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Employing Eco friendly potato disease management allows organic tropical Indian production systems to prosper

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Abstract

Serious potato diseases in West Bengal include: i) Viruses, ii) Late blight (*Phythophthora infestans*), iii) Common scab (*Streptomyces scabies*), iv) Black scurf and v) Bacterial wilt (*Ralstonia solanacearum*). Biologically based management strategies can substitute for the use of agrichemicals commonly applied under conventional production systems. Organic cultivation allows production of profitable and high quality food with less human and environmental exposure to dangerous agrichemicals as compared to conventional agricultural systems. For potato virus epidemics, planting early in the cropping season and using short duration cultivars helps to avoid early incidence and high disease severity. For combating late blight, tolerant cultivars are used in combination of seed treatment with *Trichoderma viride*, a fungal hyperparasite and other effective biological control methods.. Black scurf control is done using seed tuber treatment with 3% boric acid or *Trichoderma viride*. Plant Growth Promoting and biological control bacteria such as *Bacillus* spp. and/or *Pseudomonas fluorescens* have been using by the potato growers nowadays as seed coating and soil application to manage deadly diseases i.e, bacterial wilt and common scab. Organic amendments such as soil application of composts, green manure, FYM and oilcakes to suppress soil borne pathogens and crop rotation have also enabled the organic potato growers to combat these threats effectively during production of table and seed potatoes. Although no single method gives a high range of efficacy for a broad range of diseases by using a tool chest of biological methods in symphony high reliable ranges of control are possible under many conditions without dependence on expensive and toxic chemical methodologies.

Keywords :

Introduction

Modern agriculture depends on high input of chemical fertilizer and pesticides for crop production. Although such technology-based agricultural practice has increased agricultural productivity and abundance, the resulting ecological and economical impacts have not always been positive. Environmental pollution and food safety due to chemical contamination have become a great concern worldwide (Hsieh, 2000). Organic farming is an integrated farming system which involves both technical aspects (soil, agronomy, weed, and pest management) and economic aspects (input, output, and marketing) as well as human health. Chemical-free safe foods produced from organic farms are widely welcomed by consumers around the world today, especially in North America, Europe, South America, Asia and Oceania. Due to the great global market demand, production of organic foods has been increasing rapidly nowadays (Briones, 2004). In India, a comprehensive policy on organic farming has been proposed by the Ministry of Agriculture. The government promotes organic farming to emphasize the need to reduce the use of harmful chemicals on the farm. The government identifies progressive farmers to participate in organic farming training, and to help them form "Organic Farming Association" at the village level. According to Prabha, 2002, there are three types of organic farmers in India such as a) Farmers who follow the old pattern of indigenous farming practice b) Farmers who are practicing "biodynamic agriculture" or "natural farming" on their own small and medium-sized lands and c) Private companies engaged in large-scale organic farming for export. India produces primary organic products (Potato, coffee, tea, spices, fruits, vegetables, cereals, as well as honey and cotton). Domestic organic markets and consumer awareness are underdeveloped in India, but interest is growing at a faster rate. On the domestic market, organic food is usually sold directly from farmers or through specialized shops. At present, organic products receive a price premium of 20-30 percent over conventional products (FAO, 2002). The organic approach of disease management are nowadays adopted by the potato growers in small scale. Serious potato diseases are Viruses caused by PVX, PVY and PLRV, Late blight caused by *Phytophthora infestans* (Mont.) de Barry, Bacterial wilt caused by *Ralstonia solanacearum* (Smith.) Yabuuchi et al, Black scurf caused by *Rhizoctonia solani* Kuhn and Common scab caused by *Streptomyces scabies* (Thaxter.) Walksman and Henric (Basu et al, 2003). Keeping this view in mind, the following studies were conducted.

Objectives

1. This paper aims to look into the formulation and establishment of organic strategies to combat the diseases under West Bengal potato production system.
2. Different organic methods have been successfully introduced in the field by the farmers to manage these dreadly diseases effectively for maintaining the soil health without polluting the environment.
3. Some important organic approaches with their practical utility and successful adoption under West Bengal conditions are discussed here very briefly.

