Journal of
Plant Pathology & Microbiology
ISSN: 2157-7471

Siddique et al., J Plant Pathol Microbiol 2016, 7:7
DOI: 10.4172/2157-7471.1000364

Research Article Open Access

Comparative Efficacy of Different Fungicides against Late Blight Diseases of Potato incited by *Phytophthora infestans* (Mont.) de Bary and its Management

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Abstract

Efforts made in present investigation to evaluate the concentration of few commonly used fungicides for their comparative efficacy against *Phytophthora infestans* (Mont.) de Bary- the incited of late blight, with a view to select the most effective fungicides for the disease management. The highest (99.70) percentage of disease control and the highest yield (26.68 ton/ha) were recorded on fungicides containing 3.5 mg/L Sunoxanil 72 WP (Cymoxanil 8%+Mancozeb 64%) with 3.0 ml/L Contaf 5EC (Hexaconazol 5%) during 2015-2016. The lowest (75.68) percentage of disease control and the lowest yield (15.67 ton/ha) were recorded on fungicides containing 2.0 mg/L Ridomil MZ 72 (Metalaxyl 8%+Mancozeb 64%) with 1.0 ml/L Autostin 50 WDG (Carbondaxim 50%) during 2014-2015. It was concluded that Sunoxanil 72 WP (Cymoxanil 8%+ Mancozeb 64%) acted as the best fungicide when applied as prophylactic measures. Sunoxanil 72 WP (Cymoxanil 8%+ Mancozeb 64%) was combined with Contaf 5EC (Hexaconazol 5%) showed the best result when applied as curative measures. On the other hands when Actiphose (Phosphorous acid)) was used with Mancozeb (Indrofil M-45) showed comparatively better performance. Plant growth as well as its yield gradually decreased due to the application of Carbondaxim.

Keywords: Potato; Late blight; Management; Hexaconazole; Mancozeb; Sunoxanil 72 WP; Autostin50 WDG; Actiphose; Ridomil MZ 72; Disease index; Disease control

Introduction

Bangladesh is mainly an agro-based country. It is a thickly populated small country with an area of 14.48 million ha. According to an estimate by Bhuiyan et al. [1], net cultivable land would decrease from 8.42 million ha in 2000 to 7.89 million ha in 2025 and population would increase from 127.22 million in 2000 to 168.96 million in 2025. The per capita net cultivable land would reduce from 0.066 ha in 2000 to 0.047 ha in 2025 [1]. The population has doubled in the last 30 years despite a decline in the annual population growth rate from 2.26 in 1961 to 1.47 in 2004. Potato is a staple food in the developed countries and which accounts for 37% of the total production in the world [2]. Considering the trend of population growth and consequently the increased demand for food in the country and dwindling cultivable land area, the potato is likely to play a vital role in the future. For the whole year, it is used as the main vegetables. Potato production in Bangladesh in the fiscal year (FY) 2012-2013, hit a new record of 8.603 million tones surpassing the record of 8.38 million tons in FY'2011. The production witnessed a negative growth in FY'2012 when it plunged to 8.205 million tones - 2.08 percent fall compared to that of FY'2011. The Bangladesh Bureau of Statistics (BBS) in its latest release, said potato, the most consumed vegetable item of the country was cultivated on 0.444 million hectares of land in FY'13. The acreage had increased by 14,000 hectares compared to that of FY'2012 which also helped achieve a higher output. Potato was produced on 4.6 million hectares in FY'2011. On the other hand, in Bangladesh, exports crossed the one-lac-tons (0.1 million ton) mark for the first time in the FY 2013-14, rising threefold from only 28,416 tons in the previous year, according to the Department of Agricultural Extension (DAE). Earning also trebled to $33.82 million in 2013-2014 compared to the previous year, Export Promotion Bureau data shows, this is a milestone. Potato is one of the main commercial crops grown all over the country. In Bangladesh, potato is mainly consumed as vegetables. Various other food items (Singara, Samucha, Chop, chips, different first food etc.) are also made from potato. Adequate supply of potato stabilizes the vegetable market all round the year. Recently, the government has been trying to diversify food habits and encourage potato consumption to reduce pressure on rice. So, potato is becoming an important food for food security in Bangladesh. So Potato is one of the leading vegetable crops with immense yield potential giving remunerative income to the farmers and having excellent nutritional value.

