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Management of Late Blight (*Phytophthora infestans*) of Potato (*Solanum tuberosum*) through Potato Cultivars and Fungicides in Hararghe Highlands, Ethiopia

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Abstract

Late blight caused by Phytophthora infestans *(Mont) de Barry) is widespread, serious and devastating disease of potato in the world also in Ethiopia. Field experiments were conducted at Haramaya University and Hirna research sub-station in 2010 main cropping season to evaluate fungicide combinations and their spray schedules for late blight management and tuber yield of three potato cultivars and to find out an economical fungicide spray schedule to manage the disease on the cultivars. Laboratory experiment was also done during the same period to test the* in vitro *sensitivity of* Phytophthora infestans *isolates to metalaxyl. The field experiments were laid as factorial arrangement in RCBD with three replications of three potato cultivars and six fungicide spray schedules including the control. Application of Ridomil at the first two spray followed by mancozeb at the next two spray proved the best management schedule on each cultivar and gave the highest yield, 36.42 t/ha, 38.98 t/ha and 29.86 t/ha on cultivar Gabbissa, Badhasa and Chiro respectively at Haramaya whereas 29.67 t/ha, 36.63 t/ha and 24.59 t/ha on cultivar Gabbissa, Badhasa and Chiro, respectively at Hirna. Applications of RR-MM sequences at 10 and 7 days interval can reduce the disease and increase yields potentially as well as in monetary benefits. Ten isolates were tested for metalaxyl sensitivity under a concentration of 0µg/ml, 5µg/ml and 100µg/ml using 99.5% analytical grade metalaxyl, brought 100% of the isolates tested were found metalaxyl sensitive. Extensive testing of large number of isolates for metalaxyl sensitivity and characterizing the variability of the pathogen population in the country is still warranted for effective management of the disease.*

Key words: *Potato cultivars, late blight, fungicide, cost benefit analysis. Metalaxyl sensitivity, P. infestans isolates*

Introduction

Potato (*Solanum tuberosum*) is one of the most important food crops in the world and has been consumed by humans for more than 8000 years. Farmers in Ethiopian highlands began cultivating the tuber known locally as denech as a guarantee against cereal crop failures (CIP, 2008). The crop is widely grown in the highland and mid altitude areas of the country.

Hararghe in eastern Ethiopia is one of the major potato producing regiossns of the country and potato is grown in both the rainy and dry seasons. The increases in potato production in Hararghe is spurred by ever increasing population pressure, land fragmentation and the impossibility of sustaining farm families' livelihoods from cereal production (Eshetu *et al*., 2005).

The presences of regional domestic markets around nearby cities outlet have contributed to the development of potato production in Hararghe highlands such as Haramaya, Dedder and Hirna. However, the high yields of potatoes grown on the producers' level is significantly lower than it's potentially achievable (30-40 t/ha). This is partly attributed to the lack of better yielding modern cultivars by the producers and different types of diseases (Eshetu *et al.*, 2005).

Late blight caused by *Phytophthora infestans* (Mont) de Berry) is the major destructive and the most serious fungal disease of potato and affect its leaves, stems and tubers (Bekele and Hailu 2001). The late blight develops most rapidly at low temperatures and high humidity (Fry *et al.*, 1998). African farmers experience serious losses due to the favorable environmental conditions for diseases development and continuous presence of late blight inoculum (Olanya *et al.*, 2000b). The average global crop losses of all diseases combined was approximately 12.8% of the potential production but potato alone was subjected to 21.8% loss (James, 1981). In Ethiopia the disease causes 100% yield loss on unimproved local cultivar, and 67.1% on a susceptible variety (Bekele and Yaynu, 1996).

Past studies have revealed that the occurrence of metalaxyl resistance in *P. infestans* populations is associated with severe late blight epidemics, genetic diversity and pathogen resurgence (Davidse *et al*., 1981; Goodwin *et al*., 1992). Due to the current and intensive use of metalaxyl in combination with other fungicides, it is crucial to monitor the pathogen isolates sensitivity to identify build up of fungicide resistance and thereby modify fungicide usage strategies.

