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Effect of Varieties and Fungicides on Potato Late Blight (*Phytophthora infestans*, (Mont.) de Bary) Management

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Abstract

Late blight of potato which is caused by *Phytophthora infestans*, (Mont) de Bary is an important disease of potatoes (*Solanum tubersolum*) and is a prevalent disease in all potato producing areas of Ethiopia. A field experiment was conducted for two consecutive years (2016 and 2017) under the main rainy season to develop integrated management options for late blight disease of potato at Bursa District, Sidama Zone, SNNPRS, Ethiopia. Two improved varieties having different level of resistance, four registered fungicides, and two unsprayed plots (control) were arranged in a factorial randomized complete block design with three replications. The result showed that all fungicides significantly reduced the infection of late blight as compared to the unsprayed treatments at both seasons. Two way interaction of variety by fungicide showed significant difference on controlling disease severity and increasing tuber yield in 2017. Fungicides Matco (Metalaxyl-8%+Mancozeb-64%) and Boss (Metalaxyl+Mancozeb) 72% WP significantly reduced severity of the disease as compared to Bacticide (Copper Hydroxide) and Mancozeb (Diathane-M45) in 2017 cropping season. Whereas in 2016 the disease pressure was low as the result there was no significant difference between fungicides. Depending on the fungicides efficacy and varietal reactions to the disease (21.82 to 30.47 t ha^{-1}) and (20 to 36.84 t ha^{-1}) tuber yield were obtained from the sprayed plot in 2016 and 2017, respectively. On the other hand from unsprayed plots, 10.63-18.63 t ha^{-1} and 8.8-17.4 t ha^{-1} tuber yield was obtained in 2016 and 2017 cropping seasons respectively. The mean yield advantage of fungicide sprayed plots for both varieties was 62% as compared to the unsprayed ones. The study confirmed that host resistance level and fungicide efficacy played an important role in host–pathogen–fungicide interaction to reduce the severity of late blight on potato. Therefore, it was confirmed that the combined effects of growing moderately resistant cultivars with the application of fungicides Matco at two spray frequency in 10 day intervals reduced the yield loss and damage caused by late blight even under high late blight pressure.

Keywords: Late blight; Potato; Fungicide; Efficacy; Host resistance

Introduction

Late blight of potato caused by the Oomycete fungus *Phytophthora infestans* (Mont.) de Bary is by far the most destructive disease of potato and causes tremendous yield losses [1]. In Ethiopia, the disease occurs throughout potato producing areas and is difficult to produce the crop during the main rainy season without chemical protection [2]. The disease caused 100% crop loss on some local cultivars, and 67.1% on susceptible varieties. Depending on the variety, the average yield loss due to late blight in Ethiopia was also estimated to be 6.5%-70% [3].

In Ethiopia thirty one potato varieties with different resistance level to *P. infestans* were released and registered [4]. However, resistance in potato to *P. infestans* is notoriously unstable, so the actual levels of resistance of the released cultivars affected within a short time [2].

A number of fungicides are introduced into Ethiopia through different pesticide supplier companies to manage fungal diseases for different crops. Of all the registered fungicides, about 36% are known to be recommended for late blight disease management [5]. However during the farmers need assessment in Sidama and Gedeo zones of SNNPRS, only two fungicides (Ridomil and Mancozeb) were introduced to farmers through an agricultural extent ion system and farmers mentioned that the efficacy of each fungicides became reduced to control late blight [6]. As compared to the number of introduction and registered fungicides; the rate of adoption is very low.

It is known that the application of limited number of fungicides repeatedly in a specific area increases the insensitivity of the pathogen and decreases the efficacy of the fungicides due to the pathogen strain shifting to resist the fungicides. Standard recommendations for delaying the development of insensitivity to fungicides in fungal pathogens include rotating classes of fungicides [7]. In addition, the use of cultivars with different level of resistance can reduce both fungicide and application frequencies [8]. To delay the insensitivity pathogen to fungicides, to reduce environmental contamination, to minimize farmers input costs during the production period and to gather information on the relative level of resistance of each cultivar and their value of resistance in reducing fungicides need, a sort of adaptive research [9].

Therefore this paper was prepared to convey information on integrated fungicides and varieties effect against potato late blight to obtain maximum benefit from the production of potatoes.

Materials and Methods

Description of the study area

The experiment was carried out for two consecutive years (2016 and 2017) under the main rainy season at Bursa District, Sidama zone,

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SNNPRS, Ethiopia. The District is located at 06°35′ 89′′ N, and 38° 34′ 24′′ E., with total rain fall per annum of 1400 mm with an average annual temperature 15.5°C. The altitude is 2655 meter above sea level (masl). The area was hot spot for potato late blight disease.