Materials and Methods

Effect of organic sources of nutrients for potato production:-A field trial was conducted during two successive years (2002-03 and 2003-04) to study the influence of organic sources of nutrients on potato production as compared to inorganic sources (Chettri et al., 2005). The experiment included the seven treatments including control.

Table 1: Tuber yield and economics of potato as influenced by organic sources of nutrients.

Treatment	Total tuber yield (q/ha)	Cost of cultivations (Rs./ha)	Price of productions (Rs./ha)	Net returns (Rs./ha)
T_1 (FYM@30t/ha)	268.70	43,800	80,610	36,810
T_2 (FYM@20t/ha+ Biofertilizers)	224.36	43,400	67,308	23,908
T_3 (FYM@10t/ha+Biofertilizers +Crop residues)	**243.59**	**42,900**	**73,077**	**30,177**
T_4 (FYM@20t/ha+ Biodynamics,BD-500)	220.94	43,380	66,282	22,902
T_5 (Biodynamics,BD-500+ Biofertilizers)	212.60	42,480	63,780	21,300
T_6 (Recommended dose of NPK)	281.78	48,120	84,534	36,414
T_7 (No use of FYM and NPK)	207.80	42,300	62,340	20,040
CD(P=0.05)	39.53	-	-	-

Results showed that, maximum tuber yield (281.78 q/ha)was found when potato crop was fertilized with inorganic sources of nutrients(T6) .Tuber yield of potato under organic sources of nutrients was lower but, it was statistically significant particularly in case of treatment receiving FYM@30t/ha and FYM@10t/ha+ Biofertilizers (*Azotobacter* and *Phosphobacteria*) +crop residue of previous crop. Overall, organic sources of nutrients (FYM) alone @30t/ha or in combination with biofertilizer and crop residues gave qualitative and comparable yield. Hanumann (2003) also found that, organic farming is efficient, energy saving, maintain stable yield over the years and keep soil healthy for future generation, giving only 20% less yield than conventional method, but were profitable. Hence, due to consistent returns, farmers have been accepting and adopting this method very spontaneously.

Avoiding vector pressure to manage the viruses: - For managing potato virus epidemics, especially in case of seed crop, planting early in the cropping season helps to avoid early incidence and high disease severity. The viruses i.e, PVX, PVY and PLRV spread mainly through one or more aphid vectors species in non persistent manner. Therefore, the seed crop is raised only in aphid free periods (October-December/January) in the plains of West Bengal starting with healthy seeds, field inspection for rouging all infected /off type plants, dehaulming the crop as soon as the aphids cross the critical limit of 20 aphids/100 compound leaves. In West Bengal, maximum viral incidence (52%) occurs during the spring crop (January to April). But, In early crop (October to January) the incidence of viruses is least (5%) causing less damage to the crop (Konar and Basu, 2003). Hence, in this seed producing areas of eastern plains, due to low aphid population in early crop, there is a least chance of losses in yield and infiltration of viruses in the medium maturing varieties which are in active stage of tuberisation. In this method, non judicious use of pesticides is avoided and cost of production is less. Hence, the farmers will get high price from their qualitative produce.

Development of warning system for late blight in West Bengal (Basu, 2003)

A detailed study was conducted for 10 years (1990-2000) in Hooghly area (major potato growing belt) to detect the pattern of late blight development in the plains of West Bengal by Basu and Mukhopadhya (2000). It is now ascertained that, late blight appears regularly between 1st and 3rd week of January in the plains of this region depending upon the types of cultivars grown, when the environmental conditions are congenial for its development 7 days before the onset .Environmental data were recorded from regional weather stations. Input variables are daily maximum and minimum air temperature (°C), daily maximum and minimum relative humidity (%), daily rainfall (mm) and sunshine hours.

This forecasting model was developed under West Bengal condition and has been used since 2000. The model contains four criteria used to assess the risk of potato late blight disease caused by the fungus *Phytophthora infestans*. The following environmental conditions are considered favorable for the disease development and it's further spread: a) Temperature ranges from 12.8°C-21.7°C b) Relative humidity ranges from 65-98% c) Sunshine hours 0.5 d) Rainfall ranges from 5.6-6.3mm. Warnings are issued daily by Bidhan Chandra Krishi Viswa Vidyalaya, West Bengal and distributed through press and broadcasting systems, when these conditions occur for three to four consecutive days. The risk of disease outbreak increases with the number of favorable days. This model has been tested in several locations where, moderate to severe potato late blight occurs at regular intervals. Lower disease severity than expected can occur in locations where low or no inoculum is present due to low disease pressure in previous. This model has been validated and implemented in West Bengal. The limitation of this model is that, it does not differentiate between initial infection conditions and subsequent infection events; it provides a warning of the risk of infection anytime during the season.

