

Efficacy of different fungicide spray schedules for control of potato late blight in Southwestern Uganda

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Abstract

Potato cultivars grown in Uganda have low levels of general resistance to late blight. As such, most commercial potato farmers rely on fungicide applications for control of *Phytophthora infestans*, the causal agent of late blight. This study investigated the comparative advantages of using different frequencies of application of Ridomil (MZ 58), Ridomil once and Dithane M-45 (Mancozeb, 80% WP) subsequently, and Dithane M-45 for management of potato late blight. The highest marginal benefit was achieved by applying Ridomil once and Dithane M-45 subsequently at intervals of 14 and 21 days. The lowest marginal benefit was with sole Ridomil application at 21 day spray interval. With weekly sprays it was more economical to apply Dithane M-45 than Ridomil first followed by Dithane M-45 subsequently.

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1. Introduction

Potato (*Solanum tuberosum* L.) has become an important staple and cash crop in the highlands of eastern Africa. These areas experience moderate temperatures (about 15–22°C) and receive relatively high amounts of rainfall (>1200 mm per year) that are favourable for potato production (Sikka et al., 1991). However, these same conditions favour severe epidemics of late blight (causal agent, *Phytophthora infestans* (Mont) de Bary), and as such, late blight is a major limitation to potato production in high humid elevations. Olanya et al. (2001) estimate losses due to late blight to average about 30–75% on susceptible varieties.

The use of protectant and systemic fungicides for managing late blight has perhaps been the most studied aspect of late blight management in temperate countries (Olanya et al., 2001). In tropical Africa, however, fungicide application intervals, frequency of application

and timing, and fungicide dose response relationship have not been well investigated. In Cameroon however, Fontem and Aigheh (1993) reported that fungicides applied for late blight management increased tuber yield by as much as 60%.

While it is known that protectant fungicides need to be applied more frequently in wet weather (Schepers, 1996), it is precisely under these conditions that effective spraying is difficult. If rainfall continues for several days then the protection from a purely protectant product is rapidly lost and the crop cannot be sprayed again. Even when the rain stops the soil can be so saturated that it does not permit ease of movement in the field for efficient spraying. Preventive fungicides principally inhibit spore germination and penetration, but once the pathogen enters the leaves, these fungicides become ineffective. Under such conditions a product having some curative and systemic activity, such as metalaxyl is desirable (Schwinn and Margot, 1991). However, pathogens can easily develop resistance to systemic fungicides like metalaxyl because they have single site mode of action (Deahl et al., 1995).

To reduce the risk of selecting strains of *P. infestans* resistant to systemic fungicides, farmers are usually

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advised to apply mixtures of a systemic and a broad spectrum protectant fungicide (Samoucha and Cohen, 1989) and/or reduce the number of sprays per season (Staub and Sozzi, 1984). A plausible alternative is to apply a systemic fungicide to provide curative treatment, and then subsequently use a protectant fungicide. The other option is to apply a protectant until disease symptoms appear, and then make a curative treatment of a systemic fungicide. Little is known about the benefits of these alternative approaches. Dithane M-45 (Mancozeb 80% WP), a contact protectant fungicide and Ridomil MZ 63.5 (a systemic fungicide with a combination of metalaxyl and mancozeb) are the most commonly used fungicides in Uganda.

In Uganda, resistant varieties are not available to most potato growers. Consequently, some farmers use fungicides as the sole means of limiting field losses due to late blight. Unfortunately, these fungicides have not been adequately tested for efficacy on potato late blight in the country. The aim of this study was to test the efficacies of common fungicides for management of late blight, and establish the appropriate spray interval for control of late blight on potato in Uganda.

2. Material and methods

The field trials were conducted at Kalengyere Research Station in southwestern Uganda (2450 m above sea level) during the late 1997A and 1997B season and during the 1998A and 1998B seasons. The A and B refer to the first (February–July) and second (September–January) seasons, respectively. In 1997, planting were done on 17 April and 1 December for the A and B seasons, respectively and 17 April and 1 September for the A and B seasons in 1998.