Planting materials and fungicides

The experiment included two factors: Potato varieties and fungicides. Potato varieties Belete (moderate resistant) and Gudenie (moderately susceptible) for late blight were obtained from Holeta Agricultural Research Center. The four fungicides, Matco (Metalaxyl-8%+Mancozeb-64%) 2 kg/ha, Boss 72% WP (Metalaxyl+Mancozeb) 2 kg/ha, Bacticide (Copper Hydroxide) 2.5 kg/ ha, Mancozeb (Diathane-M45) 3 kg/ha were obtained from registrants company in the country. Two untreated plots (one for each variety) were employed as a control for comparison.

Experimental design and plot establishment

The experimental design was a randomized complete block with factorial arrangement. The treatments were replicated three times. The plot size on which each treatment placed was 3 m × 2.8 m with 0.7 m and 0.3 m between rows and plants respectively. Recommended doses of fertilizers, Nitrogen Phosphate sulfate (NPS) and urea, were applied based on the national fertilizer recommendation for potato crop. Crop husbandry practices, such as cultivation, earthling up and weeding, were carried out according to the recommendation.

Fungicide application

Each fungicide was applied as per the recommendation of the manufacturer using a manually-pumped knapsack sprayer of 15 liter capacity. Spraying was started 45 days after emergence as soon as the onset of the disease was observed on moderately susceptible variety. Subsequent applications were done for each fungicide two times per cropping season for moderately resistant variety (Belete) and three times per season for moderately susceptible variety (Gudenie) at 10 day intervals. As the spray interval and frequency was studied for moderately resistant and moderately susceptible [2].

Data collection

Both disease and yield data were collected. The data on disease severity consisted of disease onset (DO), and late blight severity which was taken at 10 day intervals on foliage and stem infection. Disease severity was scored using CIP 1-9 scale [10] 1: None or very few lesions on the leaflets (0% foliage affected), 2: (3% foliage affected), 3: (10% foliage affected), 4: (25% foliage affected),5: (50% foliage affected), 6: (More than 50% but less than 75% stem and foliage affected), 7: More than 75% but less than 90% affected), 8: Only very few green areas of stem and leaf (much less 10%) and 9 : 100% foliage completely destroyed. The yield data consisted of total, marketable and unmarketable tuber yields. All units of measures of tuber yields from kg/plot were converted in to t ha^{-1}.

Disease and yield analysis

The significance of disease severity and tuber yield (marketable and total yield) were tested by using analysis of variance (ANOVA). Mean separation was carried out by using Fisher's protected least significant difference test at 5% significance level (LSD). The SAS statistical package version 9.1 was used for analysis [11]. The yield loss due to disease was calculated as: 100 (Y- X/Y), where Y is the most protective plot yield in the treated plot and X is the remaining treated and untreated control plots [12].

Fungicides	Cost of fungicides (EtB)	Labor (EtB)	Total cost
Bacticide	1500	150	1650
Matco	1400	150	1550
Mancozeb	900	150	1050
Bos 72%	1300	150	1450
Cost of spraying per ha=50 birr per man * 3 man day\=150 birr, EtB=Ethiopian Birr.			

Table 1: Average cost of production of potato for different fungicides for one spray on hectare base.

Marginal analysis

Cost analysis: The gross return obtained from each treatment was calculated using adjusted tuber yield (15%) obtained per hectare and the average local market price of potato during the production period. The net return was calculated by subtracting the total variable cost (TVC) (Table 1) from gross return. To identify the best treatment having greater net benefits MRR (%) computed according to the CIMMYT (1988) [13] procedure. At the end the best treatment with higher benefit was selected.

Results and Discussion

Disease development

Late blight was occurred in both years during the study seasons which indicate that the presence of inoculums and favorable conditions for late blight development. However, epidemics of potato disease were different in 2016 and 2017 cropping seasons. The disease pressure was high in 2017 than in 2016 cropping season. The maximum disease score on the unsprayed plot on moderately susceptible variety was 6 and 8 in 2016 and 2017 cropping seasons respectively. The occurrence of variability in late blight pressure among over season has been reported [14]. The difference in late blight epidemics may be attributed to several factors. Temperature, rainfall and humidity play important role in the development of late blight epidemics. The host resistance also play an important role in our study, the maximum disease score (5) recorded in moderately resistant variety, while on moderately susceptible variety (Gudenie) the disease score (8) was recorded (Table 2).The result agree with previous study, use of fungicides in combination with resistant cultivars has reduced the foliar late blight in potato crop [8].