Up to date knowledge on the sensitivity of *P. infestans* isolates to metalaxyl which is in the fore front of late blight control is important for making fungicide use decision and for effective management of the disease. Metalaxyl sensitivity test should be done in major potato growing regions of Ethiopia because the progress was not studied after 2002. To reduce such losses and severeness of the disease, management options must be forwarded including up to date information on metalaxyl sensitivity have principal advantage to decide the control measures. Hence, this study was undertaken with the following objectives: to evaluate fungicide combinations and their spray schedules for late blight management and tuber yield of potato cultivars, to test the *in vitro* sensitivity of *P. infestans* isolates to metalaxyl and to determine the economics of fungicide application.

Materials and Methods

The study was consisted of two components viz. field experiment and laboratory experiment. Different fungicide spray schedules of Ridomil and mancozeb were tested for the management of late blight on three potato cultivars at two locations as a field experiment and *in vitro* sensitivity test of *P. infestans* isolates to metalaxyl as laboratory experiment.

Description of the Study Areas

The field experiments were conducted at Haramaya University research center Rare and Hirna sub research station. Haramaya University (Rare) is located at 42° 30′ E longitude and 9° 26′ N latitude and at an altitude of 1980 meters above sea level. The site receives a mean annual rainfall of 780 mm, with mean minimum and maximum temperature of 8.25°C and 24.4°C, respectively. Whereas Hirna is located at 41° 4′E longitude and 9° 12′N latitude and at an altitude of 1870 meters above sea level. The site receives a mean annual rainfall of 990-1010 mm with an average temperature of 24°C (ALARC, 1997).

Treatments and experimental design

The experiment consisted of three potato cultivars (Gabbissa, Badhasa and Chiro which are moderately resistant, susceptible and highly susceptible to late blight, respectively) and the fungicides Ridomil Gold MZ 68% and mancozeb 80% WP were used in six different spray schedules including unsprayed plots as a control. The experiments at each location were conducted in 2010 main cropping season.

A three by six factorial treatment combination of three potato cultivars with six spray schedules (Unsprayed control, Ridomil (R), Mancozeb (M), RR-MM, MM-RR and RMRM sequences) were arranged in randomized complete block design (RCBD) with three replications. Potato cultivars were planted in four rows with spacing 0.3 m, 1 m, 1.5 m and 0.75 m between plants, plots, replications and rows respectively. All recommended agronomic practices were done.

Table 1: Potato cultivars used in the field experiment to evaluate against *P. infestans* during 2010 main cropping season at Haramaya University and Hirna

No	Cultivars	Yield (t/ha)	Days to Maturity	Year of Release	Reaction to late blight
1	Gabbissa	40.0	85-110	2005	Moderately resistant
2	Badassa	40-59	96-117	2001	Susceptible
3	Chiro	41.0	95-120	1997/98	Highly susceptible

Source (Ministry of Agriculture, 2005 and 2008)

Data collection

Disease assessment: Disease incidence and severity were recorded from 10 pre-tagged plants in the central two rows of each treatment. Disease incidence was recorded two times at both locations. Disease severity was recorded five times every seven days using leaf area damaged based on James (1971) diagrammatic key. The scores were changed in to percentage severity index (PSI) for the analysis using the formula (Wheeler, 1969).

Metalaxyl Sensitivity Test

Metalaxyl sensitivity test was carried out employing the method of CIP (1997) with slight modification. Unlike CIP (1997) where using potato tubers is baiting indicated, leaves were directly moist chambered and sporangia were harvested.

In vitro test for metalaxyl sensitivity

Metalaxyl was evaluated at three concentrations namely 0, 5 and 100 µg/ml. Analytical grade metalaxyl (SIGMA- ALDRICH, Steinheim, Germany) with a lot analysis of 99.5% was used for the test.

