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The effect of the application frequency and dose of Mancozeb on the management of potato late blight in Rwanda

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Abstract
Objectives: Experiments were conducted at the Institut des Sciences Agronomiques du Rwanda during two seasons 2005 B and 2006 A to test the efficacy of reduced rates of mancozeb in controlling potato late blight when applied at different frequencies on potato cultivar Kirundo, and establish an appropriate spray interval.
Methodology and results: The standard application program of Ridomil MZ at 2.5kg ha^{-1} $application^{-1}$ alternating with Dithane M_{-45} at 2.0 kg ha^{-1} $application^{-1}$ applied at a 10-day interval was compared with Dithane M_{-45} alone applied at 5, 10 and 15-day spray intervals at 50 and 100% of the manufacturer's recommended application rate. Potato late blight was effectively controlled by the standard program of Ridomil MZ alternating with Dithane applied at 10-day intervals. The 5-day application interval program using Dithane alone at 50 and 100% of the recommended application rates was as effective as the standard program but the 10 and 15-day programs were not significantly different from the non-treated. Decline in yield was correlated with increase in foliar late blight severity.
Conclusion and application of findings: Effective control of potato late blight can be attained by combining host resistance and managed fungicide applications even in a variety that is relatively susceptible to potato late blight such as Kirundo. In dry years it would be reasonable to reduce applications of fungicide but to do so would require the development and establishment of a real-time potato late blight prediction model adapted to the region.

Key words: Fungicide, integrated disease management, *Phytophthora infestans,* plant resistance, potato cultivar

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Introduction
Phytophthora infestans (Mont.) de Bary, is an oomycete that causes late blight of potato (*Solanum tuberosum* L.), and is the most important disease constraining potato production in Rwanda (ISAR, 2004). Potato late blight is mainly controlled by fungicide applications (Schumann, 1991; Olanya *et al*., 2001) but the problem is currently compounded by global demand to decrease reliance on pesticides due to their perceived

adverse impact on the environment. Moreover, the cost of fungicides used to protect potato crops against late blight is relatively high (CIP, 1999). Therefore, there is a need to find effective control methods to manage potato late blight in a safe, environmentally benign manner and at low cost.

Breeding for resistance has resulted in varieties more tolerant to *P. infestans* but complete resistance has not yet been achieved to control the disease without additional protection with fungicides (Umaerus *et al*., 1983; Bradshaw *et al*., 1995; Douches *et al*., 1997). There are some resistant varieties but high levels of stable resistance have not been achieved. Following the occurrence of new and more virulent strains of *P. infestans*, Fry (1977a) observed that the use of protective fungicides could complement cultivar resistance to reduce foliar potato late blight. Kirk *et al*., (2001) stated that reduced application rates and frequencies of a protectant residual fungicide could be successfully incorporated into a control program based on host resistance. A sustainable and most cost effective means of managing the disease could be through exploitation of host plant resistance among other components of integrated disease management strategies (Muhinyuza *et al*., 2004; Kirk *et al*., 2005).

In tropical Africa, fungicide application intervals, frequency of application and timing, and fungicide dose response have not been well investigated. In Uganda, however, Kankwatsa *et al*. (2002) reported that weekly application of Dithane M_{-45} (active ingredient mancozeb) is economical. In Rwanda, most potato farmers use protectant fungicides to limit losses due to late blight. However, effect of these fungicides on potato late blight, when used in combination with varietal resistance has not been evaluated in the country. Kirundo is one of the seven potato late blight relatively resistant varieties released in Rwanda in the 1990s and it is one of the highly preferred varieties due to its agronomic characteristics (ISAR, 1992).

The objectives of this study were to test the efficacy of reduced rates of mancozeb (Dithane M-45) applied at different frequencies on “cv. Kirundo” and establish an appropriate spray interval for control of potato late blight.

Materials and methods

Site description, agronomic practices and experimental design: The trials were planted at Kinigi in Ruhengeri research center of ISAR. Kinigi is located at an altitude 2200 meters above sea level, on longitude 29 º 38’ East and latitude 1º 30’ South (ISAR, 1987). This area has 20% organic volcanic soils. It receives bimodal rainfall with the short and long rains being received in October-mid December and March-June, respectively. Annual temperature and rainfall average 16ºC and 1400 mm, respectively. Rwanda has two rainfall seasons; the first referred to as A, usually occurs between September and February, while the second referred to as B, and occurs between March and July. Potatoes can be planted two or more times a year, depending on the rainfall pattern. For the experiments described here, soils were prepared for planting by hand held tools two days prior to planting. Fertilizers were applied at a rate of 250 $kg.ha^{-1}$ (total N) in equal split doses at planting and hilling. Weeds were controlled by hilling and hand cultivation. Seeds for planting were supplied by the seed propagation facility at ISAR Ruhengeri and were determined to be free of late blight by visual inspection. The cultivar was planted in two seasons, the first one in February 2005 (Experiment ID = 2005B) and the second one in November 2005 (Experiment ID = 2006A) in two-row plots with 0.8 m and 0.3 m spacing between and within the rows, respectively. Whole tuber seed of the selected cultivar was used in the experiment. The experimental design was a randomized complete plot design with four replicates.