Two popular potato cultivars, Kisoro and Kabale, were planted in a randomized complete block design arranged in split-split-plots replicated 4 times. The main plots were cultivars, sub-plots were spray intervals (7, 14 and 21 days) and sub-sub-plots were fungicide sprays (Dithane M-45 alone, Ridomil alone, Ridomil applied once followed by Dithane M-45 and a non-sprayed control). The size of each main-plot, sub-plot and sub-sub-plot was 14.4 m × 8.4 m, 14.4 m × 2.8 m and 3.6 m × 2.8 m, respectively. Well-sprouted potatoes were planted at 70 cm between row spacing and 30 cm within row spacing. Spraying began at about 85–90% plant emergence, which was 20–30 days after planting. Dithane M-45 was obtained from *Twiga Chemicals*, Nairobi, Kenya and Ridomil from *Syngenta*, Nairobi, Kenya.

Late blight (LB) was assessed weekly starting when traces of LB were observed and continuing until physiological maturity. It was based on percent leaf

area affected (PLAA) (Henfling, 1987). Yield per plant (kg) and tuber yield per plot area were measured at maturity. Disease severity data (% PLAA) were used to calculate apparent infection rates (r) and area under disease progress curves (AUDPC) as described by Campbell and Madden (1990). The apparent infection rates (r) were calculated basing on the linearized logistic model (Van der Plank, 1963; Campbell and Madden, 1990).

Percent data were transformed by arcsine to normalize variance (Steel et al., 1997) and used to calculate AUDPC. Disease and yield data were subjected to analysis of variance (ANOVA) using MSTATC computer programme. The Least Significant Difference test (LSD) at 5% probability level was used to separate significant treatment means. Percent disease control (PDC) was calculated as $100 \times$ [the differences in AUDPC values between treated and control plots]. Percent yield gain was computed for each fungicide treatment as $100 \times$ [(plot yield – yield in non-fungicide sprayed control)/plot yield]. Additionally, the disease data (AUDPC) were related to tuber yield by correlation analysis (Steel et al., 1997).

To determine the economic benefit of fungicide usage, gross revenue was calculated (t/ha) using the local market price (Ug. Shs. 10,000 or US\$=7.5) for 100 kg of ware tubers. Costs that vary with treatment included fungicide and labour costs. Marginal rate of return was calculated as gross revenue (yield in t/ha × the cost per kilogram) divided by variable cost (CIMMYT, 1987).

3. Results

During 1997A, there was very low rainfall (46.1 mm/month), temperatures were high (14–22°C) and the relative humidity was low (<89.0%). These unfavourable weather conditions not only hindered proper potato growth and tuberisation, but also suppressed development and progress of late blight. The first few lesions that developed during the cool nights dried up during the day. The amount of late blight increased slightly at about 70 days after planting. The maximum disease level recorded during the seasons was <10%. Thus data for this season are not presented.

During 1997B, late blight became very severe even though late blight did not start to increase until late in crop growth when the crop was bulking. Nevertheless, late blight progressed faster on the non-sprayed potatoes followed by those sprayed with Dithane M-45 (Fig. 1A). Disease progress on the plots sprayed every 7 days was markedly lower than on the plots sprayed every 14 and 21 days. Furthermore, disease development started earlier on cv. Kabale (69 days after planting) than on Kisoro (75 days after planting) (Fig. 1A and B).