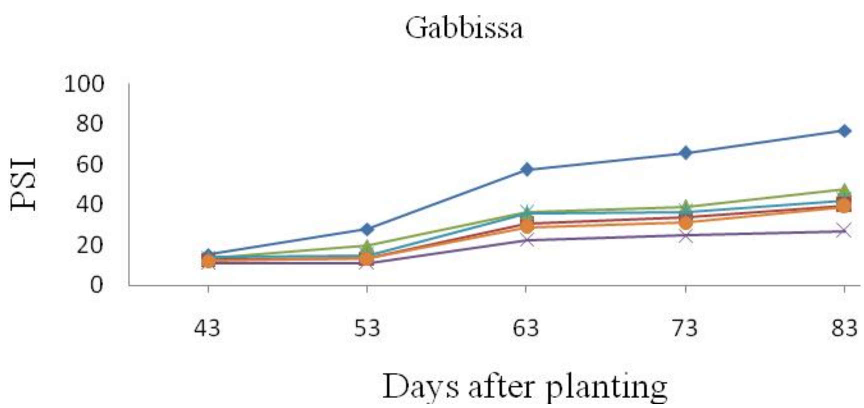
Results and Discussion

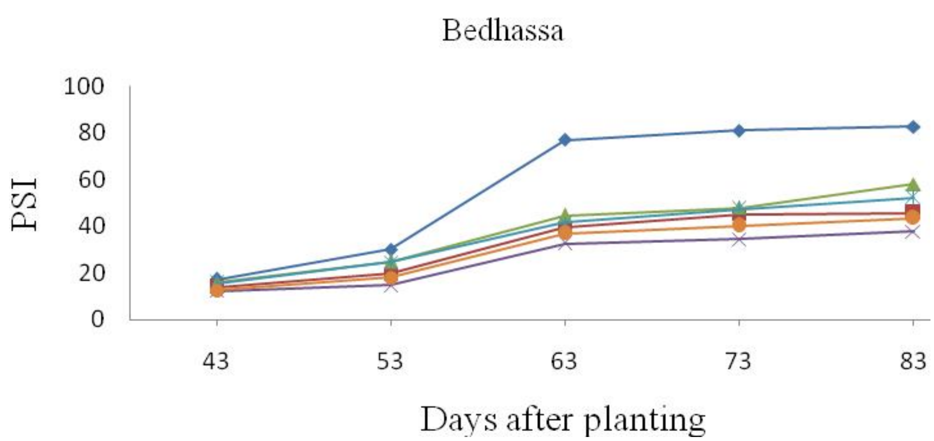
Effect of Fungicide Spray Schedules and Varietal Reaction on Potato Late Blight

Percent severity index (PSI)

All fungicide sprayed schedules significantly differed from the unsprayed control ($p<0.001$) in terms of reducing the disease. Ridomil at the first two sprays with mancozeb at the next two sprays (RR-MM) resulted in the lowest level of late blight severity recorded when compared to other treatments at both locations (Figure 2 and 3).

The mean severity of plots treated with different fungicide spray schedules ranged from the least 27.03% for cultivars Gabbissa sprayed with Ridomil at the first two sprays with Mancozeb at the next two sprays (RR-MM sequence) at 10 and 7 days interval plots to the highest 96.97% for highly susceptible cultivar Chiro control at Haramaya and at Hirna (Figure 2 and 3).





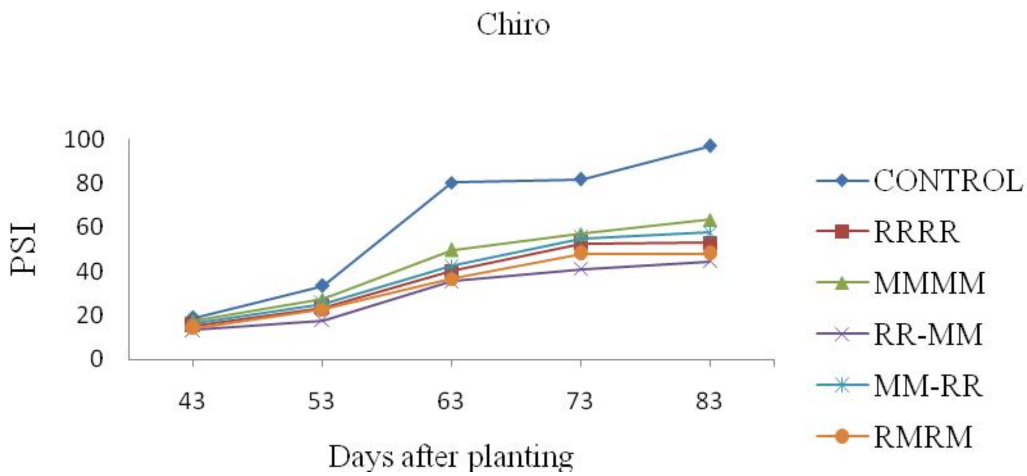


Figure 1: Potato late blight progress curve as affected by different fungicide spray schedules on three potato cultivars at Haramaya during 2010 main cropping season.