Fungicide treatments*:* The fungicides [Ridomil Gold MZ 68 WG (40 g ai metalaxyl + 640 g ai mancozeb kg^{-1}; Syngenta Crop Protection, Inc., Basle, Switzerland) and Dithane M_{-45} (mancozeb

800 g ai kg^{-1}; Dow, SA) were used. The manufacturer's recommended application rates (MRAR), to achieve late blight control were 2.5 kg per ha per application (0.1 kg a.i metalaxyl + 1.6 kg a.i manconzeb) per ha and 2.0 kg per ha per application (0.8 kg a.i. mancozeb) per ha for Ridomil Gold MZ and Dithane, respectively. Fungicides were applied with an ATV hand-held sprayer (R&D Sprayers, Opelousas, LA, U.S.A.) at $1m.s^{-1}$, and delivered 230 L H_20 per ha (3.5 $kg.cm^{-2}$ pressure) with three XR11003VS nozzles per row positioned 30 cm apart and 45 cm above the canopy. The standard program of Ridomil MZ at MRAR alternating with Dithane M_{-45} at MRAR applied on a 10-day interval was compared to Dithane M_{-45} applied at a 5, 10 and 15-day spray intervals at 50 % MRAR (1.0 kg per ha per application: 0.4 kg a.i. mancozeb per ha per application) and 100 % MRAR (2 kg per ha per application: 0.8 kg a.i. mancozeb per ha per application).

Microclimate Measurement: Climatic variables were measured with a Campbell CRX10 weather station (Campbell, Ogden, Utah, USA) mounted within the trial area. The weather station was equipped with precipitation, soil moisture, soil temperature, air temperature and air relative humidity sensors located within the potato canopy on site. Microclimate within the potato canopy was monitored beginning when 50% of the potato plants had emerged and ending when canopies of healthy plants reached 100% senescence.

Disease evaluation and data analysis: As soon as late blight symptoms were detected the observation of disease started for all plants. Each plant within each plot was therefore visually rated at 7-day intervals for percent leaf and stem (foliar) area with late blight lesions. The mean percent blighted foliar area per treatment was calculated. Evaluations continued until untreated plots reached 100% defoliation. For all plots and assessment dates, the area under the disease progress curve AUDPC (Campbell and Madden, 1990) was calculated and the relative area under the disease progress curve [RAUDPC] was used to estimate the relative severity of foliar late blight using the following formula:

$$RAUDPC = \frac{\sum (T_{i+1} - T_i) * \left(\frac{D_{i+1} + D_i}{2} \right)}{T_{Total} * 100}$$

where T_i was the i^{th} day after emergence when an estimation of percent foliar late blight was made, D_i was the estimated percentage of area with blighted foliage at Ti and T_{Total} was the number of days after emergence at which the final foliar assessment was recorded. All plots were harvested by hand in June 2005 for season A and in March 2006 for season B, and yield ($t.ha^{-1}$) determined. Data were analyzed using SAS (SAS-Institute 2005. JMP version 5) and Least Significant Differences at $\propto$ = 0.05 (LSD) were calculated using the appropriate error terms. LSD was used to determine if there were significant differences among treatments.

Results

Climatic conditions for late blight development: The climatic conditions were conducive for development of late blight during the growing season for experiment 2005B, with regular rainfall occurring, temperature around 18°C and relative humidity (RH) around 80% throughout the season. The monthly rain peak was in May (2005B) and in November (2006A), which coincided with the highest relative humidity (86.5% in 2005B and 78.8% in 2006A). During season 2006A, climatic conditions were not conducive for late blight development (Table 1). Rainfall was irregular and average relative humidity was below 70% for most of the season, which was not conducive for potato late blight development, which requires free moisture on leaves for successful infection. However, the soil moisture was sufficient to promote tuber development and growth.

Disease severity: Disease severity was very high during season 2005B with scores (percentage leaf area infected) ranging between 10% on the treatment 100% MRAR applied every 5 days (the most effective) to 90% on the untreated control (Fig. 1) by the end of the growing season. Late blight initiation was delayed and symptoms developed more slowly in treatments of Ridomil and Manconzeb applied every 10 days, 100% MRAR applied every 5 days and 50% MRAR applied every 5 days. Compared to all other treatments disease severity was generally high in untreated plots compared to treated plots (Fig.1). During season 2006A, weather conditions were not conducive for late blight development and the disease severity scores were very low (Fig. 2). These unfavourable weather conditions suppressed development and progress of late blight (Fig.2). There was a significant difference between the treatments during season 2005B. The application of Dithane at 100% and 50% MRAR every 5 days resulted in low values of RAUDPC. The application of the two doses at 10 and 15 days resulted in relatively high values of RAUDPC though still less than the untreated control (Fig.3). There was no significant difference between all the treatments including the untreated plots during season 2006A (Fig.3).

