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Management of tomato diseases in the coastal zone of Odisha through integrated approach

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Abstract
Tomato crop is attacked by a large number of pathogens and cause huge losses of marketable fruit yield which has rendered open field tomato production uneconomical. Therefore, an integrated approach involving physical, biological and chemical module has been formulated to manage the tomato diseases during four consecutive years from 2014-15, 2015-16, 2016-17 and 2017-18 at AICRP on Vegetable Crops, OUAT, Bhubaneswar during *Rabi* season. Results showed that integration of different approach involving seed priming with Seed Pro (*Bacillus subtilis*, IIHR strain) @4g/ kg of seed followed by soil application of Seed Pro (*Bacillus subtilis*, IIHR strain) @10g/kg of soil while filling of pro trays and soil drenching of Seed Pro (*Bacillus subtilis*, IIHR strain) @5% after seed germination followed by covering with 50- mesh nylon net of nursery bed supplemented with border row planting (2 rows) of maize at least 15 days before transplanting of seedlings in the main field followed by seedling dip with 0.1% (Carbendazim 12%+Mancozeb 63% WP) at the time of transplanting and sequential spraying with Acephate 75% WP @1.5g/l on 10 DAT, Fipronil 5% SC @1.5ml/l on 20 DAT, Copper hydroxide 77% WP (2.0g/l) on 25 DAT, imidacloprid 70% WG @2g/15l on 40 DAT, Fenamidone 10% + Mancozeb 50% WDG (0.25%) two to three times from 45 DAT at 10 days intervals substantially reduced *per cent* incidence/intensity of different disease like damping off (71.1%), collar rot (67.5%), early blight (76.5%), tomato spotted wilt (66.7%) and tomato leaf curl virus((71.7%) as compared to control. So, farmers who are facing lot of problem due to attack of different disease in tomato crop during *Rabi* season, can grow their crop by adopting the technologies involving The treatments combination also recorded maximum fruit yield (352q/ha) with highest economic return (Rs.249592.5) with maximum B:C ratio of 3.2.

Keywords: Tomato, management, integrated approach, *per cent* disease incidence/ severity, B:C

Introduction
Tomato (*Lycopersicon esculentum* L.) originated South America belongs to Solanaceae family is a widely grown vegetable in the world. It is the popular vegetable of because of its taste, colour and high nutritive value and also for its diversified use. It is known as productive as well as protective food and consumed in our daily life and is a good source of antioxidants Sgherri *et al*. (2008) [1]. The leading producer of tomato in the world is USA followed by China, Italy, Turkey, Egypt, Spain, Romania, Brazil and Greece. In India the major tomato producing states in the country are Madhya Pradesh, Andhra Pradesh, Karnataka, Gujarat, Odisha, Chhattisgarh, West Bengal, Tamil Nadu, Bihar, Maharashtra, Uttar Pradesh, Haryana and Telangana. These states account for about 90% of the total production of the country as reported by Monthly report on tomato, Horticulture Statistic Division, Department of Agriculture, Cooperation & Farmers Welfare, Govt. of India, June 2020 [2]. There has been a gradual increase in area under tomato cultivation in India, while the productivity has been fluctuating ranging from 14.70t/ha in 1991-92 to 21.20t/ha in 2013-14 (NHB 2015) [3]. The estimated production of tomato in India is about 205.72 Lakh t (Tonnes), eight percent higher than the normal production as well as last year production as reported by State Directorates of Horticulture (2018-19 and 2019-20) [4].