Area under disease progress curve

The area under disease progress curve (AUDPC) is a very convenient summary of plant disease epidemics that incorporates initial intensity, the rate parameter, and the duration of the epidemic which determines final disease intensity (Madden *et al.*, 2008). Significant differences were observed among the cultivars with different fungicide schedules in terms of AUDPC. Late blight severity (mean %-days of AUDPC) was calculated in the range of 16.62 - 63.00 at Haramaya and 15.04 -56.78 at Hirna from highly susceptible cultivar Chiro and moderately resistant cultivar Gabbissa, respectively. On moderately resistant cultivar, Gabbissa the AUDPC values were significantly less than with from Badhasa and Chiro during 2010 cropping season. This was due to the genotypic resistance characteristics of cultivar Gabbissa to late blight reaction (Table 4).

However, the highest AUDPC mean values were obtained on unsprayed plots of Chiro, Badhasa and Gabbissa, which were significantly too fold from all the sprayed plots at both locations (Table 4). The fungicide spray schedule mancozeb at the first two spray followed by Ridomil at the next two spray ranked third on controlling the disease in all cultivars. The lowest AUDPC was distinctly shown by the fungicide schedule applying Ridomil at the first two spray followed by Mancozeb at the next two sprays less than two and half fold, two fold and double, from unsprayed plots of cultivar Gabbissa, Badhasa and Chiro at Haramaya and more than two and half fold and two and half fold from unsprayed plots of the same cultivar at Hirna.

Effect of fungicide spray schedules on yield and yield components of potato cultivars

Percent tuber infection

Number of blight infected tubers as recorded by visual observation and then by counting, with late blight significantly ($p<0.001$) varied among all the treatments within cultivars at both locations (Table 7). Earlier investigation indicated that, tubers are usually infected by inoculum produced on the plant foliage that is subsequently washed down to the soil by water movement resulting from rainfall and irrigation (Fry, 2008). The overall mean percent tuber infection in the present study was 9.83 and 5.83 at Haramaya and Hirna, respectively, with the highest 26.33% (RF = 525.1 mm) at Haramaya and 15.67% (RF= 780.0 mm) at Hirna infection observed on unsprayed plots of cultivar Chiro. This infection of potato tubers by *P. infestans* may be initiated by zoospores, sporangia or oospores washed in precipitation or irrigation water from plant foliage and deposited in soil (Fry, 2008).

The least tuber blight infection was observed on plots treated with Ridomil at the first two spray followed by Mancozeb at the next two spray at both locations over the cultivar Gabbissa, Badhasa and Chiro respectively both locations (Table 3). However, cultivar Gabbissa exhibited least tuber blight mean percent value through unsprayed plot to treated plots than the two other cultivars. Generally, cultivars with foliage blight resistance show lower number of tuber blight infection (Collins *et al*., 1999) as was the case with Gabbissa. Hence, the epidemiology of the foliar phase of late blight is correlated to infection in the tuber phase and vice versa (Bain *et al.*, 1997).

Table 2: Effect of fungicide schedules on AUDPC and disease progress rate (r) of late blight in potato cultivars during 2010 main cropping season at Haramaya and Hirna

		Haramaya		Hirna	
Potato cultivar	Fungicide Schedule	AUDPC (% -days)	r	AUDPC (% -days)	r
Gabbissa	Unsprayed	43.05 b	0.1 b	40.31 c	0.04 gh
	RRRR	22.54 jk	0.03 ef	18.75 hi	0.02 l
	MMMM	26.35 i	0.04 ef	25.27 df	0.03 ijk
	RR-MM	16.62 l	0.02 f	15.04 j	0.02 m
	MM-RR	25.29 i	0.04 ef	22.55 fg	0.03 k
	RMRM	20.97 k	0.03 ef	17.63 ij	0.02 l
Badhasa	Unsprayed	55.36 a	0.1 b	48.61 b	0.08 b
	RRRR	29.59 fg	0.06 de	22.34 fgh	0.04 ij
	MMMM	32.34 de	0.09 bc	26.44 de	0.05 de
	RR-MM	24.56 ji	0.05 e	18.09 ji	0.02 l
	MM-RR	31.56 ef	0.09 bc	23.46 efg	0.04 gh
	RMRM	26.94 hi	0.05 de	20.22 ghi	0.03 jk
Chiro	Unsprayed	63.00 a	0.14 a	56.78 a	0.1 a
	RRRR	32.38 de	0.08 bcd	23.07 efg	0.05 ef
	MMMM	38.20 c	0.09 bc	27.87 d	0.07 c
	RR-MM	29.05 gh	0.06 cde	20.87 ghi	0.04 hi
	MM-RR	34.31 d	0.08 bcd	24.63 def	0.05 d
	RMRM	29.61 fg	0.08 bcd	22.68 fg	0.04 fg
Mean		31.97	0.06	26.72	0.049
CV%		4.68	11.92	8.34	5.87
LSD(0.05)		2.48	0.03	3.71	0.004

