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Effect of Integrating Planting Time, Fungicide Application and Host Resistance on Potato Late Blight Development in South-western Uganda

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Abstract

The presence of inocula all year round poses a daunting challenge to the management of late blight [causal agent *Phytophthora infestans* (Mont.) De Bary] of *Solanum* potato in the highlands of eastern Africa. Commercial production depends heavily on use of fungicides and, to some extent, host resistance. In this study, integration of host resistance and fungicide application reduced late blight severity by more than 50% and resulted in yield gains of more than 30% when compared with the untreated control. The study demonstrated that susceptible varieties can be successfully grown in the region if well-timed fungicide sprays are administered. Under high late blight pressure, fungicide application was necessary but integration of resistant cultivars in late blight management assisted in reducing the amount and frequency of fungicide applications. However, integration of timely planting (early planting) is difficult due to limitations in weather monitoring and the subsistence nature of the farming system in the eastern African highlands.

Introduction

Late blight (causal agent *Phytophthora infestans* (Mont.) De Bary) is the most important potato disease in the tropical highlands of sub-Saharan Africa, including Uganda (Bhagsari et al., 1994; Olanya et al., 2001). Yields from farmers' field are very low averaging 7 tonnes/ha compared with 35 tonnes per hectare in research stations (Low, 1997) partly because of late blight. Its severity depends mainly on cultivar susceptibility and weather conditions for sporulation and spread of the pathogen. Subsequent yield loss depends on how early and quickly the disease destroys the foliage and haulms (Harris, 1992). Yield may be decreased by as much as 40–42% (Sikka et al., 2000; Olanya et al., 2001) although in areas where the disease is severe, total crop failures are not uncommon. Little, however, is known about the actual losses caused by the disease in different parts of the region and on different cultivars.

Farmers' practice in eastern Africa has in some cases included the use of fungicides to control the disease, without necessarily considering efficacy, and a well-timed and judicious economic spraying schedule. Breeding efforts in the region have largely focused on the use of host resistance to manage the disease. One of the released cultivars, Rutuku (Uganda II) accounts for more than 40% of the potatoes grown in Uganda. Generally, however, there is no strategic deployment of cultivars as a management tool against the disease. Although there are studies indicating that scheduling plantings (for example, early season planting), to limit disease development by avoiding peak late blight periods are feasible (Parry, 1990), empirical evidence to support this practice is lacking for the eastern African highlands.

Integrated disease control is an approach that includes several options for controlling a particular disease (Fry and Shtienberg, 1990; Isubikalu et al., 1999; Niklaus et al., 2000). Although fungicide applications (Olanya et al., 2001; Ojiambo et al., 2001), planting resistant cultivars (Mukalazi et al., 2001) and manipulating planting dates are known to retard late blight development, their interactive effect on late blight epidemics in Uganda is not known. Even if one control method is effective, it is advisable to adopt a strategy of integrated control in order to reduce the risk of losing the efficacy of that single method (Parry, 1990). Hence, this study investigated the effects of combining planting date, fungicide application, and host resistance on late blight epidemics and potato yield, and established yield loss in potato genotypes of different levels of resistance to the disease.

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Materials and Methods

Uganda has two rainfall seasons, the first, usually March–July, and the second, September–January. In this article, these two seasons are referred to as A (first season) and B (second season). The experiment was conducted at Kalengyere Research Station for four consecutive seasons beginning in the March–July 1997 season. Kalengyere (2450 m above sea level) is located in the major potato-growing region of south-western Uganda. The growing conditions are similar to those in the temperate zones, except that the day length is the same throughout the year, and the crop can be planted two or more times a year, depending on the rainfall pattern.

The monthly rains peak during 1997A was received in April, 1997B in November, whereas during 1998A the rain peak was received in February, and in October for 1998B (Fig. 1). Minimum and maximum daily temperatures were 11 and 21°C for 1997A (April–July), 11 and 21°C for 1997B (August–December), 10 and 22°C for 1998A (February–May), and 11 and 22°C for 1998B (August–December). The mean monthly rainfall for these seasons were 54.6, 104.1, 104.8 and 82.9 mm, and the relative humidity averaged at 88.6, 89.3, 90.7 and 89.1%, respectively. The soils are typically Andosol with a pH of 5.7 (Van der Zaag, 1994). On average, relative humidity averaged over 90% during each season (Figs 1 and 2). These conditions resulted in varying levels of late blight during three of the four seasons of study.

The experimental design was a randomized complete block in a split–split plot arrangement, with planting dates as main plots, replicated three to four times in each season depending on seed availability. One set of varieties was sprayed with the fungicide Dithane M-45