But production of tomato is severely affected by several biotic and abiotic factors. High incidence of diseases in tomato is primarily due to high temperature, rainfall, relative humidity round the year. Among the diseases, damping off of seedlings (*Pythium* sp., *Phytophthora* sp., *Rhizoctonia solani*, *Sclerotium rolfsii*, *Fusarium solani*, etc.), bacterial wilt (*Ralstonia solanacearum*), fusarial wilt (*Fusarium oxysporum* f. sp. *lycopersici*), basal stem rot (*Sclerotium rolfsii*), leaf mosaic (Tomato mosaic virus) and leaf curl (Tomato leaf curl virus) are major diseases causing considerable loss in yield with the finding of Bhagat *et al.* (2013) [5]. ToLCV has risen to alarming proportions in the plains of India and has become a limiting factor in tomato cultivation particularly during summer crop (February to May) in southern Indian states (Saikia, and Muniyappa, 1989) [6] and Sadashiva *et al.* 2002) [7] and autumn crop (August to December) in northern plains (Som, 1973) [8], Mayee *et al.* 1974 [9] and Banerjee and Kalloo, 1987) [10] and both early-autumn and autumn-winter (September to February) in Eastern India (Nath, 2003) [11] and Chattopadhyay *et al.* 2011) [12] causing yield loss up to 100% in favourable condition (Green and Kalloo, 1994) [13]. Farmers used to manage leaf blight diseases with spray schedules utilizing two or more different fungicide groups or fungicide formulations containing two different chemical groups at least for 8-10 times in one growing season in order to limit the development of fungicide resistant strains of *A. solani* which have been reported overseas (Pasche *et al.* 2004) [14] and (Rosenzweig *et al.* 2008) [15]. On the other hand, management of whitefly with the use of systemic insecticides at for 10-12 times is a common practice among the tomato growers of eastern India. Exclusive reliance on fungicides/insecticides as a control strategy against these biotic stresses has resulted in several undesirable effects like pesticide pollution, resurgence of secondary pests, fungicide/insecticide resistance, elimination of beneficial fauna and different human health hazards. Resistance management is a key consideration for these biotic stresses in tomatoes. The most common methods of preventing resistance to fungicides include minimizing the number of applications per season of 'at-risk' products, using fungicides with diverse modes of action and applying them in alternation or as mixtures (Staub 1991) [16], (Brent and Hollomon, 2007) [17]. It has also been reported that the use of physical barrier can protect the crop against ToLCV disease (CropLife 2008) [18]. It is reported that 50 mesh screens are indeed highly efficient in excluding whiteflies in nursery but these protection alone may not sufficiently protect against leaf curl disease since some whiteflies are still able to enter main field through gaps in entrances and on personnel. Alfalfa and maize can act as barrier crops in main field against the attack leaf hopper and beet curly top virus of tomato (Antignus *et al.* 2001) [19]. Managing the diseases through chemicals alone is not satisfactory in view of the environmental concerns and cost benefit ratio. Therefore, an attempt has been made to manage the important diseases of tomato through an integrated approach by combining barrier crop and economic use of bioagents and chemicals in the coastal belt of Odisha which is regarded as the most promising tomato growing belts in India.

Materials and Methods

Experimental Site and plants growing

The experiment was conducted in a randomized block design with four replications under All India Coordinated Research Project on Vegetable Crops at Central Research Station OUAT, Bhubaneswar (East and SE Coastal Plain Zone, $20^0$15'N latitude and $85^0$52' E longitude) during the Rabi season of three consecutive years of 2014-15, 2015-16 and 2016-17. Seeds of tomato variety Utkal Kumari were sown in well prepared nursery beds separately under low cost poly house covered with 200µm UV-stabilized polyethylene film. After germination six separately prepared seed beds were covered with 50-mesh nylon net and all the nursery management practices were followed in time without disturbing the insect proof net. Twenty-five days old separately treated seedlings were transplanted to the main field previously surrounded with 2 rows of maize sown 30 days before transplanting of tomato seedlings accommodating 30 plants in individual plot measuring 3.0 m x 2.7 m. Plots were divided into six treatment combinations following Randomized Block Design with four replications and different cultural managements were followed in time.

Treatment combinations

Covering of nursery bed with nylon mosquito net with 50 mesh was the common in all treatments.

T1: Treatment with biological control
Nursery treatment

a. Seed priming with Seed Pro (*Bacillus subtilis*, IIHR strain) @4g/kg of seed,
b. Soil application of Seed Pro @10g/kg of soil while bed preparation, and
c. Soil drenching with Seed Pro @5% after seed germination.

Main field treatment: Seedling dip with Seed Pro @5% and three sprays with Seed Pro @1.0% at 10 days interval starting from 45 days after transplanting (DAT).

T2: Treatment with fungicides

a. Nursery treatment: Seed treatment with Captan 50% WP (2g/kg) + drenching with Fosetyl Al 80% WP @0.1% immediately after germination+spray with Copper hydroxide 77% WP (2.0g/l) at 3-5 leaf stage.
b. Main field treatment: Seedling dip with 0.1% (Carbendazim 12%+Mancozeb 63% WP)+spray with Copper hydroxide 77% WP (2.0g/l) on 25 DAT+spray with Fenamidone 10%+Mancozeb 50% WDG (0.25%) two to three times from 45 DAT at 10 days intervals.

T3: Treatment with Insecticides

Main field treatment: Spray with Acephate 75% WP @1.5g/l on 10 DAT+spray with Fipronil 5% SC @1.5ml/l on 20 DAT+spray with Imidacloprid 70% WG @2g/15l on 40 DAT.