LSD = Least Significant Difference, CV = Coefficient of Variation, Means within the same column followed by the same letter (s) are not significantly different, R = Ridomil and M = Mancozeb applied with the indicated sequence in four successive sprays, AUDPC = area under disease progress curve, r = disease progress rate

Table 3: Effect of fungicide spray schedules over mean percent value of tuber blight number on potato cultivars during 2010 main cropping season at Haramaya and Hirna

Potato cultivar	Fungicide schedule	NBT at Haramaya	NBT at Hirna
Gabbissa	Unsprayed	11.00 de	5.00 gh
	RRRR	2.33 ij	1.33 k
	MMMM	5.33 gh	2.00 jk
	RR-MM	1.00 j	0.67 k
	MM-RR	5.00 hi	1.67 jk
	RMRM	2.00 j	1.00 k
Badhasa	Unsprayed	18.00 b	11.00 b
	RRRR	6.67 fgh	6.00 fg
	MMMM	13.00 cd	8.67 de
	RR-MM	5.00 hi	3.00 ij
	MM-RR	12.00 d	7.00 f
	RMRM	6.33 fgh	5.00 gh
Chiro	Unsprayed	26.33 a	15.67 a
	RRRR	9.00 ef	7.33 ef
	MMMM	16.67 b	10.33 bc
	RR-MM	8.00 fg	4.00 hi
	MM-RR	15.67 bc	9.00 cd
	RMRM	8.67 ef	6.33 fg
Mean		9.83	5.83
CV%		16.82	15.08
LSD (0.05)		2.67	1.46

LSD = Least Significant Difference, CV = Coefficient of Variation, Means within the same column followed by the same letter (s) are not signicantly different, R = Ridomil and M = Mancozeb applied with the indicated sequence in the four successive sprays, NTB = number of blighted tubers MTW = mean tuber weight

Relative yield loss

The yield loss that was incurred for each of the fungicide schedules were calculated relative to the yield of maximum protected plots i.e. RR-MM schedule with 38.98 t/ha, 36.42 t/ha and 29.86 t/ha at Haramaya and 36.63 t/ha, 29.67 t/ha and 24.59 t/ha at Hirna for cultivars Badhasa, Gabbissa and Chiro, respectively (Table 10). The highest levels of yield loss of 45.8%, 23.15% and 21.71% occurred in the untreated plots of cultivar Chiro, Badhasa and Gabbissa respectively at Haramaya as compared to the best protected plots sprayed with systemic fungicide Ridomil in the first two spray followed by two sprays of contact fungicide mancozeb. The corresponding values were 43.35%, 40.96% and 28.54% at Hirna for unsprayed plots of the three cultivars.

Olanya *et al.* (2001) estimated losses due to late blight to average about 30–75% on susceptible cultivars, however, in Ethiopia the disease causes 100% yield loss on unimproved local cultivar, and 67.1% on a susceptible cultivar (Bekele and Yaynu, 1996). Hence, the second highest percent yield loss was recorded from plots sprayed with mancozeb as a sole application at both locations. However, next to RR-MM, the least yield loss 3.41%, 12.36% and 16.82% at Haramaya and 2.56%, 4.41% and 12.75% at Hirna occurred on cultivars Gabbissa, Badhasa and Chiro, respectively sprayed with Ridomil alternated with mancozeb (Table 10). Therefore, overall use of resistant cultivars would potentially reduce losses due to late blight and reduce the cost of crop protection in potato production.