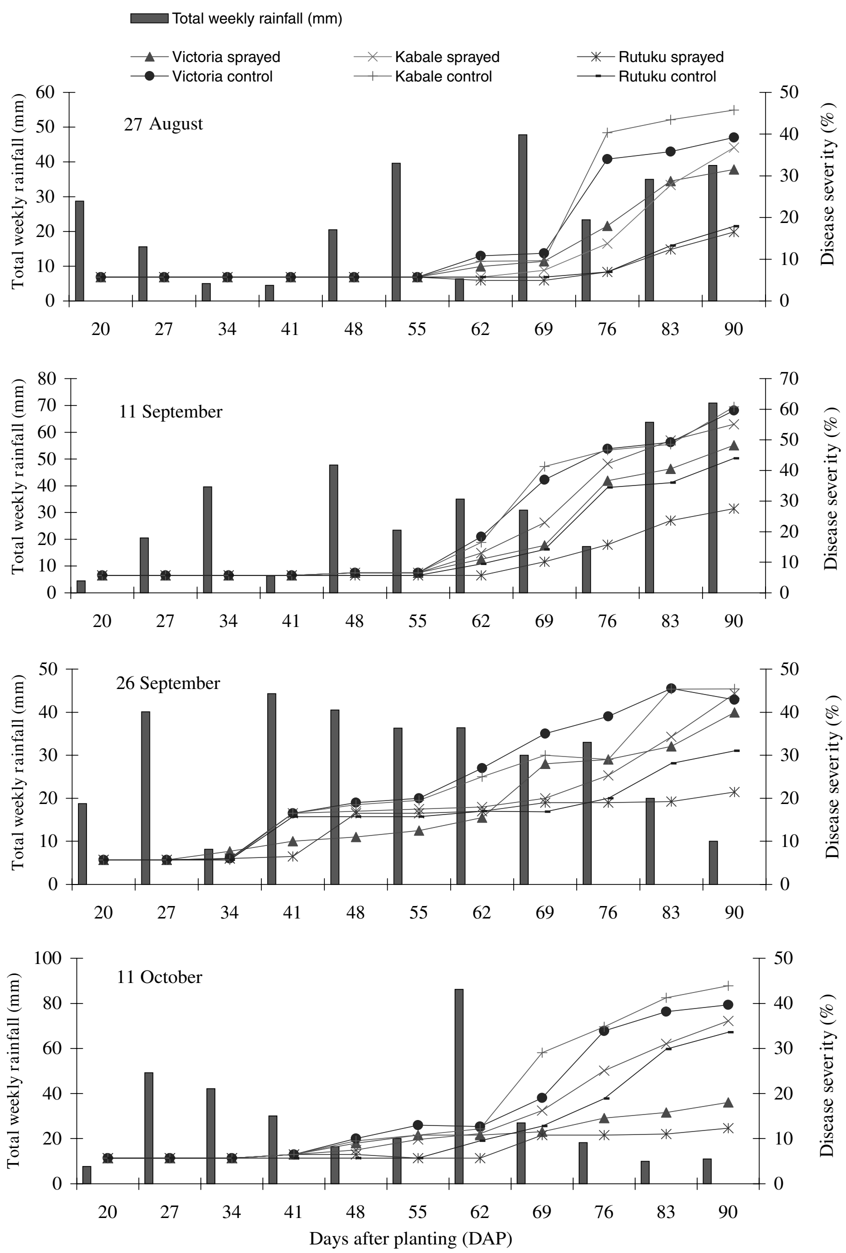

Fig. 1 Late blight progress on three potato cultivars sprayed with Dithane M-45 as compared to untreated control and planted on four dates at 15-day intervals at Kalengyere Research Station, season 1997B

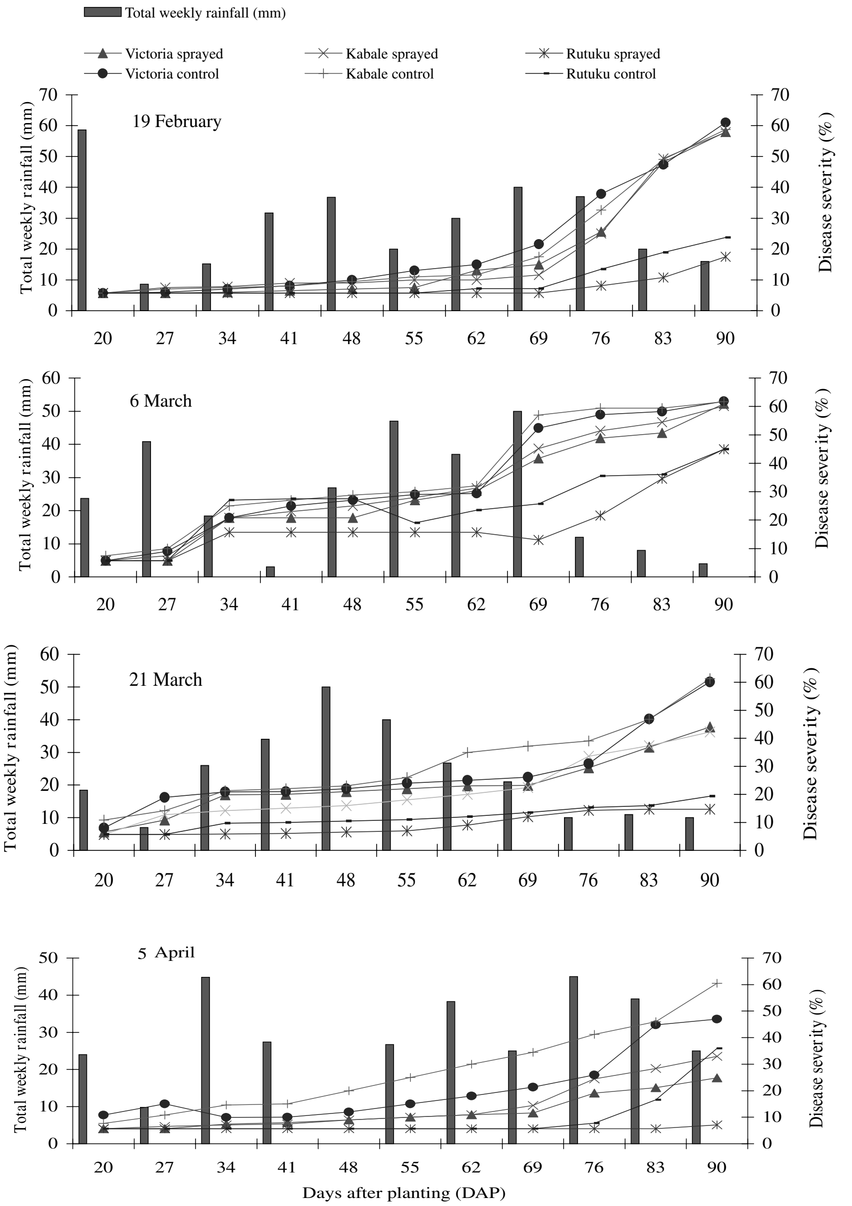

Fig. 2 Late blight progress on three potato cultivars sprayed with Dithane M-45 as compared to untreated control and planted on four dates at 15-day intervals at Kalengyere Research Station, season 1998A

(Mancozeb 80 WP, obtained from Twiga Agro-Chemical Industries, Nairobi), at a rate of 2.8 kg/ha to control late blight whereas the control plots were not sprayed. The sprayed and non-sprayed plots constituted the subplot treatment. Three varieties with different levels of resistance to late blight were used in this study. These were Rutuku (tolerant), Victoria (moderately tolerant) and Kabale (susceptible). The three varieties constituted the sub-sub-plots and were planted at 30 cm within rows, and 70 cm between rows. Each sub-sub-plot measured 3.6 m × 2.1 m and contained four potato rows (approx. 47 619 plants/ha).