TABLE 1: Environmental conditions during experimental seasons 2005B and 2006A at Kinigi Station, ISAR Ruhengeri Research Center.

Climatic variable	2005B				2006A			
	Mar	Apr	May	Jun	Nov	Dec	Jan	Feb
Mean air temperature (°C)	16.4	15.4	15.2	14.7	14.95	16.2	15.26	21.48
Mean soil temperature (°C)								
Maximum	18.6	17.6	17.9	17.4	18.2	17.5	18	15.91
- Minimum	18.4	17.4	17.9	17.4	17.7	16.7	16	15.26
Mean soil moisture (ratio)								
- Maximum	0.41	0.43	0.45	0.42	0.39	0.31	0.35	0.024
- Minimum	0.4	0.42	0.43	0.4	0.29	0.22	0.21	0.018
Total precipitation (mm)	167.1	135.4	167.1	104.4	93.1	29.9	55.8	2.54
Air Relative Humidity (%)	73.8	81.1	86.5	83.5	78.8	68.9	72.5	54.6

Effect of treatments on tuber yield: In season 2005B, the yield was low in all the treatments due to the high disease pressure. In season 2006A, the tuber yield was higher in all the treatments than the yields realized in season 2005B. The average yield for the plots treated with 50 and 100% dose rates of Dithane at 5 days application was compared to other treatments (Fig.4). The application of dithane at frequencies of 10 and 15 day intervals resulted in lower yield compared to the 5-day application intervals (Fig 4). However, applying dithane at 10 or 15 day intervals gave significantly greater yields when compared to the untreated control (Fig. 4).

Relationship between potato late blight and tuber yield: During the season 2005B, there was a negative effect of potato late blight on tuber yield. Decline in yield was correlated with increase in foliar late blight (Fig. 5).

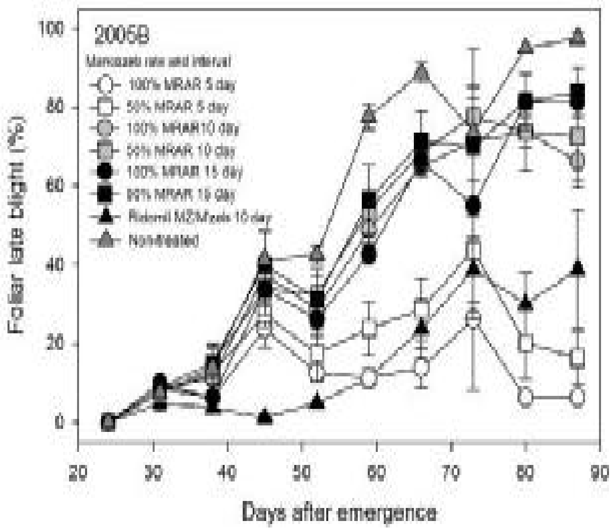

Figure 1: Effect of varying mancozeb application rates and frequency on progress of foliar late blight in potato cv. Kirundo in season 2005B trial. MRAR= manufacturers recommended application rate.

Discussion

In season 2005B, the average yield in the untreated control was low compared to the treated plants. In 2006A, the average yield in the untreated control was not statistically different when compared to the treated plots. The fungicide Dithane M-45 significantly reduced the potato late blight severity at all application rates when applied at 5-day intervals. A substantial reduction of disease severity was also observed when the fungicide was applied at 10-day intervals at 100% recommended rates. The 5-day application interval using Dithane alone at either 50 or 100% MRAR were as effective as the standard program of Ridomil MZ alternating with Dithane applied on a

10-day interval. Potato late blight was also effectively controlled by the standard program of Ridomil MZ alternating with Dithane applied on a 10-day interval.

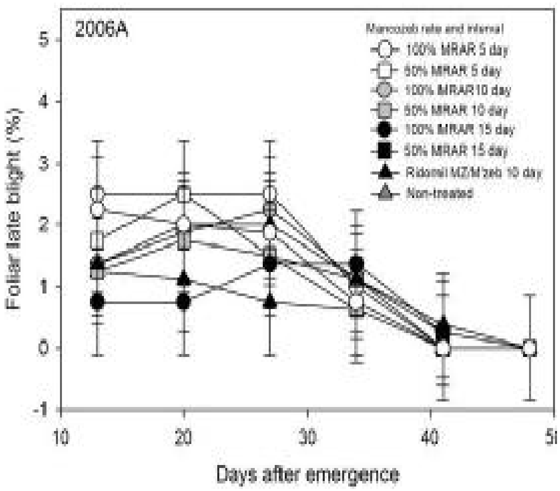

Figure 2: Effect of varying mancozeb application rates and frequency on progress of foliar late blight in potato cv. Kirundo in season 2006A trial. MRAR= manufacturers recommended application rate.