Table 2: Effect of fungicide schedule on tuber yield and relative yield loss of three potato cultivars during 2010 main cropping season at Haramaya and Hirna

Potato cultivar	Fungicide schedule	Yield at Haramaya (t/ha)	Yield at Hirna (t/ha)	Yield loss at Haramaya (%)	Yield loss at Hirna (%)
Gabbissa	Unsprayed	22.82[gh]	17.79[hi]	21.27[cd]	28.54[bc]
	RRRR	31.82[bcd]	25.03[cdef]	7.63[fg]	6.16[fg]
	MMMM	26.05[efgh]	19.30[ghi]	18.45[cde]	24.35[cde]
	RR-MM	36.42 [ab]	29.67[bc]	0.00[g]	0.00[g]
	MM-RR	29.19[cde]	21.74[fhg]	8.94[f]	6.58[fg]
	RMRM	32.39[bc]	25.64[cdef]	3.41[fg]	2.56[g]
Badhasa	Unsprayed	24.42[fgh]	22.12[fgh]	23.15[cd]	40.96[ab]
	RRRR	31.83[bcd]	27.45[cde]	13.71[f]	12.67[fg]
	MMMM	27.32[defg]	24.88[def]	15.48[cdf]	25.98[c]
	RR-MM	38.98[a]	36.63[a]	0.00[g]	0.00[g]
	MM-RR	29.75[cde]	29.45[b]	14.67[df]	24.35[cde]
	RMRM	36.09[ab]	33.80[ab]	12.36[def]	4.41f[g]
Chiro	Unsprayed	22.15[h]	16.40[i]	45.8[a]	43.35[a]
	RRRR	27.71[cdef]	23.22[efg]	24.12[cd]	35.25[abc]
	MMMM	22.99[gh]	18.49[ghi]	37.58[ab]	32.42[abc]
	RR-MM	29.86[cde]	24.59[ef]	0.00[g]	0.00[g]
	MM-RR	27.33[defg]	22.87[efg]	30.74[cd]	25.30[cd]
	RMRM	28.67[cdef]	24.20[ef]	16.82[def]	12.75[def]
Mean		29.21	24.63	16.35	18.09
CV%		9.67	11.60	27.53	22.26
LSD(0.05)		4.68	4.74	8.13	12.68

LSD = Least Significant Difference, CV = Coefficient of Variation, Means within the same column followed by the same letter (s) are not signicantly different, R = Ridomil and M = Mancozeb applied with the indicated sequence in the four successive sprays

Cost Benefit Analysis

Partial budget analysis indicated that the systemic fungicide Ridomil had the highest total cost but the unsprayed plots had the lowest cost (Table 14 and 15). On the other hand partial budget analysis indicated that all fungicide spray schedules used on the three cultivars gave high gross field benefit and marginal rate of return.

At Haramaya on cultivar Badhasa, the computed value for partial cost benefit showed that the maximum total gross yield benefit 70805.9 Ethiopian Birr per hectare was obtained from plots treated with Ridomil in the first two sprays with mancozeb in the next two sprays followed by plots treated with Ridomil and mancozeb alternatively with a gross yield benefit of 59365.9 Ethiopian Birr per hectare (Table 14). Even though lower gross yield benefits were obtained from mancozeb sprayed plots, it gave higher gross yield benefit than control. The same was true at Hirna for cultivar Badhasa, but the moderately resistant and highly susceptible cultivars (Gabbissa and Chiro) gave less gross yield benefit than the susceptible cultivar Badhasa at both locations.

Variation in net benefit had been among the three cultivars at both locations. At Haramaya cultivar Badhasa had the highest net profit of 44962.4 Ethiopian Birr per hectare with marginal rate of return (MRR) 865.1% from plots sprayed with RR-MM followed by plots treated with Ridomil and mancozeb alternatively.

At Hirna, in each cultivar highest net profit was obtained on plots treated with Ridomil RR-MM. Even if Badhasa is a susceptible cultivar, it gave higher gross yield benefit and net benefit than the moderately resistance cultivar Gabbissa when sprayed with fungicides. This is may be due to the high yielding nature of the cultivar even in sever epidemics. Therefore, reasonable benefits were obtained in the fungicide sprayed plots at both locations.
Macleod and Sweetingham (1999) indicated that when assessing a crop for risk, it is also necessary to asses it for the potential to cover the cost of application which depends on the potential yield. Fungicides are used because they provide effective and reliable disease control, deliver production in the form of crop yield and quality at an economic price and can be used safely (Rechcing, 1997).