Late blight caused by *Phytophthora infestans* (Mont.) de Bary is a major threat to Potato production in Bangladesh because of its increasing distribution and brutality [3]. Common fungicides used by farmers and potato producing companies are Indrofil M-45 (Mancozeb 80%), Sunoxanil 72 WP (Cymoxanil 8%+Mancozeb 64%), Contaf 5EC (Hexaconazol 5%), Autostin50 WDG (Carbondaxim 50%), Ridomil Gold (Mefenoxam 8%+Mancozeb 64%), Actiphose (Phosphorous acid) etc. Chemical control of this disease is playing a vital role in potato production as resistant varieties are being not available. In traditional methods, most of the farmers or potato producing companies are trying to control this late blight disease by using only moncozeb or combined with carbondaxim. In most of the cases, they failed to control this disease. Although the Mancozeb gave good control of late blight of potato but when the environment is in disfavor its controlling power gradually reduce and farmers face great difficulties. Fungicides encourage the development of resistance in *Phytophthora infestans*

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Received June 20, 2016; **Accepted** July 05, 2016; **Published** July 07, 2016

Citation: Siddique NA, Aktar MS, Swapon NH (2016) Comparative Efficacy of Different Fungicides against Late Blight Diseases of Potato incited by Phytophthora infestans (Mont.) de Bary and its Management. J Plant Pathol Microbiol 7: 364. doi: 10.4172/2157-7471.1000364

and the pathogen requires higher doses of fungicides in controlling the disease, which disturbs the cost benefit ratio and environment. To eliminate an extensive and un-judicial use of fungicides, the present studies were carried out to get best effective spray interval, combination and number of spray under conditions before and after the disease appearance.

Materials and Methods

The field experiments were carried out in different potato project experimental farms of Ejab group ltd. at Thakurgaon and Dinajpur district in Bangladesh. The research was done in season of 2014-2015 and 2015-2016 respectively. The crop was raised as per standard agronomic practices during main season (November to March). These advanced lines/varieties were planted in a randomized complete block design with four replications. Each replicate consists of 1 acre (4047 square meter) land. Two experimental blocks were selected in Thakurgaon district and two were in Dinajpur district. Each set consisted of six fungicides with different interval which served in each block and the treatments were randomized within these block. Experiment was conducted on large scale involving four varieties named Diamant, Cardinal, Asterix, Lady Rosseta. About 42 thousand tubers were sowing per acre at each replicate. The timing of applications was based on the condition for late blight disease. All treatments were curative and prophylactic spray. Six selected fungicides viz; Indrofil M-45 (Mancozeb 80%), Sunoxanil 72 WP (Cymoxanil 8%+Mancozeb 64%), Contaf 5EC (Hexaconazol 5%), Autostin50 WDG (Carbondaxim 50%), Ridomil Gold (Mefenoxam 8%+Mancozeb 64%), Actiphose (Phosphorous acid) were evaluated under field conditions.

First spray of the fungicides was carried out one month after the sowing of crop and was continued at intervals of 07 days till haulm-pulling of potatoes. The data were recorded one day before spray. Concentration of components is the most important factor to prophylactic and curative of diseases control. When the environment is in disfavor to potato plants growth or pathogens are extremely spread on atmosphere, the concentration of chemicals might be increased to prevent from epidemic. Percentage area of disease Control (PADC) was recorded at 7 days intervals after the last spray.

$$\%\ \text{Area of disease control}\ (\text{PADC}) = \frac{\text{Area affected}}{\text{Total plant area}} \times 100$$

Results

Chemical control remains the most important control measure against late blight. Growing potatoes without using fungicides has become unthinkable in most varieties of Bangladesh. The control strategy is primarily preventive but in case the pathogen infects extremely the potatoes leaves, this epidemic must be stopped by using more powerful formulations. In the field experiment it was observed that all fungicides when applied as prophylactic spray significantly reduced the foliage infection of late blight over untreated control. The foliage infection due to prophylactic spray at different fungicides was recorded after 71 DAS (day after sowing).