Data collection began immediately after late blight symptoms appeared on the susceptible variety, and this was continued at weekly intervals. The data collected included severity scores based on a 0–100% scale (Henfling, 1987). Late blight severity data were subsequently used to calculate apparent infection rates (r) and areas under disease progress curves (AUDPCs) following procedures described by Campbell and Madden (1990). The apparent infection rates (r) were calculated based on the linearized logistic model (Vanderplank, 1963; Campbell and Madden, 1990), as

$$r = (1/t_2 - t_1)\ \log_e[x_2(1 - x_1)/x_1(1 - x_2)]$$

where amount of disease at time $t_1 = x_1$, amount of disease at time $t_2 = x_2$ (Vanderplank, 1963). At harvest, average yield per unit area planted was recorded and later used to compute yield per hectare.

Data were analysed using the MSTATC computer program and involved analysis of variance (ANOVA), and correlation analysis (Steel et al., 1997). The least significant difference test (LSD) at $P = 0.05$ and 0.01 probabilities were used to separate significant treatment means, the P level depending on the F statistics. Percentage yield gain due to fungicide treatment was calculated for each cultivar as 100 × (fungicide sprayed plot yield – yield in control)/plot yield (Fontem and

Table 1
Summary of ANOVA tables for various disease indices used to assess late blight development on three potato cultivars planted on four different dates and sprayed with Dithane M-45 during 1997B, 1998A and 1998B at Kalengyere Research Station

		Mean squares								
		1997B			1998A			1998B		
Source	d.f.	% severity	AUDPC²	Yield (t/ha)	% severity	AUDPC²	Yield (t/ha)	% severity	AUDPC²	Yield (t/ha)
Replication	3	20.1 NS	45698.8 NS	36.5 NS	78.6 NS	107335.8 NS	38.9 NS	46.1 NS	16946.1 NS	703.4 NS
Planting date	3	1602.8*[1]	713287.9*	660.7*	1129.1*	2271867.3*	5.5 NS	1746.1*	344453.7*	159.7 NS
Error	9	41.2	12473.6	16.7	45.0	135138.6	20.9	55.8	12184.1	104.2
Fungicide	1	24.2.0*	1552857.6*	733.8*	1464.8*	1245968.1*	395.9*	6264.6*	2988780.7*	1216.0*
Planting date × fungicide	3	170.9*	24579.0*	18.8*	707.4*	419112.4*	86.0*	370.7*	78259.6*	581.7*
Error	12	36.2	12420.9	5.0	16.1	96847.5	22.4	15.2	6889.7	87.9
Cultivar	2	3287.8*	1160947.2*	29.9*	8008.6*	4675758.1*	53.3***	5474.5*	2399775.3*	160.7*
Planting date × cultivar	6	62*	44072.9*	91.6*	279.5*	135585.0*	22.7***	235.5*	110585.0*	152.9*
Fungicide × cultivar	2	186.9*	13105.3*	9.0*	21.6*	268660.9*	1.4*	414.3*	239815.3*	27.6*
Planting date × fungicide × cultivar	6	16.5*	12713.0*	17.6**	46.6*	69184.2*	42.7*	75.8*	38605.4*	85.5*
Error	48	19.6	11141.0	10.0	28.0	106937.9	25.1	68.1	17519.0	67.5

[1] *, **, *** Significant at P = 0.05, P = 0.01, respectively; NS, not significant.
[2] Calculated based on arcsine-transformed percentage leaf area blighted at different assessment dates.

Aighew, 1993). To establish the profitability of each spray treatment, marginal rates of return were computed following CIMMYT (1987) procedures.

Results

Percentage leaf area blighted (% severity) and AUDPC

Disease severity was low during the first season (1997A) with late blight severity scores (percentage leaf area infected or percentage severity) ranging between 2.5% on the tolerant cultivar (Rutuku) to 23.5% on the susceptible cultivar. Late blight AUDPC was slightly higher on Victoria (138) than on Kabale (131). Early in this season, very few lesions were observed. However, towards crop maturity (about 75 days after planting) more lesions were observed on the first and second plantings (18 April and 3 May, respectively) than on the later two plantings, because of the drastic reduction in temperatures, and presence of mist/dew. In the subsequent sections data for the 1997A season are not discussed.

The ANOVA results indicated that the two-way interactions were significant during the four seasons of study (Table 1). This was also true of the three-way interactions (planting date × fungicide treatment × cultivar), implying that late blight development was influenced by the interactive effects of planting date, cultivars, and fungicide treatment. However, to try to isolate these interactive effects, only the two-way interactions are considered in detail in the subsequent sections.

The highest amounts of disease were recorded during 1997B and 1998A because these two seasons coincided with the heaviest rainfall which favoured rapid late blight development (Figs 1 and 2). During 1998B late blight developed late in the season. The highest late blight severity was recorded during the second planting (11 September). For this season, there was a high response (disease reduction) to fungicide application. The AUDPC data (Fig. 3) also show a similar trend. This trend was maintained in 1998A but differences in late blight severity between sprayed and unsprayed plots were less pronounced than in 1997B. Application of Dithane M-45 markedly reduced late blight severity in 1998B (see Fig. 5), but late blight was most severe on the untreated plots planted on 14 August (second planting).