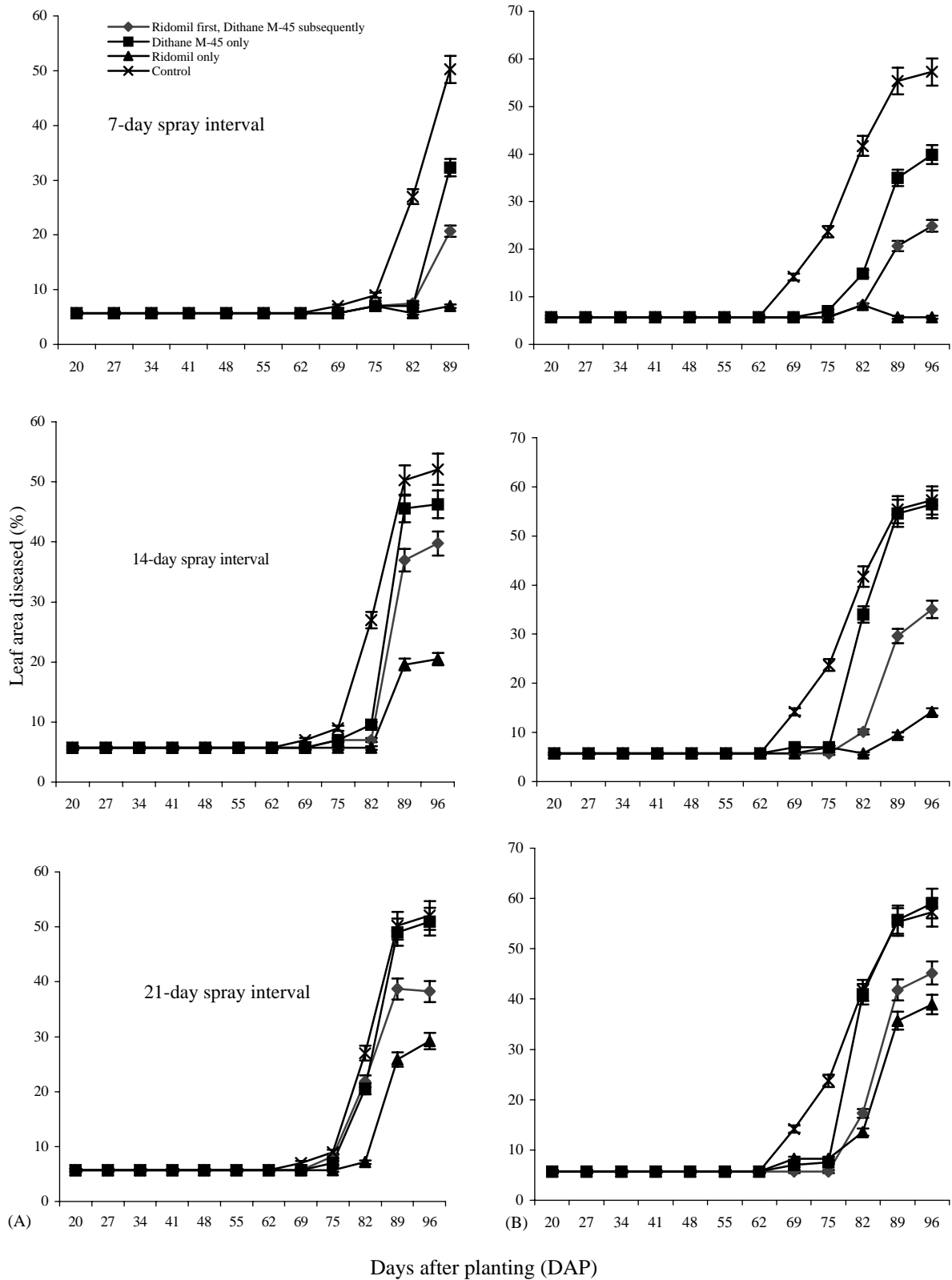


Fig. 1. Effect of different fungicide applications on late blight progress on cultivar Kisoro (A) and Kabale (B) during the 1997B season.

Application of Ridomil alone and Ridomil once plus Dithane M-45 subsequently at intervals of 7 days greatly retarded late blight progress.

Similarly, during 1998A, disease was least severe on plots sprayed with Ridomil alone and Ridomil once plus Dithane M-45, irrespective of spraying interval and