Evaluation of fungicides against late blight of potato in natural field condition as prophylactic spray (protective spray) during 2014-2015 and 2015-2016

Six fungicides were collected from the local markets and were tested for their antifungal potential against *Phytophthora infestans* under natural field conditions in protective as well as curative manner. Most of the fungicides are more efficient when applied prior to infection than after the infection has occurred or after the symptoms have appeared. Effective protective (prophylactic) spray interval were 43 DAS, 50 DAS, 57 DAS while 64 DAS 71 DAS spray interval gave minimum protection against late blight of potato. Perusal of data presented in Tables 1 and 2 showed that the prophylactic application of Indrofil M-45 (Mancozeb 80%), Sunoxanil 72 WP (Cymoxanil 8%+Mancozeb 64%), Ridomil MZ 72 (Metalaxyl 8%+Mancozeb 64%) with four additional spray of the respective fungicides at 7 days interval during 2014-2015 and 2015-2016 respectively. Among the different concentrations of fungicides the highest 95.34% of disease control was observed on Sunoxanil 72 WP (Cymoxanil 8% + Mancozeb 64%), containing 3.5 mg/L (Table 2, plot-6) during 2015-2016 and was followed by 91.28% disease control on same fungicide containing 3.0 mg/L) during 2014-2015 (Table 1, plot-6 Figure 1). In the present investigation, it was also found that the highest 23.65 ton/ha yield was recorded at Sunoxanil 72 WP (Cymoxanil 8%+Mancozeb 64%), containing 3.5 mg/L (Table 2, plot-6 Figure 2) during 2015-2016 and was followed by 21.67 ton/ha same component having 3.0 mg/L during 2014-2015) (Table 1, plot-6 Figure 1). The lowest percentage of disease control was recorded at 82.92% on fungicides containing 2.0 mg/L Ridomil MZ 72 (Metalaxyl 8%+Mancozeb 64%) and the lowest yield was recorded at 16.87 ton/ at same concentration (Table 1, plot -7 Figure 1).

Evaluation of fungicides against late blight of potato in natural field condition as prophylactic spray (protective spray) and curative spray during 2014-2015 and 2015-2016

Analysis of variance indicates that varieties, treatments, spray interval, interactions between varieties, treatments and spray interval were highly significant. Effective protective (prophylactic) spray interval were 43 DAS, 50 DAS, 57 DAS while 64 DAS 71 DAS spray interval gave minimum protection against Late Blight of Potato. In the present investigation, it was observed that different concentration and combination of different fungicides showed the most effective

Treatments	Plot no.	Doses	Prophylactic spray					Yield in ton/ ha
			Percentage Area of disease control (PADC)					
			43 DAS	50 DAS	57 DAS	64 DAS	71 DAS	
Indrofil M-45 (Mancozeb 80%)	1	2.00 gm/L	99.34	93.56	82.86	79.65	84.61	17.67
	2	2.50 gm/L	99.42	95.34	85.67	82.65	87.15	18.56
	3	3.00 gm/L	99.89	95.95	88.95	87.97	90.33	19.67
Sunoxanil 72 WP (Cymoxanil 8% + Mancozeb 64%)	4	2.00 gm/L	99.76	94.42	86.76	83.92	88.35	19.87
	5	2.50 gm/L	99.57	96.24	88.04	85.15	89.05	20.97
	6	3.00 gm/L	99.88	97.67	89.98	87.98	91.28	21.67
Ridomil MZ 72 (Metalaxyl 8%+Mancozeb 64%)	7	2.00 gm/L	99.26	90.67	80.98	77.89	82.92	16.87
	8	2.50 gm/L	99.46	92.68	83.95	80.87	85.47	17.43
	9	3.00 gm/L	99.76	94.98	85.87	82.65	87.16	18.23

Table 1: Percentage of diseases reduction over control as prophylactic spray at different concentrations during 2014-2015.