The interactive effects of planting date × cultivar on late blight disease progress (AUDPC) are shown in Fig. 3. Disease levels (AUDPC) were high during 1997B, and cultivar differences were significant in all the plantings. In this season, the highest severity was observed in the second planting for all cultivars, and Kabale consistently recorded the highest AUDPC for all the different plantings. This was also true in 1998A, except in the first planting where Victoria was slightly more diseased (but not significantly) than Kabale. Both cultivars consistently recorded significantly higher disease levels than Rutuku as was the case in 1997B. In 1998B, however, Victoria had more disease than Kabale in all four plantings, although the differences in amount of disease between the two cultivars were not significant.

The fungicide × cultivar interactions were highly significant in 1997B (P = 0.0003), 1998A (P = 0.0001) and

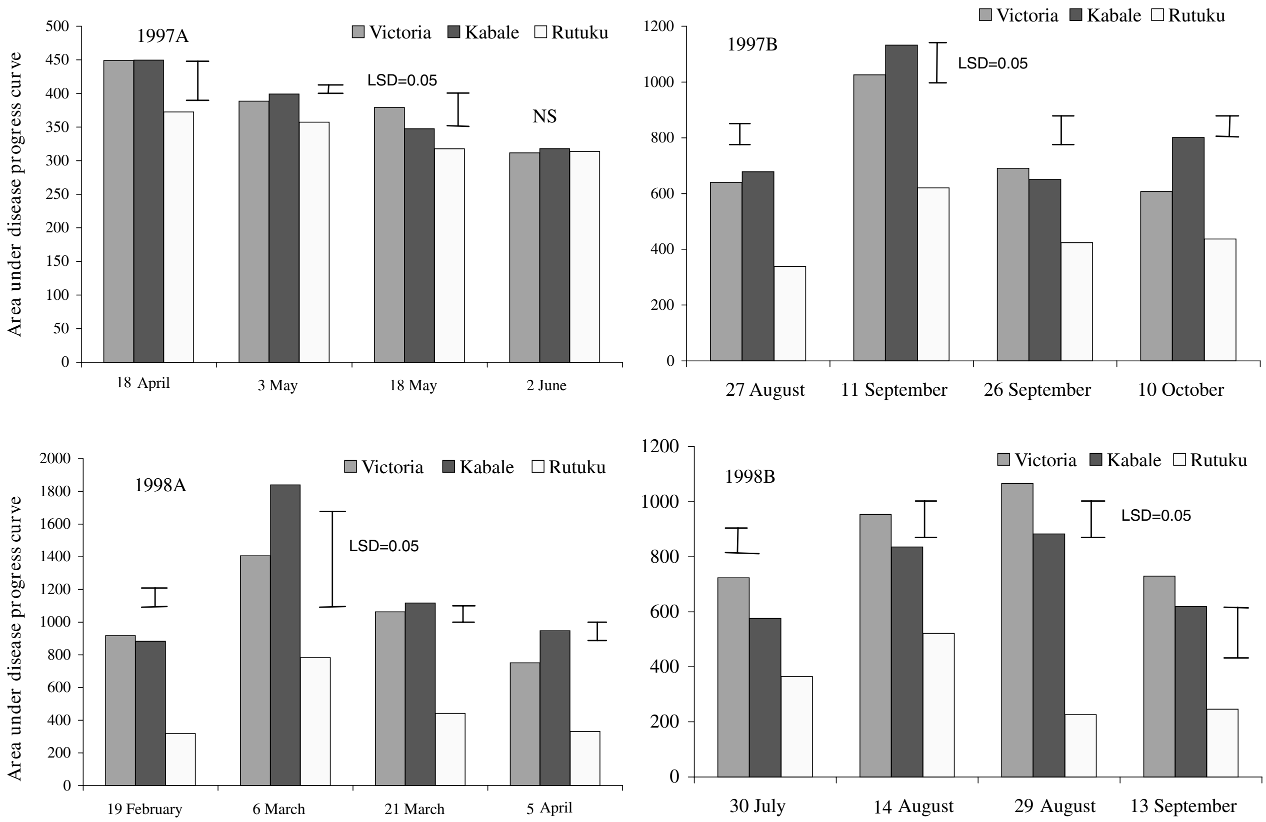

Fig. 3 Effect of planting date × cultivar interaction on late blight AUDPC on three potato cultivars, planted on different dates at Kalengyere Research Station, during 1997A, 1997B, 1998A and 1998B

1998B ($P = 0.0044$) (Fig. 4) when late blight was severe. Unlike Victoria and Rutuku, Kabale was most diseased, and did not display great reduction in late blight severity in the sprayed plots. In 1998A, application of Dithane M-45 did not cause significant reduction in late blight severity on Rutuku, since this cultivar supported only low levels of late blight. In contrast, application of Dithane M-45 significantly reduced late blight severity on both Kabale and Victoria, Kabale being more blighted than Victoria. A similar trend, to that in 1998A was shown in 1998B except that Victoria was more blighted than Kabale. Figure 4 indicates that in both control (non-sprayed) and sprayed plots, Rutuku had the lowest and Victoria the highest AUDPC in 1998B; Kabale had the highest AUDPC in 1997B and 1998A. The effect of fungicide application was significant for both Victoria and Kabale during 1997B, 1998A and 1998B.

Apparent infection rate

Planting date × fungicide application × cultivar interactions were significant ($P = 0.01$) in the three seasons (1997B, 1998A and 1998B). As the two-way interactions of these main effects were significant, they are presented here. Table 2 shows that development of late blight epidemic was retarded by fungicide treatments in all the plantings. Additionally, Table 3 shows that the moderately tolerant cultivar (Victoria) supported more disease development and recorded higher apparent infection rate (r) than the most susceptible cultivar (Kabale); the rate of disease progress was lowest on the tolerant cultivar (Rutuku).

The trend of apparent infection rate was different in 1997B when Kabale was severely affected by late blight. Furthermore, the apparent infection rate was most rapid on the potatoes that were planted on 11 September; this planting coincided with wet and cool weather conditions. During 1998B the value of r was low on the late planted (fourth) crop but significantly higher on the second planting (14 August). The second planting coincided with higher rainfall and cool temperatures. Of the three genotypes used Kabale was most affected by late blight during the first planting of 1998B. However, in the subsequent plantings Victoria was most and Rutuku the least affected.