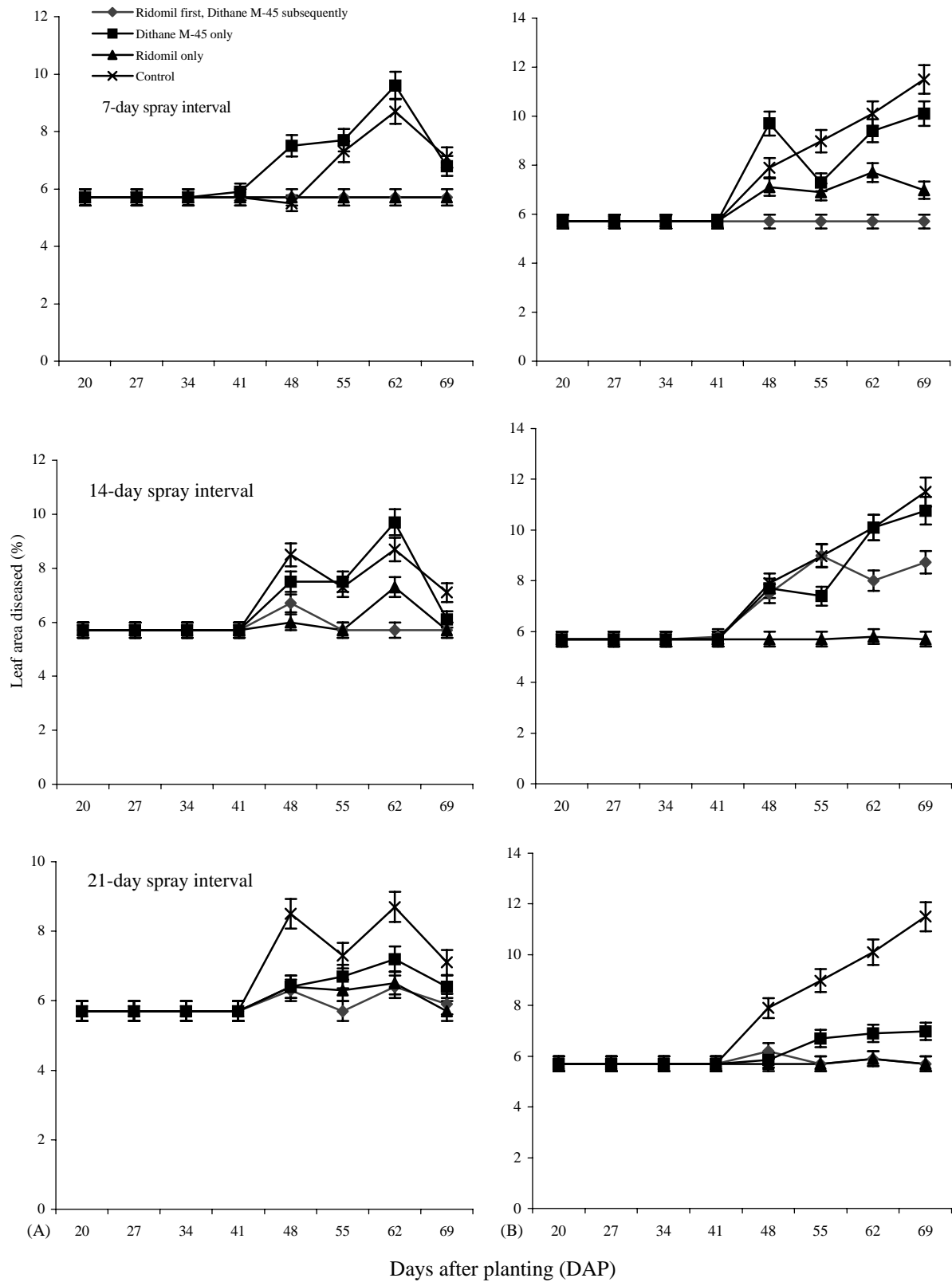


Fig. 2. Effect of different fungicide application schedules on late blight progress on cultivar Kisoro(A) and Kabale (B) during the 1998A season.

cultivar (Fig. 2). Unlike during 1997B, in 1998A the overall disease level was lower but the difference in effectiveness of the fungicides was quite apparent

(Fig. 2). In plots sprayed with Ridomil alone and Ridomil once plus Dithane M-45 subsequently, at a 7 day interval, there was little disease increase

throughout the season after commencement of the sprays.

Likewise, in 1998B the application of Ridomil on both cultivars at 7 days interval was very effective in reducing late blight AUDPC. However, as the spray interval increased, the fungicide effectiveness decreased. At 21 days spray interval, application of Dithane M-45 alone was not effective.

3.1. Late blight AUDPC and apparent infection rates

During 1997B, 1998A and 1998B the interactive effect of cultivars × spray interval × fungicide was significant for both AUDPC and *r* (Table 1). This occurred because Kabale exhibited differential (reduced) response with the 21-day spray interval. Plots sprayed at a 7-day interval had the lowest AUDPC values while non-sprayed plots had the highest values. The same trend was also shown by the apparent infection rate, *r* (Table 3). Table 3 shows that the rate of late blight progress was faster on non-sprayed Kisoro than Kabale but on sprayed plots, *r* was not significantly different between the two cultivars.

