%)	25.20	32.11	22.98	30.67	24.09	31.42
T_{12}	Three sprays of soapnut extract (10%)	21.57	13.09	19.48	10.75	20.52	11.96
T_{13}	Three sprays of neem leaf extract (10%)	24.20	26.87	22.26	26.57	23.23	26.73
T_{14}	Three sprays of silica @ 2ml/lit	21.40	12.19	19.29	9.69	20.34	10.99
T_{15}	Control	19.08	-	17.59	-	18.33	-
	S.Em±	0.34		0.40		0.22	
	C.D at 5%	0.99		1.16		0.64	

*Mean of three replications
** Values in parenthesis are arc-sin transformed values

Table 4: Economics of SAR chemicals, fungicides, bio-agents and phytoextracts sprayings for the management of early blight of tomato Cv. Arka Alok (Pooled)

Tr. No.	Treatment	Basic input cost (Rs.)	Additional cost (Rs.)		Total input cost (Rs.)	* Yield (t/ha.)	** Gross returns (Rs.)	Increase in yield over control (t/ha.)	Additional returns due to treatment (Rs.)	ICBR
			SAR/Fungicide/ bioagent/phyto Extract	Labour cost (Rs,)						
T_1	Spraying of Salicylic acid @ 0.1%	1,78,762	55	-	1,78,817	22.03	4,40,600	3.7	74,000	0.39
T_2	Spraying of Benzoic acid @ 0.1%	1,78,762	77.50	-	1,78,839.5	23.13	4,62,600	4.8	96,000	0.53
T_3	Spraying of Chitosan @ 0.1%	1,78,762	42.50	-	1,78,804.5	21.49	4,29,800	3.16	63,200	0.35
T_4	Seed biopriming with *Trichoderma viride*	1,78,762	55	-	1,78,817	20.93	4,18,600	2.6	52,000	0.29
T_5	Seed biopriming with *T. viride* + 2 sprays of *T. viride*1%	1,78,762	410	1200	1,80,372	22.36	4,47,200	4.03	80,600	0.44
T_6	Seed biopriming with *Pseudomonas fluorescens*	1,78,762	55	-	1,78,817	22.14	4,42,800	3.81	76,200	0.42
T_7	Seed biopriming with *P. fluorescens* + 2 sprays of *P. fluorescens* 1%	1,78,762	410	1200	1,80,372	24.20	4,84,000	5.87	1,17,400	0.65
T_8	Seed treatment with Captan (@ 2 g/kg) + 3 sprays of Mancozeb (0.25%)	1,78,762	1800	1800	1,82,362	27.87	5,57,400	9.54	1,90,800	1.04
T_9	Seed treatment with Captan (@ 2 g/kg) + 3 sprays of tebuconazole 50% + Trifloxystrobin 25% WG (0.05%)	1,78,762	6203	1800	1,86,365	31.72	6,34,400	13.39	2,67,800	1.43
T_{10}	Seed treatment with Captan (@ 2 g/kg) + 3 sprays of Propiconazole (0.1%)	1,78,762	2550	1800	1,83,112	29.28	5,85,600	10.95	2,19,000	1.19
T_{11}	Three sprays of Marvel (0.5%)	1,78,762	3750	1800	1,84,312	24.09	4,81,800	5.76	1,15,200	0.62
T_{12}	Three sprays of soapnut extract (10%)	1,78,762	550	1800	1,81,112	20.52	4,10,400	2.19	43,800	0.24
T_{13}	Three sprays of Neem leaf extract (10%)	1,78,762	375	1800	1,80,937	23.23	4,64,600	4.9	98,000	0.54
T_{14}	Three sprays of Silica @ 2ml/lit	1,78,762	1575	1800	1,82,137	20.34	4,06,800	2.01	40,200	0.22
T_{15}	Control	1,78,762			1,78,762	18.33	3,66,600	-	-	-

* Mean of three replications
** Selling rates of tomato @ Rs. 10000/t

Conclusion:

The present investigation on integrated management of early blight of tomato indicated that seed treatment with captan followed by 3 sprays of tebuconazole 50% + trifloxystrobin 25% WG @ 0.05 or propiconazole (0.1%) or mancozeb (0.25%) effectively protect the crop from the disease. Biopriming followed by sprays with bio-agents may also protect the crop from early blight damage. SAR inducing chemicals when applied at 2 leaf stage offer resistance to tomato plant up to 45-50 DAT.

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