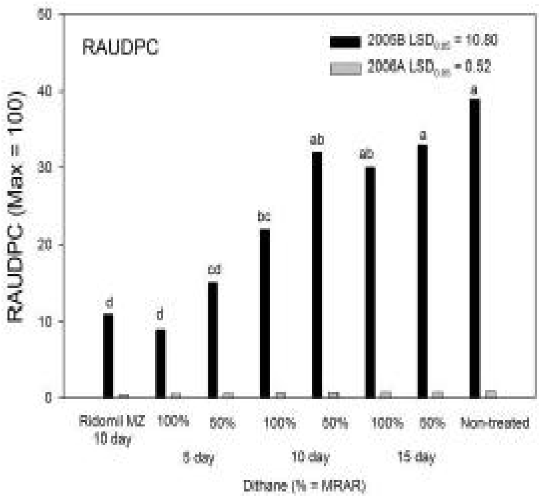

Figure 3: Foliar potato late blight on potato cv. Kirundo expressed as the relative area under the disease progress curve (RAUDPC). The letters on the top of columns are mean separation groups. MRAR = manufacturers recommended application rate.

On the basis of this study, and as it has been stated by Muhinyuza *et al.* (2004) and Kirk *et al.* (2005), there is a possibility for using managed fungicide application in combination with the resistance of a potato variety. Overall, the use of resistant varieties would potentially reduce losses due to late blight and reduce the cost of crop protection in potato production. The results of this study were also consistent with previous studies (Fry, 1977 a & b; Kirk *et al*., 2001; Muhinyuza *et al.* 2004; Kirk *et al*., 2005, Nærstad *et al*., 2007) and indicated that a combination of cultivar resistance and managed application of protective fungicides will reduce foliar late blight to acceptable levels in most situations. However, when environmental conditions were extremely favorable for the development of late blight, lower application rates (50% MRAR) combined with increased application frequencies (10 and 15-day intervals) provided unsatisfactory control.

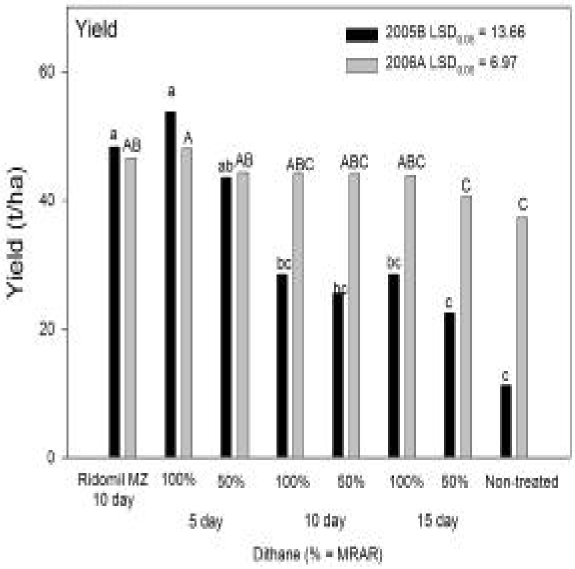

Figure 4: Effect of dose rates and application frequencies of Dithane on tuber yield, comparing seasons 2005B and 2006A. The letters on the top of columns are mean separation groups.

The unfavourable weather conditions of the season 2006A did not favor late blight development although there was inoculum present early in the season. This was due to the drought and then no natural development of late blight because weather conditions were not met for the disease development. This resulted in the increase of tuber yield. Effective control of potato late blight can be attained by the use of managed fungicide applications in combination with the resistance of the variety relatively resistant to potato late blight such as Kirundo. In dry years it would be reasonable to reduce applications of fungicide but to do so would require the development and establishment of a real-time potato late blight prediction model adapted to the region.

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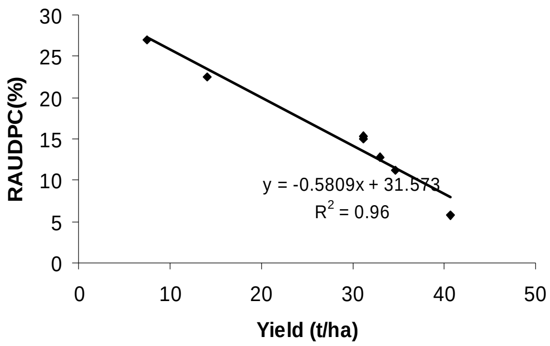

Figure 5: Effect of potato late blight on tuber yield in season 2005B.

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