During 1998A planting was done on 17 April which was later than the usual planting time because of absence of well sprouted seed. This trial coincided with very low rainfall and warmer temperatures, both of which were unfavourable for development of late blight epidemics. There was thus low late blight severity resulting in low AUDPC and low disease.

In general, however, irrespective of the spray interval, potatoes sprayed with Ridomil alone had significantly lower AUDPC (Table 2) and *r* (Table 3) than for the other spray combinations. In all seasons, PDC depended on cultivar × fungicide × spray interval interaction.

3.2. Effect of spray treatment on potato yield

Except during 1997A, all the fungicide treatments and spray intervals increased yields considerably. There was marked high response to fungicide application in 1997B, except where Dithane M-45 was applied alone at 14 days intervals. Yield increases (% yield gain) were highest on potatoes sprayed with Ridomil alone, and Ridomil first followed by Dithane M-45 subsequently. Furthermore, yields of potatoes sprayed every 7 days were higher than those sprayed every 21 days.

In 1998, the highest yield gain was from weekly application of Dithane M-45 plus Ridomil, and Ridomil alone. Weekly application of Dithane M-45 alone resulted in markedly less yield benefit compared to Ridomil first then followed by Dithane M-45 subsequently (Table 4). Dithane M-45 applied on a 14-day interval resulted in higher yield benefits on cv. Kabale (14.9%) than on Kisoro (9.8%). There was hardly any benefit when Dithane M-45 was applied at 21 days

Table 1
Mean squares for various disease indices used to assess symptoms of late blight and yield of cvs. Kisoro and Kabale during 1997B, 1998A and 1998B^a

Source	df	1997B			1998A			1998B		
		AUDPC ^b	<i>r</i> units/day	Yield (t/ha)	AUDPC	<i>r</i> units/day	Yield (t/ha)	AUDPC	<i>r</i> units/day	Yield (t/ha)
Replication	3	42319.9	0.001	93.0*	12636.0ns	0.000ns	23.8ns	12793.3ns	0.000	145.6
Cultivar	1	366375.2*	0.000ns	270.6*	9363.6*	0.002*	8.0*	117.9	0.000*	144.7*
Error	3	18620.2	0.002	3.2	8270.4	0.001	22.9	20429.3	0.000	519.6
Spray interval	2	418013.5*	0.008	34.1	3587.8*	0.000**	24.5*	117553.7*	0.001**	49.0*
Cultivar × spraying interval	2	11695.2*	0.000*	20.2*	2184.2**	0.000**	24.7*	8957.2**	0.000	23.9*
Error	12	24115.2	0.001	77.0	1627.7	0.000	11.5	15999.2	0.000	206.3
Fungicide	3	1836047.6*	0.015*	60.7*	13545.5*	0.001*	3.8*	1518572.9*	0.002**	76.3*
Cultivar × fungicide	3	115445.9*	0.001	29.6*	3846.3**	0.000**	0.7ns	9756.4**	0.000**	8.4**
Spraying interval × fungicide	6	63774.9*	0.002*	17.3*	2719.7**	0.000**	28.0*	56381.5*	0.001**	340.1*
Cultivar × spraying interval × fungicide	6	18603.2*	0.000**	20.3*	1941.0**	0.000**	10.9*	7047.3*	0.000**	57.5*
Error	54	23590.9	0.001	19.0	5216.5	0.000	29.3	18379.9	0.000	268.9

*Significant at *P* = 0.05.

**Significant at *P* = 0.01.

^a A, B correspond to the first (February–July) and second (September–January) growing seasons, respectively.

^b Area under disease progress curve.