Alteration of date of planting to avoid the severity of late blight

An investigation on different dates of planting was conducted by Maiti and Basu, (2006) which identified the suitable date of planting for this region, when diseased sprouts and tuber rotting will be less and tuber yield will be more. Artificially inoculated potato tubers of cultivar, Kufri Chandramukhi were used for planting. Data on tuber rotting and emergence of diseased sprouts were recorded at five days intervals up to 45th day after planting. Healthy and uninoculated tubers of same potato cultivars were planted as control. The infected tubers on germination did not produce any diseased sprouts when planted on 1st week of November during every year. Tuber rotting on the other hand, was maximum (51.9 to 60.4%) during that period. The incidence of diseased sprouts was insignificant in crop planted during 1st week of November as compared to healthy one. Diseased sprouts were also quite low (4.1 to 5.3%), when inoculated tubers were planted on second week of November and at the same time, tuber rotting was quite high (25.2 to 29.4%). Maximum diseased sprouts (13.8% to 15.5%) and minimum tuber rotting (8.2 to 10.2%) was noticed when inoculated tubers were sown during 1st week of December during both the years.

Table 2: Influence of date of planting on disease sprouting (%) and tuber rotting (%).

Planting week	Incidence of diseased sprouts (%)				Tuber rotting (%)			
	2004-05		2005-06		2004-05		2005-06	
	I	C	I	C	I	C	I	C
1st wk of Nov.	0	0	0	0	60.4 (51.00)	0	51.9 (46.09)	0
2nd wkof Nov.	4.1 (11.68)*	0	5.3 (13.31)	0	29.4 (32.85)	0	25.2 (30.13)	0
3rd wk of Nov.	6.3 (14.54)	0	8.1 (16.54)	0	11.8 (20.05)	0	13.4 (21.47)	0
4th wk of Nov.	13.6 (21.64)	0	15.3(23.03)	0	11.3 (19.64)	0	13.0 (21.13)	0
1st wk of Dec.	13.8 (21.81)	0	15.5(23.18)	0	8.2 (16.64)	0	10.2 (18.63)	0
CD(P = 0.05)	2.85	-	2.31	-	1.76	-	2.46	-

* Figures in the parenthesis are angular transformed values, I = Inoculated, C = Control (Healthy)

Tuber rotting was max. at higher soil temperature(>30 °C) and soil moisture(80%) during early part of November. Planting during 1st week of December, showed reduction in soil temperature (<30 °C) and soil moisture (78%) and had least chance of development of diseased sprouts (<10%) and tuber rotting (around 10%). Hence, the crop escapes the disease and gives the expected yield. Thus, delayed planting helps to manage the disease by reducing use of chemicals and producing quality tubers. This organic approach of planting is now widely accepted and adopted by the potato growers of this region.

Biological management of late blight

Table 3: Effect of seed dressing with antagonists on late blight disease and yield of potato.

Antagonists	Dose (g kg^{-1} of seed)	Disease severity (%)	PEDC (%)	Yield (t ha^{-1})	Yield increase over control (%)
T_1– *T.harzianum*(2x10^7)	5.0	25.4 (30.26)*	44.8 (42.02)	19.5	46.4 (42.94)
T_2 – *T viride(*2 x 10^7)	5.0	30.3 (33.40)	34.2 (35.79)	18.5	38.7 (38.47)
T_3– *G. virens(*2 x 10^7)	5.0	32.6 (34.82)	29.2 (32.71)	18.0	35.1 (36.33)
T_4– *P.fluorescens*(10^9)	2.5	26.7 (31.11)	41.7 (40.22)	19.0	42.5 (40.69)
T_5*Bacillus subtilis*(10^9)	2.5	29.3 (32.77)	36.3 (37.05)	18.6	39.6 (39.00)
T_6*Bacilluscereus*(10^9)	2.5	30.7 (33.67)	33.1 (35.12)	18.0	35.1 (36.33)
T_7 - Control	-	46.1 (42.76)	-	13.8	-
CD (P = 0.05)	-	1.87	2.73	1.07	3.33