Variety fungicides interaction on the control of late blight

The disease score on sprayed plots was consistently smaller than unsprayed plots. In treated plots the mean disease score ranged from 2.3 to 4.13 and 2.3 to 4.8 for variety Belete and Guidenie respectively (Table 2) whereas on untreated plots, disease severity score ranged from 4.5 to 5.5 and 7 to 8 for Belete and Gudenie varieties respectively.

The two way variety by fungicide, interaction is shown in Table 2. In both years there was significant difference among treatments. All fungicides significantly control the disease in 2016 as compared to uncontrolled plots. However there were no significant differences among fungicides and varieties in controlling the disease on the protected/sprayed plot. Unlike this, in 2017 there was significant difference ($p<0.05$) among fungicides in controlling the disease. Particularly mancozeb treated plots were significantly differed from the remaining tested fungicides. The disease scored on mancozeb treated plots was significantly greater than others on both varieties. This might be due to the insensitivity of the pathogen to repeated application of

Varieties	Fungicides	Yield (t/ha)				Disease severity	
		2016	Yield loss (%)	2017	Yield loss (%)	2016	2017
Bellete	Bacticide	29.67a	2.63	32.55abc	11.60	2.3c	3.4cde
	Matco	30.47a	0.00	36.84a	0.00	2.3c	2.4de
	Boss 72%	29.07a	4.59	35.05ab	4.00	2.3c	2.3e
	Mancozeb	27.46a	9.88	30.2cd	18.24	3.67c	4.13b
	Unsprayed /Control	18.63b	38.50	17.04f	53.74	4.5b	5b
Gudenie	Bacticide	25.87a	11.01	30.0bcd	3.00	3.67c	4.03bc
	Matco	29.07a	00	30.9bcd	00	3.33c	3.2cde
	Boss72%	27.62a	4.99	29.76cd	12.07	3.67c	2.3cd
	Mancozeb	21.82a	29.52	20.e	35.5	3.67c	4.87b
	Unsprayed Control	10.63b	63.43	8.8g	71.5	6 a	8a
	CV (%)	16.6		18.6		22.2	10.3

Table 2: The interaction of varieties and fungicide spray on the control of late blight as expressed on yield (t ha^{-1}) and disease severity in 2016 and 2017 main cropping season.

mancozeb in the area.

Variety fungicide combination effect on tuber yield

There was no significant yield differences ($p<0.05$) among fungicides in 2016 opposed to 2017. But there was statistically significant difference between fungicides treated and untreated plots in 2016. In 2017 significant differences were observed among fungicides and variety combinations. Higher tuber yield was obtained on Matco and Boss sprayed plots as compared to Bacticide, and mancozeb sprayed plots and plot with no any fungicides. In the present investigation it was observed that the spray with mancozeb was not found effective. It might be due to continuous and increased use of Mancozeb may lead to the development of resistant strain of *P. infestans* [15].

The significant result obtained through the interaction of fungicide and variety ($P<0.05$) indicating the effect of fungicides varies with varieties. Higher yield, 27-37 t ha^{-1} and 20-31 t ha^{-1}, was obtained from the protected plot of moderately resistant (Belete) and susceptible (Gudenie) varieties, respectively. Whereas on the unsprayed plot yielded 8.8-10.63 t ha^{-1} and 10.63-17.04 t ha^{-1} on varieties Gudenie and Belete respectively. The result is in agreement with the studies conducted by Bekele et al. which indicated potato yield loss due to late blight has been attributed primarily to the degree of susceptibility or tolerance/resistance of potato varieties and disease management strategies.

Estimated yield loss

Late blight disease caused 38% and 53% yield loss on an unsprayed plot of Belete variety in 2016 and 2017 respectively. On the fungicide sprayed plots 5%-12% (2016) and 4%-18.2% (2017) yield loss was observed as compared to the best protective fungicide plot (Table 2). While in the unprotected plot of moderately susceptible variety Gudenie, 63% and 71.5% yield loss was recorded in 2016 and 2017 cropping seasons respectively. In the protective plot of variety Gudenie 5%-29.52% and 3%-35.5% yield loss recorded in 2016 and 2017 respectively. The result is in agreement with previous report that average yield losses due to late blight in Ethiopia were also estimated to be from 6.5%-70% on improved variety, indeed farmers used fungicides when the disease pressure is very high [16]. In general the mean yield advantage of fungicide sprayed plots for both varieties was 62% as compared to the unsprayed plots. The obtained result was mentioned in the previous studies in which late blight was successfully managed with the use fungicides on resistant cultivars [8].