T4: Treatment with fungicides and insecticides

a. Nursery treatment: Seed treatment with Captan 50% WP (2g/kg) + drenching with Fosetyl Al 80% WP @0.1% immediately after germination + spray with Copper hydroxide 77% WP (2.0g/l) at 3-5 leaf stage.
b. Main field treatment: Seedling dip with 0.1% (Carbendazim 12% + Mancozeb 63% WP) + spray with Acephate 75% WP @1.5g/l on 10 DAT + spray with Fipronil 5% SC @1.5ml/l on 20 DAT + spray with Copper hydroxide 77% WP (2.0g/l) on 25 DAT + spray with imidacloprid 70% WG @2g/15l on 40 DAT + spray with Fenamidone 10% + Mancozeb 50% WDG (0.25%) two to three times from 45 DAT at 10 days intervals.

T5: Integrated management

a. Nursery treatment
    - Seed priming with Seed Pro @4g/kg,
    - Soil application of Seed Pro @10g/kg of soil while potting, and
    - Soil drenching with Seed Pro @5% after seed germination.
b. Main field treatment: Seedling dip with 0.1%

(Carbendazim 12%+Mancozeb 63% WP)+spray with Acephate 75% WP @1.5g/l on 10 DAT + spray with Fipronil 5% SC @1.5ml/l on 20 DAT+ spray with Copper hydroxide 77% WP (2.0g/l) on 25 DAT+spray with imidacloprid 70% WG @2g/15l on 40 DAT + spray with Fenamidone 10% + Mancozeb 50% WDG (0.25%) two to three times from 45 DAT at 10 days intervals.

T6: No spray (control)

Experimental data recording

The incidence of different diseases like damping off, collar ror tomato spotted wilt and ToLCV, were recorded from all the individual plot percent disease incidence was calculate by using following formula.

$$PI= \frac{\text{Number of infected plants/plot}}{\text{Total no of plants observed/plot}} X\,100$$

Whereas, percent severity of early blight disease was recorded by selecting 10 plants from each treatment and disease severity was assessed from 30 days after transplanting (DAT) up to 90 DAT at 15 days intervals by using 0-5 scale (*Chattopadhyay et. al.*, 2007) [20]. Percent disease index (PDI) was calculated by using the following formula (Friedmann *et. al.*, 1998) [21].

$$PDI= \frac{\text{Sum of individual ratings}}{\text{Total number of plants evaluated disease scale}} X\,100$$

Marketable fruits (excluding disease and insect damage fruits) of the periodical harvests from the individual plot were counted and weighed to express marketable fruit yield per plot (kg) and then it was converted to marketable fruit yield (quintal) in hectare.

Economic analysis

The cost benefit ratio (B:C) over the control was worked out separately considering different treatment combination on the basis of existing prices of inputs, hired labour wages (Rs.213.5/- per man days), market price of tomato fruit (Rs.1000/- per quintal) during the time of this study

Results and Discussion

Effect of treatments on disease incidence/ severity

Attempts were made to develop integrated management strategies, an experiment was conducted under All India Coordinated Research Project on Vegetable Crops at Horticulture Research Station OUAT, Bhubaneswar (East and SE Coastal Plain Zone, $20^0$15'N latitude and $85^0$52' E longitude) involving physical, biological and chemical module has been formulated to manage the tomato diseases during four consecutive years from 2014-15, 2015-16, 2016-17 and 2017-18 during the *Rabi* season. Disease incidences/ severity different diseases were recorded as mentioned in the materials and method and fruit yield was calculated from cumulative harvest. The results of percent disease incidence/ severity of different diseases of tomato is presented in Table 1 and figure 1. The present investigation revealed that in general all the treatment combinations had substantial positive effects on the reduction of percent disease incidence / severity over control (Figure 2). Four years pooled data revealed that minimum incidence of damping off (3.9%) and collar rot (3.7%) with maximum reduction 72.5 and 67.5% respectively were found in treatment combination comprising bioagents (T1) followed by integrated management practices (T5). Antagonistic activity of *Bacillus subtilis* against collar rot in tomato caused by *Sclerotium rolfsii* was very effective in reducing incidence (62.92%) as described by Mandal *et al*. (2017) [22]. Bioagents secreted an array of chemically diverse antimicrobial secondary metabolites and hydrolytic enzymes such as proteases, cellulases, chitinases, lipases etc. which may have a possible role in enhancing the host growth and vigor, increasing antagonistic microbial activity and enabling them to resist the attack of this pathogen (Pohronezny *et al.* 1986) [23], (Mahato *et al.,* 2017) [24] and (Abd- Allah, 2005) [25]. Severity of early blight during the course of study was significantly reduced in treatment combinations (T5) involving integrated management practices as compared to control. The minimum disease incidence (13.5%) and the maximum disease reduction (76.5%) were recorded in treatment (T5) involving integrated management practices followed by combined application of fungicides and insecticides (T4). The treatment comprising integrated management practices involve fenamidone 10% + mancozeb was found effective against early blight of tomato as reported by Manadal *et al.* 2017 [26] and the treatment combinations involved mancozeb as one of the fungicides which was found to be effective for the management of early blight in tomato as reported by Sarkar *et al*. 2015 [27]. Diseases like TOLCV and tomato spotted wilt is transmitted by whitefly and thrips respectively and incidence of these diseases depend upon movement and population of whitefly and thrips. Lowest incidence of TOLCV (7.1%) and tomato spotted wilt (4.4%) with maximum reduction of tomato leaf curl virus ((71.7%) and tomato spotted wilt (66.7%) were recorded in the plots which received the treatment integrated management practices (T5) and the treatment is statistically significant over control plots.