Table 4 shows that integrating host resistance with fungicide application significantly reduced the rate of disease progress. In all seasons, apparent infection rates were lowest where Dithane M-45 was sprayed on Rutuku (tolerant). However, reduction in apparent infection rates was greatest where fungicide was applied on the more susceptible cultivar Kabale.

Potato yield

In 1997B, yields declined markedly with late planting, and all plantings responded positively (higher yields) to fungicide application (see Fig. 6). This observation was more or less similar in 1998B, except that the third planting yielded less than the fourth planting, but

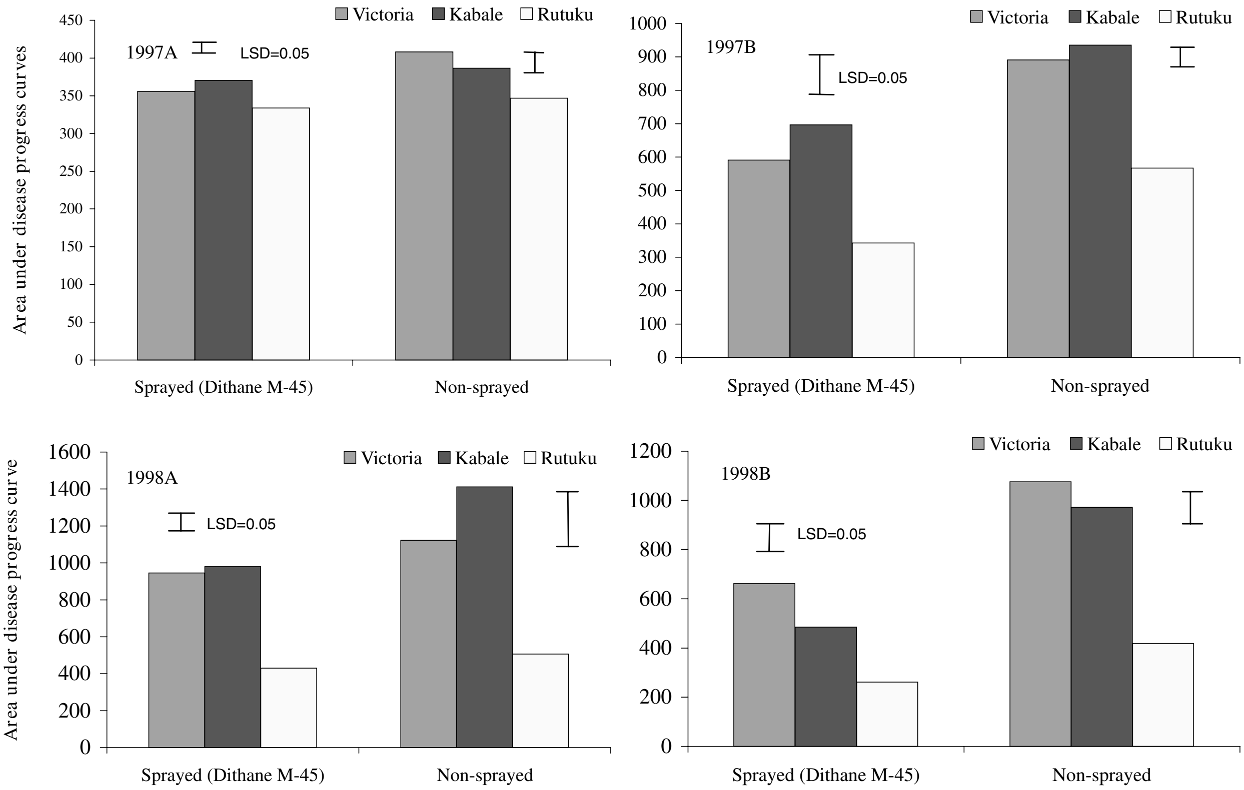

Fig. 4 Effect of planting date × cultivar interaction on late blight AUDPC on three potato cultivars, planted on different dates at Kalengyere Research Station

Table 2
Interactive effect of planting date × fungicide application on the apparent infection rate (*r*) of potato late blight during three seasons

Planting date	1997B		1998A		1998B	
	Sprayed (DM-45)	Control	Sprayed (DM-45)	Control	Sprayed (DM-45)	Control
1	0.051	0.051	0.026	0.032	0.017	0.025
2	0.061	0.068	0.061	0.071	0.060	0.079
3	0.057	0.058	0.050	0.052	0.053	0.064
4	0.028	0.046	0.026	0.032	0.009	0.026
LSD (0.05)	0.009	0.009	0.009	0.010	0.010	0.010

27 August, 11 September, 26 September, 11 October (1997B); 19 February, 6 March, 21 March, 5 April (1998A); 30 July, 14 August, 29 August, 13 September (1998B).

Table 3
Interactive effect of planting date × cultivar on the apparent infection rate (*r*) of potato late blight during four seasons

	Planting dates											
	1997B				1998A				1998B			
Planting date	27/8/97	11/9/97	26/9/97	10/10/97	19/2/98	6/3/98	21/3/98	5/4/98	30/7/98	14/8/98	29/8/98	13/9/98
Victoria	0.047	0.070	0.056	0.030	0.079	0.040	0.031	0.063	0.019	0.078	0.066	0.024
Kabale	0.065	0.074	0.061	0.046	0.081	0.039	0.030	0.066	0.028	0.072	0.059	0.017
Rutuku	0.039	0.055	0.050	0.035	0.038	0.075	0.026	0.044	0.017	0.058	0.050	0.010
LSD(0.05)	0.011	0.003	0.011	0.011	0.034	0.034	NS	0.011	NS	0.011	NS	0.009

following application of Dithane M-45, the third planting yielded slightly more than the fourth planting. During 1998B, a higher yield response to Dithane M-45 application was achieved during the first planting. Interestingly, the late-planted crop (planted on 13 September, 1998B) did not respond much to Dithane M-45 application and yielded less than the unsprayed plots (Table 5).