The benefit of fungicide treatment was evidenced on both potato varieties and on the late blight incidence. From the above result, it could be seen that variation in yield loss was observed among treatments. In all variety spray combinations, yield loss increased with decreasing tolerance level and efficacy of fungicides. Thus the impact of potato late blight on attainable yield of potato tubers was large. However, the impact of potato late blight differed with varieties, severity of late blight and environment.

Cost benefit analysis

As shown in Table 3, the marginal rate of return for the application of Mancozeb, Bacticide, Matco, and Boss 72% at two frequency spray on variety Belete is 1455%, 1663%, 2280%, -3893% respectively. In other word investing one Ethiopian birr (EtB) to spray Mancozeb, Boss 72% and Matco, on moderately resistant variety Belete provided 14.5, 16.6 and 22.8 extra net benefit of EtB. Similarly, the marginal rate of return (MRR) for variety Gudenie at three sprays frequency of Mancozeb, Boss 72% and Matcois about 1334, 443 and 2778%, respectively. This also shows that a one EtB investment to spray Mancozeb, Boss 72%, and Matco, on variety Gudenie fetched about 13.34, 4.43 and 27.78 extra net benefit Ethiopian Birr (EtB) respectively. The presnt investigation was not agree with the previous study result mentioned by benefit-cost ratios were higher for susceptible than for resistant varieties, suggesting that fungicide applications were more profitable in susceptible varieties than in resistant ones [17]. It might be due to the low disease pressure occurred during the experimental period and the genetically yield potential difference of the tested improved variety.

MRR obtained by the application of the fungicide Bacticide on both varieties was below zero (Table 3). Therefore application of this fungicide is not recommended in controlling late blight disease of potato especially for the tested varieties and locations.

Summary and Conclusion

The two way interactions between variety and fungicide on disease severity were significant compared to control at both seasons and the benefit of fungicide and host resistance on late blight management was evident.

It is apparent that the absolute impact of fungicide treatment was influenced by the resistance level of variety and environment (season). Management of late blight by spraying fungicide was greater on variety Gudenie (moderately susceptible). Yield loss variation was observed among treatments and varied with the resistance level of cultivars and disease severity.

Variety	Frequency of spray	Treatments	Adjusted yield t ha^{-1}	Gross Return(EtB)	TVC (EtB)	Net benefit	MRR (%)
Belete	0	Control	13.87	48552	0	48552	0
	2	Mancozeb	23.22	81277	2100	79177	1458
	2	Boss 72%	27.25	95379	2900	92478	1663
	2	Matco	28.61	100139	3100	97038	2280
	2	Bacticide	26.44	92552	3300	89252	-3893
Gudenie	0	Control	8.25	28887	0	28887	0
	3	Mancozeb	21.15	74048	3150	70898	1334
	3	Boss 72%	23.01	80558	4350	76208	443
	3	Matco	25.48	89191	4650	84541	2778
	3	Bacticide	24.59	86072	4950	81122	-1140

1 EtB=USD 0.04, Price of potato=3.5 EtB kg^{-1}, Gross Return=(MY) Marketable yield (t ha^{-1})* 3500 EtB, TVC (Total variable cost)=(Cost of fungicide+Cost of spraying)/ha* frequency of spray, Net return=Gross return –TVC, MRR: Marginal Rate of Return.

Table 3: Average gross return, net return and MRR (%) of potato under variety and fungicide combination in 2016 and 2017 cropping seasons.

Significant higher marketable tuber yield and higher net benefit were obtained from moderately resistant variety Belete when fungicide Matco (2 kg/ha) sprayed as soon as the onset of the disease in 10 days interval and two times spray frequency per season. Similarly three times application of Matco on variety Guidene was found to be the optimum combination in reducing disease severity and to obtain higher marketable yield.

The fungicides Matco, Boss 72% and Mancozeb were increased yield, reduced disease severity and improved net benefit. The fungicide Matco was efficient in controlling the disease on both varieties followed by Boss 72%. However Based on the economic analysis those farmers who do not have access to get fungicide Marco, they can alternatively use Boss 72% and Mancozeb to obtain reasonable yield and secure the high revenue.

Thus it is concluded that the selected fungicides should be incorporated in to package, as major input for potato production at Bursa and other Districts having similar agro ecological conditions.

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