Treatments	Plot no.	Dose	Prophylactic spray % Area of disease control (PADC) 43 DAS	50 DAS	57 DAS	64 DAS	71 DAS	Yield in ton/ha
Indrofil M-45 (Mancozeb 80%)	1	2.5 gm/L	99.64	93.76	82.96	79.85	85.01	17.97
	2	3.0 gm/L	99.32	95.84	85.87	83.65	88.27	19.36
	3	3.5 gm/L	99.82	96.75	87.85	85.97	90.24	20.47
Sunoxanil 72 WP (Cymoxanil 8% + Mancozeb 64%)	4	2.5 gm/L	99.56	95.72	87.56	84.52	89.27	19.97
	5	3.0 gm/L	99.97	96.59	90.98	87.67	92.81	21.87
	6	3.5 gm/L	99.88	97.97	91.98	90.98	95.34	23.65
Ridomil MZ 72 (Metalaxyl 8% + Mancozeb 64%)	7	2.5 gm/L	99.06	89.67	83.98	80.89	85.69	17.82
	8	3.0 gm/L	99.47	92.67	84.93	82.85	87.06	18.23
	9	3.5 gm/L	99.86	95.08	88.57	84.67	89.34	19.25

Table 2: Percentage of diseases reduction over control as prophylactic spray at different concentrations during 2015-2016.

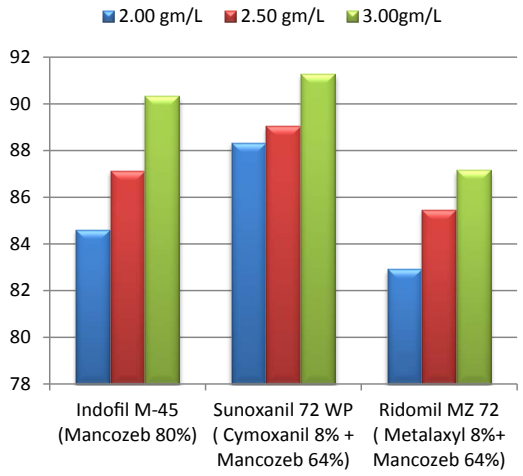

Figure 1: Showing percentage of diseases reduction over Control after 71 days after sowing as Prophylactic spray at different concentrations during 2014-2015.

role to prevent the late blight after appearance of disease (Curative). Sunoxanil 72 WP combination with Contaf 5EC (Hexaconazol 5%) when used after appearance of the disease showed the best results, the highest 99.70% of disease control containing 3.5 mg/L Sunoxanil 72 WP (Cymoxanil 8% + Mancozeb 64%) with 3.0 ml/L Contaf 5EC (Hexaconazol 5%) during 2015-2016 (plot-15) and was followed by 99.48% of disease control containing 3.0 mg/L Sunoxanil 72 WP (Cymoxanil 8%+Mancozeb 64%) with 3.0 ml/L Contaf 5EC (Hexaconazol 5%) during 2014-2015(Table 3 plot-15, Figure 3). The lowest 75.68 % of disease control was recorded on fungicides containing 2.0 mg/L Ridomil MZ 72 (Metalaxyl 8%+Mancozeb 64%) with 1.0 ml/L Autostin 50 WDG (Carbondaxim 50%) (Table 3, plot-16, Figure 3) during 2014-2015.

In the present investigation, it was also observed that the highest 26.68 ton/ha yield was recorded at Sunoxanil 72 WP (Cymoxanil 8% + Mancozeb 64%), containing 3.5 mg/L Sunoxanil 72 WP (Cymoxanil 8% + Mancozeb 64%) with 3.0 ml/L Contaf 5EC (Hexaconazol 5%) during 2015-2016 (Table 4 plot-1, Figure 4) and was followed by 25.58 ton/ha at same component containing 3.0 mg/L Sunoxanil 72 WP (Cymoxanil 8% + Mancozeb 64%) with 3 ml/L Contaf 5EC (Hexaconazol 5%) during 2014-2015 (Table 3 plot-1, Figure 3). and The lowest yield was recorded at 15.67 ton/ha on fungicides containing 2.0 mg/L Ridomil MZ 72 (Metalaxyl 8%+Mancozeb 64%)%) with 1.0 ml/L Autostin 50 WDG (Carbondaxim 50%) (Table 3, plot-16, Figure 3) during 2014-2015.