Table 2
Effect of cultivar and fungicide spray interval on late blight disease progress curve (AUDPC) and percent disease control (PDC)

Cultivars	Spray interval (days)	Fungicides	1997B		1998A		1998B	
			AUDPC	PDC	AUDPC	PDC	AUDPC	PDC
Kisoro	—	Control	809		195		738	
		R1st, D M-45 subs.	330	59.2	161	17.6	162	78.1
		Dithane M-45 alone	370	54.2	219	–12.2	162	78.1
	7	Ridomil alone	183	77.4	198	–1.6	162	78.1
		R1st, D M-45 subs.	516	36.2	168	14.1	162	78.1
		Dithane M-45 alone	617	23.8	214	–10.0	344	53.4
	14	Ridomil alone	309	61.8	174	10.7	162	78.1
		R1st, D M-45 subs.	635	21.4	170	12.8	301	59.2
		Dithane M-45 alone	734	9.2	185	5.1	503	31.8
21	Ridomil alone	394	51.3	174	10.6	162	78.1	
	Control	109		250		610		
	R1st, D M-45 subs.	349	65.9	241	3.6	162	76.6	
Kabale	—	Dithane M-45 alone	558	48.9	207	3.3	162	76.6
		Ridomil alone	178	83.6	223	17.3	162	76.6
		R1st, D M-45 subs.	462	57.7	234	10.7	187	73.0
	14	Dithane M-45 alone	462	57.7	161	6.2	523	24.3
		Ridomil alone	178	83.6	166	35.4	162	76.6
		R1st, D M-45 subs.	462	57.7	237	33.7	239	65.4
	21	Dithane M-45 alone	891	18.2	181	27.6	475	32.0
		Ridomil alone	226	79.3	162	35.1	162	76.6
		LSD (0.05)	234		80		189	
CV %	25.1		36.6		37.7			

Table 3
Apparent infection rate (r) for late blight as affected by cultivar \times spray interval interaction

Cultivar	Spray interval	1997B	1998A	1998B
		r (units/day)	r (units/day)	r (units/day)
Kisoro	Control	0.094	0.006	0.038
	7	0.055	0.002	0.026
	14	0.076	0.003	0.028
	21	0.084	0.002	0.041
Kabale	Control	0.078	0.021	0.043
	7	0.055	0.012	0.032
	14	0.073	0.014	0.035
	21	0.087	0.010	0.042
LSD (0.05)	0.023	0.008	0.008	
CV%	34.2	56.9	49.0	

A and B correspond to the first (February–July) and second (September–January) growing seasons, respectively.

interval on Kabale (1.9%), but yield increased markedly in Kisoro (17.8%). Contrastingly, application of Ridomil was beneficial on both cultivars. In 1998A, fungicide application was generally not beneficial on Kisoro, except for Ridomil, but was beneficial on Kabale.

None of the 21-day interval sprays were economic. In 1998B, yield benefits were achieved in all cases, except where Dithane M-45 was applied at 14-day interval. Based on pooled data for 3 seasons (1997B, 1998A & B),

late blight accounted for 15.6% variation in yield ($P \geq 0.05$).

3.3. Economic benefit of the different fungicide spray schedules

Ridomil applied alone at 7-day interval provided the highest gross revenue, but after deducting the cost of treatment, it had the lowest net benefit at 7 and 21 day spray intervals, and the marginal rate of return was also markedly low (Table 4). Although the highest gross revenue was obtained with Ridomil applied every 7 days, the cost of frequent sprays was very high, consequently net benefit was low. Also, while application of Ridomil at 7 day intervals had the highest gross revenue, the same fungicide application at 21 day intervals resulted in comparatively low gross revenue. With weekly sprays, it was more economical, based on marginal rate of return, to use Dithane M-45 alone than Ridomil first followed by Dithane M-45 subsequently or Ridomil alone. Dithane M-45 had marginal rate of return of 7.8 at application interval of 7 days but at 14 and 21 day intervals the marginal rates of return increased significantly. Application of Dithane M-45 alone had high benefit due partly to low variable costs. The highest marginal rate of return (19.3) was achieved by applying Dithane M-45 alone at 21-day intervals because this treatment had the lowest variable cost.