Table 5: Partial budget analysis of fungicide spray schedules on three potato cultivars at Haramaya during 2010 main cropping season

PC	TRT	MY (kg /ha)	PSP (B/kg)	SR (B/ha)	TIC (B/ha)	MC (B/ha)	NP (B/ha)	MB (B/ha)	MRR (%)	CB
Gabbisa	RRRR	15930	4.0	63720	16851.8	6975.3	46868.2	19344.3	277.3	2.7
	MMMM	11690	4.0	46760	13296.3	3419.7	33463.7	5940.2	173.7	2.5
	RRMM	20410	4.0	81640	15074.1	5197.5	66565.9	39042.4	751.2	4.4
	MMRR	14570	4.0	58280	15074.1	5197.5	42575.9	15052.4	289.6	2.8
	RMRM	17820	4.0	71280	15074.1	5197.5	52205.9	24682.4	474.4	3.5
	Control	9350	4.0	37400	9876.5	0.0	27523.5	0.0	0.0	0.0
Badhasa	RRRR	14840	4.0	59360	16851.8	6975.3	42508.2	16664.7	238.9	2.5
	MMMM	9750	4.0	39000	13296.3	3419.7	25703.7	-139.8	-4.1	1.9
	RRMM	21470	4.0	85880	15074.1	5197.5	70805.9	44962.4	865.1	4.6
	MMRR	14530	4.0	58120	15074.1	5197.5	43045.9	17202.4	330.9	2.8
	RMRM	18610	4.0	74440	15074.1	5197.5	59365.9	33522.4	644.9	3.9
	Control	8930	4.0	35720	9876.5	0.0	25843.5	0.0	0.0	0.0
Chiro	RRRR	16480	4.0	65920	16851.8	6975.3	49068.2	27624.7	396.0	2.9
	MMMM	11260	4.0	45040	13296.3	3419.7	31743.7	10300.2	301.2	2.4
	RRMM	18690	4.0	74760	15074.1	5197.5	59685.9	38242.4	735.7	4.0
	MMRR	15270	4.0	61080	15074.1	5197.5	46005.9	24562.4	472.6	3.1
	RMRM	18230	4.0	72920	15074.1	5197.5	57845.9	36402.4	700.3	3.8
	Control	7830	4.0	31320	9876.5	0.0	21443.5	0.0	0.0	0.

PC = potato cultivars, B = Ethiopian birr, TRT = treatment, MY = marketable yield, PSP = potato price, SR = sale revenue, TIC = total input cost, MC = marginal cost, NP = net profit MB = marginal benefit, MRR = marginal rate of return, CB = cost benefit ratio, R= Ridomil and M= Mancozeb applied with the indicated sequence in the four successive sprays.

Table 6: Partial budget analysis of fungicide spray schedules on three potato cultivars at Hirna during 2010 main cropping season

				Cost benefit analysis						
PC	TRT	MY (kg /ha)	PSP (B/kg)	SR (B/ha)	TIC (B/ha)	MC (B/ha)	NP (B/ha)	MB (B/ha)	MRR (%)	CB
Gabbisa	RRRR	14670	4.0	58680	18108.6	7409	40571.4	8151.0	110.0	2.2
	MMMM	13000	4.0	52000	14613.1	3913.4	37386.6	4966.2	126.9	2.6
	RRMM	17520	4.0	70080	16360.8	5661.2	53719.2	21298.8	376.2	3.3
	MMRR	14410	4.0	57640	16360.8	5661.2	41279.2	8858.8	156.4	2.5
	RMRM	16220	4.0	64680	16360.8	5661.2	48319.2	15898.8	280.8	2.9
	Control	10780	4.0	43120	10699.6	0.0	32420.4	0.0	0.0	0.0
Badhasa	RRRR	15240	4.0	60960	18108.6	7409	42851.4	10991.0	148.3	2.4
	MMMM	14150	4.0	56600	14613.1	3913.4	41986.9	10126.5	258.7	2.8
	RRMM	18390	4.0	73560	16360.8	5661.2	57499.2	25638.5	452.8	3.5
	MMRR	14500	4.0	58000	16360.8	5661.2	41639.2	9778.8	172.7	2.5
	RMRM	16410	4.0	65640	16360.8	5661.2	49279.2	17418.8	307.6	3.0
	Control	10460	4.0	42560	10699.6	0.0	31860.4	0.0	0.0	0.0
	RRRR	14500	4.0	58000	18108.6	7409	39891.4	12670.8	171.0	2.2