* Figures are angular transformed values, PEDC – Percent efficacy in disease control

A field trial for two years (2004-05 & 2005-06) on seed dressing with fungal and bacterial antagonists was proved to be significantly superior over control in all respect Maiti and Basu (2006) observed that, out of 6 antagonists, (*Trichoderma viride*, *Trichoderma haszianum*, *Gliocladium virens*, *Pseudomonas fluorescens*, *Bacillus subtilis* and *Bacillus cereus*) so far tested against *Phytophtora infestans*, causal agent of late blight disease, *T. harzianum* (2 x 10^7 cfu·g^{-1}) became highly effective in reducing the disease severity (25.4 %) followed by *P. fluorescens* (26.7%) as compared to control (46.1%). *T. harzianum* @ 5.0 g·kg^{-1} of seed and *P. fluorescens* @ 2.5 g·kg^{-1} of seed gave significant disease control (44.8% and 41.7% respectively). *T. harzianum* and *P. fluorescens* also significantly enhanced the tuber yield (19.5 t·ha^{-1} and 19.0 t·ha^{-1}, respectively) as compared to control (13.8 t·ha^{-1}). This biocontrol method of disease management is now widely adopted by the farmers. The commercial formulations of these above antagonists are also available in the market in different trade names.

Organic management of Black scurf of potato

Black scurf of potato caused by *Rhizoctonia solani* an important disease of potato responsible for poor stand in the field and reduced marketability of tubers. Conventional cultural and chemical control of this pathogen have been unsuccessful due to soil borne nature of the pathogen, wide host range and ability of sclerotia to withstand adverse soil conditions. A trial was conducted under field condition with antagonistic microflora where, these antagonists were applied as seed treatment and soil drenching (Basu and De, 2003). Seed treatment was done by treating the tubers with a suspension of spore/cell (10^8/mL) @ 250mL/kg of tubers together with 2% methyl cellulose as sticker. Soil drenching was done by applying wheat bran water (1:1) culture of antagonistic fungi ($2.5x10^7$ cfu/g of substrate) @ 200 g/kg of soil. Each treatment was replicated five times. Severity was measured in 0-4 scale. Sclerotia were collected from soil by sieving and further viability test was done by assessing the germination percentage. Potato seed tubers treatment and soil application with all antagonists significantly reduced disease incidence and severity and viability of sclerotia over control. Plots treated with antagonists also recorded increased yield and made the tubers free from infection. *T. harzianum* was most effective followed by *P. fluoroscens* and *T. viride* in reducing disease and increased yield over check. At present, due to excessive use of agrochemicals, the productivity of soil in this region is also remarkably decreased. Hence, this method may restore the soil health. Farmers have also been motivated to adopt this practice to curtail the costs of chemicals.

Table 4: Use of bioagents to manage the black scurf of potato caused by *Rhizoctonia solani*.

Treatment	Disease incidence (%)	% reduction in incidence over control	Disease severity (%)	% germination of sclerotia	% reduction in germination of sclerotia over control
A. Seed treatment					
Trichoderma. viride	48.0	49.7	3.17	20.5	77.9
Trichoderma. harzianum	43.0	54.7	2.82	16.5	82.2
Bacillus subtilis	54.0	43.9	3.45	24.5	73.6
Pseudomonas fluoroscens	45.0	52.6	2.95	18.5	80.0
B. Soil drenching					
Trichoderma. viride	53.0	44.2	3.54	26.5	71.5
Trichoderma. harzianum	50.0	47.4	3.34	24.5	73.6
Bacillus subtilis	57.0	40.0	3.68	29.5	68.3
Pseudomonas fluoroscens	52.0	45.3	3.47	25.5	72.5
Control	95.0	-	6.23	93.0	-
C.D.(P=0.05)	3.5	-	0.08	2.4	-