Effective restriction in vector population at various growth stages of the crop is crucial for successful implementing viral disease control programs. Since the TOLCV and tomato spotted wilt diseases are transmitted by whitefly and thrips, the movement of whitefly and thrips were restricted by heating back from the barrier crop which was 90-100cm in height by this time and use of white Agri polythene mulch having reflecting activity of light might have caused low level of vector population and low level of disease incidence. Our results agreed well with the observations of previous workers (Mullins and Engle 1993) [28], Ahmed *et al.* (2001) [29] and. Cahill *et al.* 1996 [30] who recommended neonicotinoid group of insecticides (thiomethoxam, imidacloprid and dinotefuron) to reduce whitefly populations in order to save tomato plants against leaf curl virus diseases.

Effect of treatments on marketable yield

Marketable yield of each treatment was calculated after several pickings in four consecutive years and presented in Table 2. The pooled data showed that fruit yield was significantly higher in all treatment combinations (253.4 to 352.9/ha) compared to control (180.4 /ha) indicating the positive effects of different treatments on increase in yield of tomato. The maximum fruit yield (352.9 q/ha) was recorded in plots receiving integrated management practices (T5) followed by T4 (335.7q/ha), T2 (321.0/ha), T1 (309.8 q/ha) and T3 (253.4 q/ha) and the treatments were statistically significant over control. The percentage increase in marketable yield over control ranged from 28.8% (T3) to 48.8% (T5). The integrated management practices could significantly reduce the incidence of tomato disease at right stages that result profuse growth of the crop and ultimately increase the maximum tune of marketable fruit yield compared to untreated control. On the other hand, susceptibility of the crop against different diseases in untreated control exhibited weak growth of the crop resulting very low yield.

Economics analysis of different treatments

The cost of cultivation was computed separately considering different treatment combination on the basis of existing prices of inputs, hired labour wages (Rs.213.5/- per man days), market price of dried chilli fruit (Rs.1000/- per quintal) during the time of this study and presented in Table 2. Results that the cost of tomato production was highly influenced by different treatment combinations. Three years pooled data revealed that the maximum net return (Rs. 2,49,592.5/-) was obtained with integrated management practices (T5) and the minimum net return was recorded in T6 (Rs. 90,020/-) which is presented in Figure 3. Similarly, the cost benefit ratio was found to be the maximum in integrated management practices (T5) (3.2) and the minimum B:C was recorded in T6 (1.9). This was happened due to high excess yield recorded in plots received proper integrated disease management practice (T5). Considering the cost of cultivation of different treatments, it is clearly indicated that T5 recorded the highest net return with highest B:C ratio though lowest disease incidence and maximum reduction of different diseases wererecorded in T5. Our results well supported by observations of previous workers (Mandal *et al.* 2017) [30].