Table 4
Economic assessment of fungicide control of late blight on two susceptible cultivars, Kabale and Kisoro, using data from three seasons

Spray interval	Fungicide (t/ha) ²	Commercial tuber yield	% yield gain	No. of 90 Kgsacks	Variable cost	Gross revenue	Net benefit	Marginal benefit	Marginal rate of return
7	R 1st, DM-45 subs. ^a	21.82	26.58	242.4	386,000	2,424,000	2,038,000	258,000	6.3
	DM-45 alone	23.16	30.83	257.3	330,000	2,570,000	2,240,000	460,000	7.8
	Ridomil alone	25.60	37.42	284.4	890,000	2,844,000	1,954,000	174,000	3.2
14	R 1st, DM-45 subs.	22.79	29.71	253.2	196,000	2,532,000	2,336,000	556,000	12.9
	DM-45 alone	18.86	15.05	209.6	140,000	2,096,000	1,956,000	176,000	15.0
	Ridomil alone	22.46	28.67	249.6	420,000	2,496,000	2,076,000	296,000	5.9
21	R 1st, DM-45 subs.	22.18	27.77	246.4	168,000	2,464,000	2,296,000	516,000	14.7
	Dithane M-45	19.47	17.72	216.3	112,000	2,163,000	2,051,000	271,000	19.3
	Ridomil alone	19.77	18.97	219.7	336,000	2,197,000	1,861,000	81,000	6.5
	Control	16.02	—	178.0	—	1,780,000	1,780,000	—	—

^aRidomil applied once plus Dithane M-45 applied subsequently.

4. Discussion

Occurrence of *P. infestans* in sub-Saharan Africa has been closely linked to the introduction of susceptible potato varieties (Hakiza et al., 2001; Olanya et al., 2001). In Uganda, potato late blight has been a serious problem since the introduction of the crop into the country in the early 1900s (Akimanzi, 1982). Since then attempts have been made to identify resistant varieties. By 1974, 11 varieties resistant to late blight had been released. During the 1990s, six varieties with resistance to late blight, Victoria, Kisoro, Kabale, NAKPOT 1, NAKPOT 2, and NAKPOT 3, were released (Sikka and Kanzikwera, 1993; Kakuhenzire et al., 1999; Hakiza et al., 2001). However, resistance to late blight in these cultivars has since been overcome and significant yield losses experienced (Mukalazi et al., 2001). Additionally, susceptible varieties are still greatly desired by farmers due to their good agronomic characteristics. Invariably, fungicides must be used to ensure disease control. It was, therefore, necessary to establish the type of fungicide needed and frequency of application. It was also important to establish the response of different cultivars to fungicidal application.

Three of the four seasons experienced high levels of late blight attack. In these seasons, Ridomil consistently retarded late blight development when used singly or in combination with Dithane M-45. The highest yields were obtained from plots treated with Ridomil, but a fungicide program consisting of Ridomil applied once and Dithane M-45 subsequently not only gave comparable yields, but was more economic. The difference in the marginal rates of return between the Ridomil once plus Dithane M-45 subsequently and Dithane M-45 alone was likely because Dithane M-45 was less

effective in controlling late blight but inclusion of Ridomil improved its effectiveness resulting in high net benefits. Thus, it is recommended that farmers should apply Ridomil once soon after the first late blight symptoms are observed then apply Dithane M-45 every 14 days.

Under heavy rainfall, Dithane M-45 being a contact (protectant fungicide) is likely to be washed away from the plants especially if there is rain immediately after or during spraying (Schepers, 1996). Neely (1970) reported that mancozeb (Dithane M-45) does not persist long on leaves, and plots sprayed at a longer interval were unprotected during the period when the environment was especially conducive to blight. Fry (1977) made a similar observation. These observations explain why using only Dithane M-45 did not give good disease control in the wetter seasons.

A highly significant and negative correlation was obtained between late blight AUDPC and yield. This is an indication that late blight contributes significantly to losses in potato yield in southwestern Uganda. The implication is that strategies must be developed to control late blight. The present study has determined that an application of Ridomil followed subsequently by Dithane M-45 sprays controls late blight and increases yields markedly. Reduction in number of applications of the systemic fungicide (Ridomil) would also reduce the risk of development of pathogen resistance to metalaxyl (Deahl et al., 1995). The frequency and number of fungicide applications needed to effectively control late blight depend on weather conditions and level of host resistance. In this study, Kabale responded better to fungicide application than Kisoro. However, where host resistance is available, such as in Rutuku, few sprays would be needed (Kankwatsa et al., 2002).

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