Formulation of IDM schedule to combat four important potato diseases

An integrated approach for managing potato diseases was formulated by Basu and Das (2002). Four IDM components (host resistance, cultural, chemicals and bioagents) were used to manage the viruses, late blight, Black scurf and common scab. In this connection, after getting positive result in the green house, six treatments were tested in the field trial for consecutive two years. The treatments are: T1= Control (late blight susceptible cultivar+ no tuber treatment+ no chemical spray+no haulm cutting), T2= disease free seeds of late blight resistant cultivars+ tuber treatment with 3% boric acid for 30 minutes to manage black scurf and common scab+ rouging to avoid viruses+2 spray of metasystox to avoid aphid vectors+2 spray of cu fungicide to manage late blight+ dehaulming to keep the tubers disease free, T3= Tuber treatment with *Trichoderma viride* to avoid black scurf and common scab, T4= Late blight resistant cultivar+2 spray of cu based fungicides, T5= late blight resistant cultivar and one spray of cu fungicide, T6= late blight resistant cultivar+1 spray of cu fungicide as prophylaxis+1 spray of ridomil. Among these treatments, T2 was most effective, which not only increased the total tuber yield (26.85t/ha) but ,also remarkably reduced the severity of severe mosaic (5.5%), leaf roll viruses (5.0%), late blight (7.0%), black scurf (5.0%) and common scab(6.0%) of potato as compared to other treatments including control. This IDM schedule is now very much popular among the farmers of this region.

Table 5: Disease development in foliage and tubers of potato.

Treatment	Late blight Severity (%)	Severe mosaic(%)	PLRV(%)	% tuber blight	% of Black scurf	% of common scab	Total tuber yield
T_1	22.6	10.6	9.5	10.0	20.0	17.5	17.50
T_2	**7.0**	**5.5**	**5.0**	**6.0**	**5.0**	**6.0**	**26.85**
T_3	8.0	6.5	7.5	5.0	6.5	12.7	17.06
T_4	6.0	8.5	9.0	4.0	10.0	13.0	20.00
T_5	12.0	9.0	8.7	5.5	11.0	13.7	18.50
T_6	10.3	10.0	8.0	7.0	12.5	15.0	17.00
CD(P=0.05)	3.28	1.98	2.25	2.53	3.12	3.50	8.20

As a result of which, use of pesticides has been remarkably reduced. Cost of production is also becoming less. On the other hand, reduced use of chemicals produces qualitative tuber yield, which is at present desired by the consumers. Therefore, farmers are getting high price from their produce.

Table 6: Formulation of IDM schedule against potato bacterial wilt (*Ralstonia solanecearum*)

Treatment	2005-06				2006-07			
	E (%)	Wilt (%)	BR (%)	Yield (q/ha)	E (%)	Wilt (%)	BR (%)	Yield (q/ha)
T_1 (seeds from wilt free area)	82	1	-	296.0	96	8	-	296.0
T_2 (T_1 + blind earthing)	82	1	-	295.0	97	7	-	307.0
T_3(T_1+ bleaching powder@12kg/ha)	82	2	-	291.0	96	7	-	313.0
T_4 (T_3+blind earthing)	**82**	**1**	**-**	**294.0**	**98**	**4**	**-**	**318.0**
T_5 (T_1+ summer ploughing)	83	1	-	279.0	96	4	-	305.0
T_6 (T_1 + paraquat as weedicide)	83	3	-	282.0	96	8	-	300.0
T_7 (Apparently healthy seeds from wilt infested crop)	83	12	-	232.0	94	18	-	240.0
CD(P=0.05)	2.45	2.05	-	42.12	1.56	2.72	-	20.65

E= emergence, BR=brown rot, - =not reported

In the areas (West Midnapore, Birbhum, Bankura and Purulia) of West Bengal, India, Potato is cultivated between the month from October–March. Day temperature during this cropping period reaches up to 38 °C. Heavy precipitation causes transmission of this bacteria from infested field to healthy field very easily. Hence, the control of the disease is difficult. However, the disease can be kept under check with agronomic practices like T4 (use of disease free seeds, application of bleaching powder, blind earthing) and ploughing of land in March and leaving the soil exposed to summer temperature during April-May (Basu, et al, 2003). This method is considered to be best out of different management practices so far available against bacterial wilt of potato.

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