Discussion

Fungicide spray for potato crop management can be reduced by using formulations of protectant fungicides with less active ingredients or reducing the rate of application or by increasing the interval between two applications or a combining of any of the above mentioned strategies. Regular application of protective fungicides in combination with resistant cultivars has reduced the foliar late blight in potato crop [4]. Ojiambo et al. [5] reported that it is possible to reduce the infection rate and ultimately the epidemic development by using lesser quantity of fungicides on a cultivars having polygenic resistance as compared to cultivar having lesser resistance. Samoucha and Cohen [6] reported that a mixture of contact and systemic fungicides gives better control of late blight than the fungicides applied singly. Systemic fungicides provide better control as compared to contact fungicides [7,8]. However, the failure of Ridomil in some times giving perfect control of the disease and in some cases the intensive frequency of usage [9,10] necessitated.

These findings were also confirmed by Speiser et al. [11] who studied the effect of copper fungicides against *Phytophthora infestans* for all the cultivars. Our results are also congruent to the findings of Pranamika Sharma et al. [12] who evaluated the fungicides mainly hexaconazole + Zineb applied at 7, 14, 21, and 28 days intervals and reported that it significantly reduced the disease. All the treatments showed significantly better foliage controlled as well as tuber yield over non-treated control. The results of this study were consistent with previous studies and indicated that the application of protective fungicides could reduce foliar late blight to acceptable levels [7,13,14]. The experiment conducted by Dhanbir et al. [15] also similar to the present findings who concluded that all of the treatments reduced the disease but 8% metalaxyl + 64% mancozed (as Ridomil MZ 72WP) was the most effective. Present result is validating the previous studies in which late blight was successfully managed with the use fungicides on resistant cultivars by Kirk et al. [16]. In the present investigation it was observed that the spray with Mancozeb 65% + Carbondaxim 12% was not found effective. It might be due to continuous and increased use

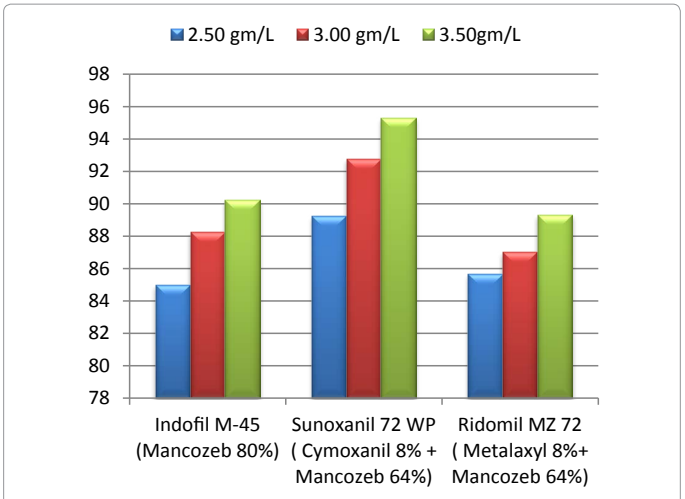

Figure 2: Showing percentage of diseases reduction over Control after 71 days after sowing as Prophylactic spray at different concentrations during 2015-2016.

Treatments	Percentage Area of disease control (PADC)							
	Plot no.	Dose	Prophylac tic spray	Curative spray			Prophylactic spray	Yield in ton/ ha
			43 DAS	50 DAS	57 DAS	64 DAS	71 DAS	
Indrofil M-45 (Mancozeb 80%)	10	2.0 gm/L	98.32	93.36	94.26	97.65	96.17	20.87
Actiphose (Phosphorous acid)		1 ml/L	-				-	
Indrofil M-45 (Mancozeb 80%)	11	2.5 gm/L	98.02	96.24	96.57	98.25	97.69	21.54
Actiphose (Phosphorous acid)		2.0 ml/L	-				-	
Indrofil M-45 (Mancozeb 80%)	12	3.0 gm/L	98.25	97.85	98.25	97.87	98.13	23.56
Actiphose (Phosphorous acid)		3.0 ml/L	-				-	
Sunoxanil 72 WP (Cymoxanil 8% + Mancozeb 64%)	13	2.0 gm/L	97.96	96.32	97.56	98.12	98.13	23.76
Contaf 5EC (Hexaconazol 5%)		1.0 ml/L	-				-	
Sunoxanil 72 WP (Cymoxanil 8% + Mancozeb 64%)	14	2.5 gm/L	98.67	97.89	98.38	98.67	98.69	24.89
Contaf 5EC (Hexaconazol 5%)		2.0 ml/L	-				-	
Sunoxanil 72 WP (Cymoxanil 8% + Mancozeb 64%)	15	3.0 gm/L	98.18	98.17	99.38	99.40	99.48	25.58
Contaf 5EC (Hexaconazol 5%)		3.0 ml/L	-				-	
Ridomil MZ 72 (Metalaxyl 8%+Mancozeb 64%)	16	2.0 gm/L	75.36	68.37	74.42	64.68	75.68	15.67
Autostin50 WDG (Carbondaxim 50%)		1.0 ml/L	-				-	
Ridomil MZ 72(Metalaxyl 8% +Mancozeb 64%)	17	2.5 gm/L	85.34	78.66	85.25	86.57	86.89	17.35
Autostin50 WDG (Carbondaxim 50%)		2.0 ml/L	-				-	
Ridomil MZ 72 (Metalaxyl 8%+ Mancozeb 64%)	18	3.0 gm/L	87.56	85.95	86.57	88.35	89.43	19.78
Autostin50 WDG (Carbondaxim 50%)		3.0 ml/L	-				-	