Table 4
Interactive effect of fungicide application × cultivar on the apparent infection rate (*r*) during one season of 1997 and two seasons of 1998

	1997B		1998A		1998B	
Potato cultivar	Sprayed[1]	Control	Sprayed[1]	Control	Sprayed[1]	Control
Victoria	0.048	0.054	0.047	0.060	0.045	0.049
Kabale	0.062	0.061	0.051	0.058	0.039	0.050
Rutuku	0.038	0.052	0.042	0.049	0.027	0.040
LSD (0.05)	0.007	0.007	0.007	0.007	0.007	0.010

[1]Sprayed with Dithane M-45 at a rate of 2.5 kg/ha.

Table 5
Effects of time of planting and chemical sprays on late blight area under disease progress curve (AUDPC) and potato yield

	1997B		1998A		1998B	
Treatments	AUDPC	Yield (t/ha)	AUDPC	Yield (t/ha)	AUDPC	Yield (t/ha)
First planting						
Sprayed	431.9	21.9	775.5	10.66	431.3	32.4
Non-sprayed	672.2	14.5	636.6	5.8	678.1	18.
PDC and PYG	35.7	33.8	17.9	45.3	36.4	42.5
Second planting						
Sprayed	787.2	13.6	1132.9	8.9	508.6	25.9
Non-sprayed	1065.2	10.5	1551.9	8.5	959.6	15.0
PDC and PYG	26.1	22.8	27.0	4.5	47.0	42.1
Third planting						
Sprayed	501.6	11.0	768.6	13.1	583.3	24.0
Non-sprayed	675.4	5.2	977.9	4.1	866.7	15.8
PDC and PYG	25.7	52.7	21.4	68.7	32.7	34.2
Fourth planting						
Sprayed	452.8	9.3	465.3	8.6	280.5	20.8
Non-sprayed	778.1	3.5	887.7	6.6	782.3	25.1
PDC and PYG	41.8	62.4	47.6	23.3	64.1	17.1

PDC, percentage disease control; PYG, percentage yield gain. Planting dates: 1, 2, 3, 4: 1997A [18 April, 3 May, 18 May, 2 June]; 1997B [27 August, 11 September, 26 September, 11 October]; 1998A [19 February, 6 March, 21 March, 5 April]; 1998B [30 July, 14 August, 29 August, 13 September], respectively.
Rainfall totalled 104.1, 104.8 and 82.9 mm in 1997B, 1998A and 1998B, respectively.

Planting dates × cultivar interactions significantly influenced tuber ware yield (Fig. 5). In 1997B, Kabale produced the highest yield in the early planting (27 August), but for the other plantings, Victoria was the highest and Rutuku consistently the lowest yielder. The trend was inconsistent in 1998A: Rutuku produced the highest yield during first planting, Kabale in the second and third plantings, and Victoria in the fourth planting (5 April). Likewise, there was no consistent trend in 1998B. For a number of plantings, cultivar differences were not significant (Fig. 5). The combination of early planting and fungicide application not only significantly reduced both rate of disease progress (Figs 1, 2 and 3) and the overall amount of disease (Fig. 3) but also led to higher yields during the four seasons (Table 5).

Generally, yield gain following application of Dithane M-45 was highest during the wetter seasons of 1998A and 1998B when late blight severity was also highest. The plantings that coincided with the wettest weather conditions (11 September 1997B and 6 March 1998A) experienced the highest disease severity and consequently the lowest yield gain (Table 5). In addition, the late plantings responded positively to fungicide application although low yield gains were achieved (Table 5).

Higher net benefits and marginal benefits were obtained from the first, second and third plantings which coincided with higher late blight levels but suitable conditions for potato growth (Table 6). Lower net benefit was obtained from the late (fourth) planting. Application of Dithane M-45 at 21 days interval (Table 6) resulted in marginal benefits ranging between 0.045 million Uganda shillings (US$ 26) from late plantings that coincided with very low late blight level to 1.1 million Uganda shillings (US$ 647) from early plantings (planting just before rainfall started). Varietal tolerance to late blight differences were not apparent in terms of net benefit although Kabale generally had the highest and Rutuku the lowest net benefit.

Discussion

Late blight epidemics are severe only when weather conditions are suitable, i.e. heavy rains, cool temperatures ($<20°C$), high relative humidity ($>0\%$), and