Chiro	MMMM	13700	4.0	54800	14613.1	3913.4	40186.9	12966.3	331.3	2.8
	RRMM	16920	4.0	67680	16360.8	5661.2	51319.2	24098.6	425.7	3.1
	MMRR	13930	4.0	55720	16360.8	5661.2	39359.2	12138.6	214.4	2.4
	RMRM	16470	4.0	65880	16360.8	5661.2	49519.2	22298.6	393.8	3.0
	Control	9480	4.0	37920	10699.6	0.0	27220.6	0.0	0.0	0.0

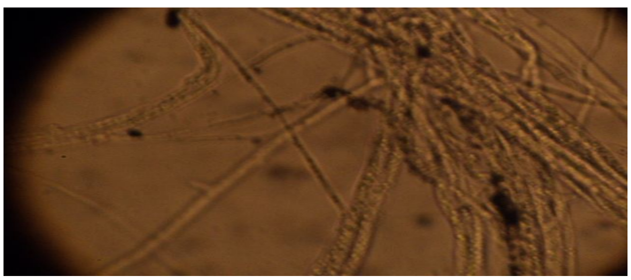
PC = potato cultivars, TRT = treatment, MY = marketable yield, PSP = potato selling price, SR = sale revenue, TIC= total input cost, MC = marginal cost, NP = net profit MB = marginal benefit, MRR = marginal rate of return, CB = cost benefit ratio, R= Ridomil and M= Mancozeb applied with the indicated sequence in the four successive sprays.

Responses of *Phytophthora infestans* Isolates to Metalaxyl

Isolates of *P. infestans* were tested for metalaxyl resistance in vitro. The average colony diameter values were calculated on the basis of growth inhibition on V8 juice agar amended with three concentrations (0, 5 and 100 µg/ml) of metalaxyl. In the past several years, due to population shift of *P. infestans*, late blight has become epidemic regardless of the control measures imposed (Sedegui *et al*., 2001).

A total of 10 isolates of *P. infestans* were obtained from infected potato leaves collected from Haramaya University main campus and Hirna research sub-station. Pure cultures of all isolates were obtained by culturing sporangia on a selective medium (V8 juice agar) amended with antibiotics. The colony morphology appeared white and fluffy with strong similarity among all isolates, and non septate mycelia under the microscope. Sporangia were caducous and lemon form to ovoid in shape (Figure 4).

A



B

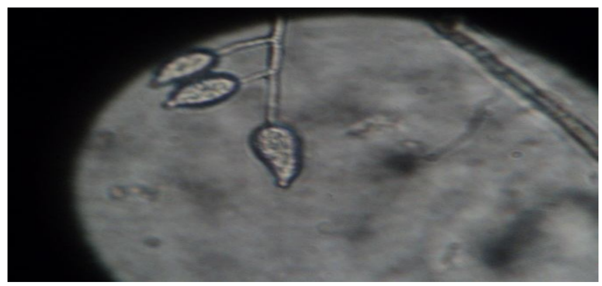


Figure 2. Mycelial growth (A) and sporangia of *Phytophthora infestans* grown in culture (B)

Table 7: Sensitivity of *P. infestans* isolates to metalaxyl inV8 juice agar after seven days of incubation

Isolate origin	Number of isolates	Metalaxyl Sensitivity		
		Resistance	Intermediate	Sensitivity
Haramaya University	7	No	No	Yes
Hirna Station Field	3	No	No	Yes

An understanding and documentation of characteristics patterns in metalaxyl sensitivity would facilitate the development of late blight management strategies regionally. All the isolates in this finding were metalaxyl sensitive. This was contrast to the recent report on the metalaxyl sensitivity of the *P. infestans* from Ethiopia; out of 41 isolates indicated that 75% of the isolates were metalaxyl sensitive, 10% intermediate and 15% resistant (Schiessen doppler *et al*., 2003).

Conclusion

In conclusion, late blight is an important disease that calls for better attention to achieve economical management with fungicides and moderately resistant cultivars. The cultivar Gabbissa appears to have comparative resistance to the late blight disease and is a promising cultivar and saying cultivar Chiro as highly susceptible it is better to categorize or grouped under tolerant cultivar. However, this cultivar can be used in combination with other control measures, wherever the disease is a pressing problem. Instead of using several fungicides indiscriminately, the use of fungicides alternatively or timely scheduled application of fungicides can substantially control the disease there by minimizing cost of production, giving maximum net benefit and avoiding risk of fungicide resistance.

For effective control of late blight, integrated management must be adopted by all producers, large and small including organic farmers, home gardeners, other specialized growers, government agencies, extension specialists and crop consultants.

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