Table 3: Percentage of Diseases reduction over Control as Prophylactic and Curative spray at different concentrations during 2014-2015.

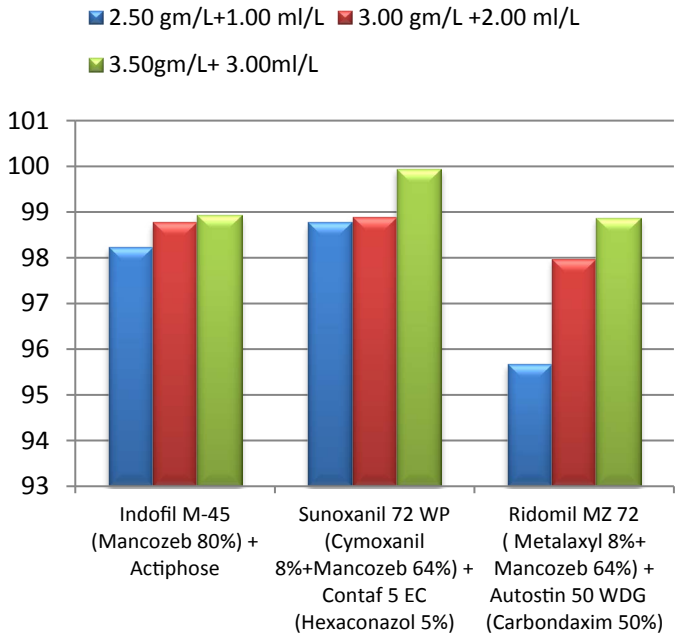

Figure 3: Showing % of Diseases reduction over Control as Prophylactic and Curative spray at different concentrations during 2014-2015.

of Mancozeb 65%+ Carbondaxim 12% may lead to the development of resistant strain of *P. infestans* and it was supported by foregoing workers [17].

In the present investigation, it is concluded that Sunoxanil 72 WP(Cymoxanil 8%+ Mancozeb 64%) acted as the best fungicide when applied as prophylactic measures as well as Sunoxanil 72 WP (Cymoxanil 8%+ Mancozeb 64%) was combined with Contaf 5EC (Hexaconazole 5%) showed the best result when applied as curative measures. Similar results were obtained by Pranamika et al. [12] Jonson et al. [18] who reported that Sunoxanil 72 WP (Cymoxanil 8%+ Mancozeb 64%) had some activity after infection. If Actiphose was also used with Mancozeb (Indrofil M-45) showed comparatively better performance. It is new finding, although Metalaxyl and Carbondaxim play on vital role to protect the late blight after appearance the disease, plant growth, tuber formation along with the yield was gradually prohibited. Therefore, It is