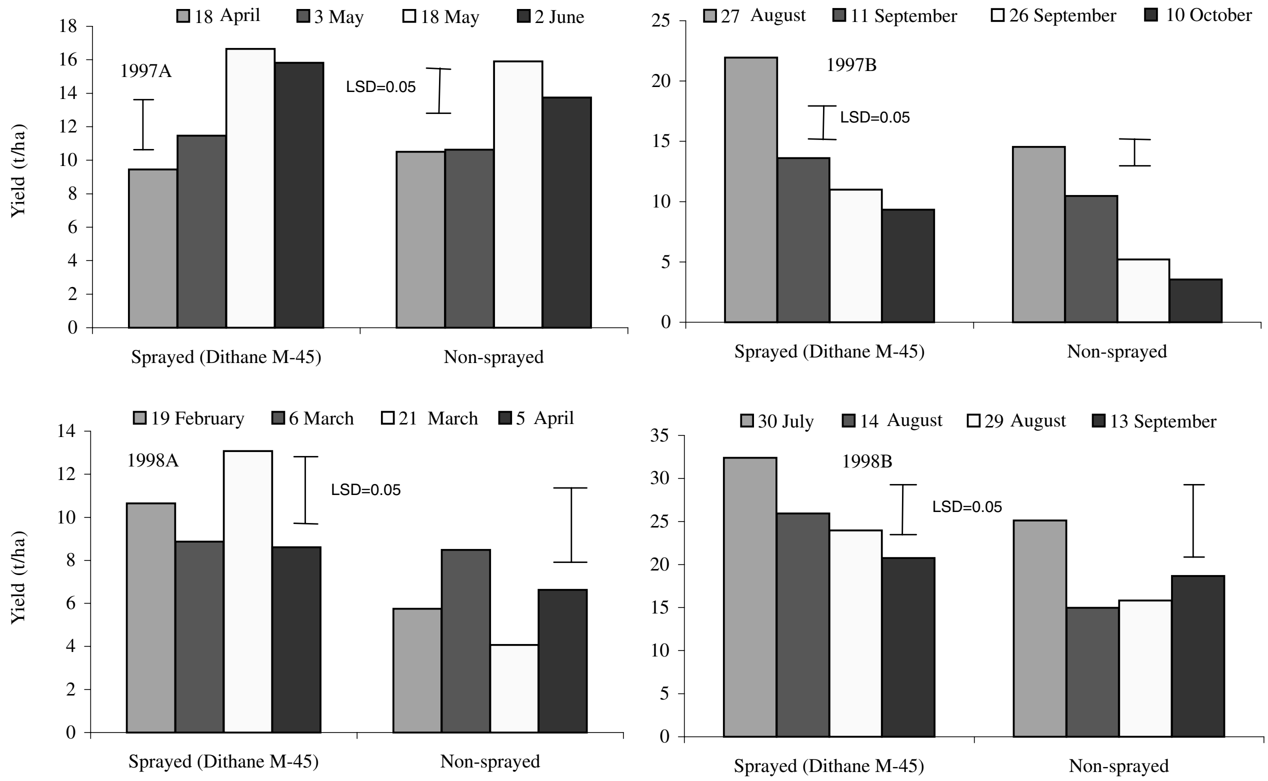

Fig. 5 Interactive effect of planting date × fungicide application interaction against late blight on potato yield at Kalengyere Research Station

Table 6
Economic assessment for fungicide control of late blight on two susceptible potato cultivars, Kabale and Kisoro using pooled data for four seasons at Kalengyere Research Station

Planting date	Fungicide	Potato cultivar	Commercial tuber yield (t/ha)	% yield gain[1]	No. 90 kg sacks	Variable cost (Ug.shs)[2]	Gross revenue (Ug.shs)[2]	Net benefit (Ug.shs)[2]	Marginal Benefit (Ug.shs)[2]	Marginal rate of return (Ug.shs)[2]
1st	Dithane M-45	Victoria	15.4	35.1	171.1	91 600	1711 000	1619 400	600 000	17.7
		Kabale	23.7	42.2	263.3	91 600	2633 000	2541 400	1111 000	27.7
		Rutuku	18.3	26.2	203.3	91 600	2033 000	1941 400	533 000	21.2
	Control	Victoria	10.0	–	111.1	–	1111 000	–	–	–
		Kabale	13.7	–	152.2	–	1522 000	–	–	–
		Rutuku	13.5	–	150.0	–	1500 000	–	–	–
2nd	Dithane M-45	Victoria	13.2	25.0	146.7	91 600	1467 000	1375 400	367 000	15.0
		Kabale	14.9	24.8	165.6	91 600	1656 000	1564 400	412 000	17.1
		Rutuku	16.9	35.5	187.8	91 600	1878 000	1786 400	667 000	19.5
	Control	Victoria	9.9	–	110.0	–	1100 000	–	–	–
		Kabale	11.2	–	124.4	–	1244 000	–	–	–
		Rutuku	10.9	–	121.1	–	1211 000	–	–	–
3rd	Dithane M-45	Victoria	17.1	40.9	190.0	91 600	1900 000	1808 400	778 000	19.7
		Kabale	16.9	34.9	187.8	91 600	1878 000	1786 400	656 000	19.5
		Rutuku	13.0	25.4	144.4	91 600	1444 000	1352 400	366 000	14.8
	Control	Victoria	10.1	–	112.2	–	1122 000	–	–	–
		Kabale	11.0	–	122.2	–	1222 000	–	–	–
		Rutuku	9.7	–	107.8	–	1078 000	–	–	–
4th	Dithane M-45	Victoria	15.4	13.0	171.1	91 600	1711 000	1619 400	222 000	17.7
		Kabale	15.3	12.4	170.0	91 600	1700 000	1608 400	211 000	17.6
		Rutuku	10.4	3.8	115.6	91 600	1156 000	1064 400	45 000	11.6
	Control	Victoria	13.4	–	148.9	–	1489 000	–	–	–
		Kabale	13.4	–	148.9	–	1489 000	–	–	–
		Rutuku	10.0	–	111.1	–	1111 000	–	–	–

Planting dates: 1, 2, 3, 4: 1997A [18 April, 3 May, 18 May, 2 June]; 1997B [27 August, 11 September, 26 September, 11 October]; 1998 A [19 February, 6 March, 21 March, 5 April]; 1998B [30 July, 14 August, 29 August, 13 September], respectively.
[1] Compared to control. [2] US$ 1 = 1700 Uganda Shillings (Ug.sh).

presence of moisture on the potato leaves for an extended period (> 8–10 h for several consecutive days) (Harris, 1992; Low, 1997). In south-western Uganda, late blight epidemics increased occasionally in the absence of rainfall, but more so in the presence of mist or night dew, which stayed on the plants from evening until the following day. Thus, variations in weather conditions explain the different epidemics which developed during the different plantings and different seasons. For example, in 1998A, when the planting began in the presence of rainfall, the first late blight symptoms were observed shortly after plant emergence, which implied that late blight epidemics started earlier. This resulted in a large amount of disease, and consequently, lower yield at harvest. Furthermore, data from the second and fourth seasons indicate that planting just before the onset of rainfall resulted in higher yields than planting after the rains had started or towards the end of the season. This is because the crop reached maturity before late blight developed to levels that would cause significant yield reductions.

In some instances, late plantings produced higher yields than early plantings. This occurred because rainfall resumed after planting the third crop which provided good growing conditions for potatoes, and more so, in the absence of late blight. This was so because the initial sources of infection dried up in the preceding dry spell, and temperatures were not suitable for late blight development.