Table 1: Effect of different treatments on diseases and yield (q/ha) of tomato (Pooled 2014-15 to 2017-18)

Treatments	% incidence of Damping off	% incidence of Collar rot	% Severity of Early blight	% incidence of tomato spotted wilt	% incidence of TOLCV
T1	3.9(2.08)	3.7(2.04)	26.25(30.45)	9.6(3.01)	16.7(23.66)
T2	5.1(2.36)	3.9(2.08)	18.6(25.31)	9.8(3.04)	13.2(20.72)
T3	12.1(3.52)	9.2(3.10)	44.7(41.93)	7.1(2.67)	9.4(17.17)
T4	5.4(2.41)	4.4(2.20)	15.9(23.01)	5.3(2.06)	8.1(15.42)
T5	4.1(2.27)	3.7(2.03)	13.5(21.23)	4.4(2.0)	7.1(14.46)
T6	14.2(3.67)	11.4(3.42)	57.4(49.35)	13.2(5.76)	25.1(29.76)
CD(0.05)	0.42	0.11	2.83	2.74	1.25

Table 2: Fruit yield of tomato (q/ha) and economics as influenced by different treatments (Pooled 2014-15 t0 2017-18)

Treatments	Yield(q/ha)	Cost of cultivation(Rs./ha)	Gross Income(Rs./ha)	Net Income (Rs./ha)	B:C ratio
T1	309.8	103296.5	309850.0	206553.5	3.0
T2	321.0	107917.0	320950.0	213033.0	2.9
T3	253.4	97453.0	247650.0	105197.0	2.5
T4	335.7	109677.8	333550.0	223872.2	3.0
T5	352.9	112640.0	362232.5	249592.5	3.2
T6	180.4	94925.0	184945.0	90020	1.9
CD(0.05)	37.35				

Field view of experimental field

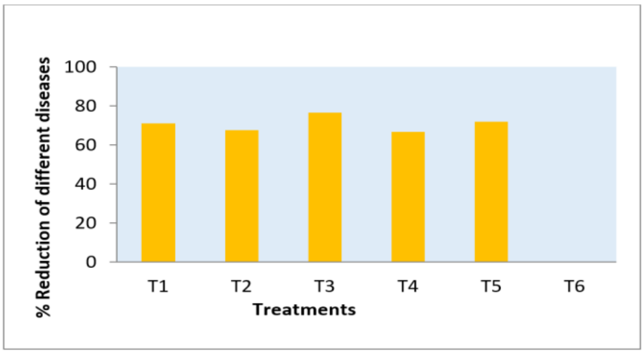

Fig 2: Effect of different treatments on reduction of different diseases

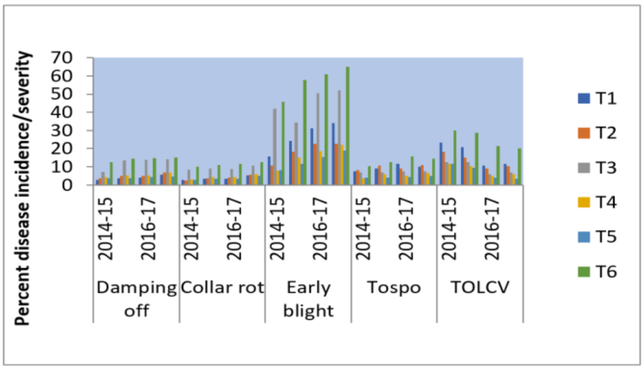

Fig 1: Effect of different treatments on disease incidence/severity

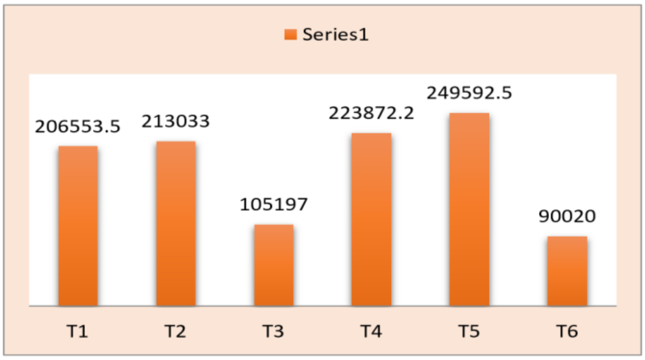

Fig 3: Net income (Rs.)

Conclusion

Therefore, it can be concluded from the present investigation that that the different diseases of tomato are the major hindrance for tomato cultivation particularly in the Coastal zone of Odisha, could effectively be reduced in a sustainable manner through integration of physical, biological and chemical management practices. Further it was revealed from the present study that the treatments were statistically equally effective in respect of reducing disease incidence by lowering the disease incidence/ intensity over the control. So, tomato growers who are facing problem from different diseases can easily grow their crop by adopting the technologies involving barrier crop, economic use of bio agents and chemicals. because this integrated disease management practice (T5) gave maximum net return (Rs. 2,49,592.5/-) with highest B:C ration (3.2).

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