Treatments	Percentage Area of disease control (PADC)							
	Plot no.	Dose	Prophylactic spray	Curative spray			Prophylactic spray	Yield in ton/ ha
			43 DAS (%)	50 DAS (%)	57 DAS (%)	64 DAS (%)	71 DAS (%)	
Indrofil M-45 (Mancozeb 80%)	10	2.5 gm/L	98.12	94.66	93.76	97.85	98.25	21.57
Actiphose (Phosphorous acid)		1.0 ml/L	-				-	
Indrofil M-45 (Mancozeb 80%)	11	3.0 gm/L	98.35	96.68	97.87	98.38	98.78	21.54
Actiphose (Phosphorous acid)		2.0 ml/L	-				-	
Indrofil M-45 (Mancozeb 80%)	12	3.5 gm/L	98.91	97.95	98.35	98.85	98.94	22.88
Actiphose (Phosphorous acid)		3.0 ml/L	-				-	
Sunoxanil 72 WP (Cymoxanil 8% + Mancozeb 64%)	13	2.5 gm/L	98.68	97.32	98.56	98.56	98.78	23.89
Contaf 5EC (Hexaconazol 5%)		1.0 ml/L	-				-	
Sunoxanil 72 WP (Cymoxanil 8% + Mancozeb 64%)	14	3.0 gm/L	98.87	98.49	98.78	98.79	98.89	24.99
Contaf 5EC (Hexaconazol 5%)		2.0 ml/L	-				-	
Sunoxanil 72 WP (Cymoxanil 8% + Mancozeb 64%)	15	3.5 gm/L	98.99	98.78	99.47	99.89	99.95	26.68
Contaf 5EC (Hexaconazol 5%)		3.0 ml/L	-				-	
Ridomil MZ 72 (Metalaxyl 8%+Mancozeb 64%)	16	2.5 gm/L	95.34	93.67	94.76	95.68	95.78	19.57
Companion (Mancozeb 65%+ Carbondaxim 12%),		1.0 ml/L	-				-	
Ridomil MZ 72 (Metalaxyl 8%+Mancozeb 64%)	17	3.0 gm/L	97.66	94.69	95.85	97.57	97.98	19.88
Companion (Mancozeb 65%+ Carbondaxim 12%),		2.0 ml/L	-				-	
Ridomil MZ 72 (Metalaxyl 8%+Mancozeb 64%)	18	3.5 gm/L	98.56	95.98	96.89	98.79	98.88	21.28
Companion (Mancozeb 65%+ Carbondaxim 12%)		3.0 ml/L	-				-	

Table 4: Percentage of Diseases reduction over Control as Prophylactic and Curative spray at different concentrations during 2015-2016.

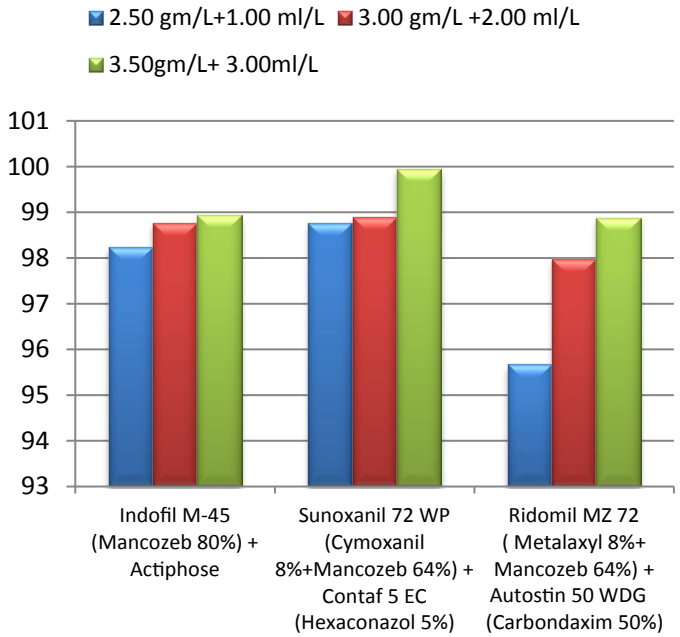

Figure 4: Showing % of Diseases reduction over Control as Prophylactic and Curative spray at different concentrations during 2015-2016.

recommended that Metalaxyl and Carbondaxim application should be avoided to protect the late blight after or before appearance the disease.

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Citation: Siddique NA, Aktar MS, Swapon NH (2016) Comparative Efficacy of Different Fungicides against Late Blight Diseases of Potato incited by Phytophthora infestans (Mont.) de Bary and its Management. J Plant Pathol Microbiol 7: 364. doi: 10.4172/2157-7471.1000364