In 1997B, late blight was quite severe in the second and third plantings. These two plantings coincided with heavy rains as well as cool temperatures, which were favourable to late blight development and spread. The first and second plantings had higher yields compared to the subsequent plantings because the disease reached destructive levels when the potatoes had completed tuberization and bulking. The subsequent plantings had low yields as well as low disease levels largely because of insufficient moisture rather than high late blight severity. Thus, Fig. 6 shows that on average disease was highest on the non-sprayed, susceptible and early plantings of 1997B, but the yields obtained from these plantings were significantly higher than the late planted crop, with lower late blight severity. This is attributed to the delay in the onset of the disease on early-planted potatoes compared to the late-planted ones. Moreover, there was higher rainfall for the early than the later plantings, which gave better growth conditions such that the crop completed tuber bulking before disease reached severe proportions. Therefore, early planting contributed to the delay in disease development and consequently gave higher tuber yield than late planting.

Of the three varieties tested, Kabale was most susceptible to late blight, but symptoms took longer to appear than on Victoria. Furthermore, Kabale produced a higher yield than Victoria and Rutuku, indicating that high yield is not only due to late blight control but to other factors such as varietal constitution. Furthermore, disease progress was slower on fungi-

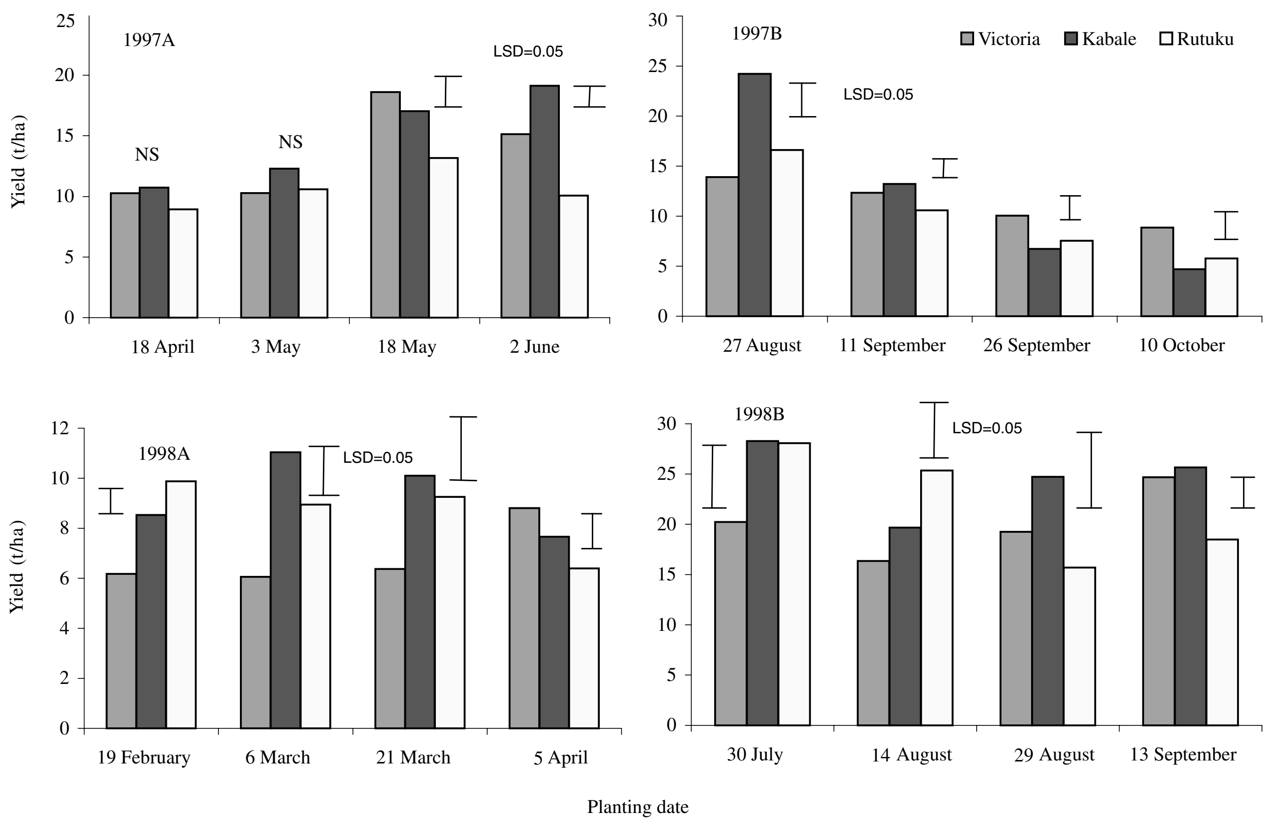

Fig. 6 Interactive effect of planting date × cultivar on yields of three potato cultivars

cide-sprayed potatoes in comparison with unsprayed control plots. This effect was more pronounced for the susceptible (Kabale) than the tolerant (Rutuku) cultivar. Consequently, the susceptible cultivar showed the best yield response to application of Dithane M-45.

Although late blight developed very early during 1998A, fungicide application was highly effective in suppressing the disease. Late blight severity was highest on the second planting which coincided with the wet and humid conditions. The high yield response following Dithane M-45 application indicates that susceptible varieties can be successfully grown as long as there is timely and proper application of fungicides. Although moisture predisposed the plant to late blight, it allowed better potato growth and minimized the deleterious effects of late blight. Thus, integrating host resistance and fungicide application is important for successful late blight management (Fry and Shtienberg, 1990).

The highest percentage disease control (PDC) was obtained during 1998B when late blight was most severe. The highest yield gains were obtained during 1998B as a result of fungicide application. This implies that the highest benefit of fungicide application was during the season when late blight was very severe. These periods were also optimum for plant growth, produced better yields and resulted in higher marginal rates of returns. Thus, under heavy late blight epiphytotics, fungicide application is important. The greatest response to fungicide application was recorded in the early planting, which also recorded the highest late blight severity. Therefore, farmers will benefit more from early plantings if well-timed fungicide sprays are administered.

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