Impact of Fungicide Application and Late Blight Development on Potato Growth Parameters and Yield in the Tropical Highlands of Kenya and Uganda

Article *in* African Crop Science Journal · January 2001

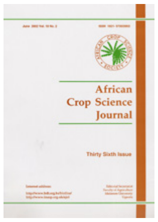
DOI: 10.4314/acsj.v9i1.27643 · Source: OAI

7 authors, including:

Peter Ojiambo
North Carolina State University

Modesto Olanya
USDA-ARS, Eastern Regional Research Center, Wyndmoor, PA

Gregory Allan Forbes
International Potato Center



African Crop Science Journal
AFRICAN CROP SCIENCE SOCIETY
ISSN: 1021-9730 EISSN: 2072-6589
VOL. 9, NUM. 1, 2001, PP. 225-233

African Crop Science Journal, Vol. 9, No. 1, March 2001, pp. 225-233

Impact of Fungicide Application and Late Blight Development on Potato Growth Parameters and Yield in the Tropical Highlands of Kenya and Uganda

P. S. Ojiambo, S. Namanda, O. M. Olanya, R. El-Bedewy, J. J. Hakiza[1], E. Adipala[2] and G. Forbes[3]
International Potato Centre (CIP), Sub-Saharan Africa Region, P.O. Box 25171, Nairobi, Kenya
[1]Potato Research Program, NARO, Kalengyere, P.O. Box 722, Kabale, Uganda
[2]Makerere University, P.O. Box 7062, Kampala, Uganda
[3]International Potato Centre (CIP), Quito, Ecuador

Code Number: CS01052

ABSTRACT

The effects of fungicide application and late blight development on potato varieties with different levels of resistance to late blight were quantified in Kenya and Uganda during the 1999 cropping seasons. Experiments were laid out in a randomised complete block design with three replications in three sites, Loreto and Kabete in Kenya and Kalengyere Research Station in Uganda. At each experimental site, plots consisted of 4 m rows with plants spaced at 0.75m x 0.3 m. Treatments consisted of three potato varieties and four application intervals of Dithane M-45 arranged in a factorial combination. Areas under disease progress curves (AUDPCs) was significantly lower in the sprayed plots than in the unsprayed plots. Disease levels were lower in plots with 7 days application interval and most severe in plots of 21 days spray interval. Yields were higher in the 7 days intervals and lower in the 14, 21-days intervals and in the unsprayed plots. Fresh tuber weights and dry tuber weights were higher in the sprayed plots and lower in the unsprayed plots, respectively. At Kabete, Kerr's Pink had the highest AUDPC value of 2139.3 and disease was least on Asante with an AUDPC value of 409.4. The corresponding AUDPC values for the control plots were 671.5, 945.6 and 2367.8 for Asante, Tigoni and Kerr's Pink, respectively. At Loreto, disease was also most severe on Kerr's Pink with an AUDPC value of 2076.3 and least severe on Tigoni that had an AUDPC value of 444.8. The corresponding AUDPC values for the control plots were 840.4, 1000.2 and 2740.0, for Tigoni, Asante and Kerr's Pink, respectively. The highest tuber yield of 41.3 t ha^{-1} recorded at Kabete for Asante was significantly higher than yields of Kerr's Pink (22.0 t ha^{-1}) but was not different from the yields of Tigoni (39.9 t ha^{-1}). At Loreto, Tigoni had the highest yields of 34.6 t ha^{-1} that was significantly different from that of Kerr's Pink (6.2 t ha^{-1}) in the sprayed plots. At Kalengyere, disease levels were significantly ($P = 0.05$) lower in the sprayed plots than in the control plots and disease severity was least on variety Rutuku (AUDPC value of 17.9) in 7 day spray interval. Tuber yields were significantly ($P = 0.05$) higher in the sprayed plots and highest tuber yield was recorded on variety Kabale (39.5 t ha^{-1}) in plots with 7 day spraying interval.

Key Words: East Africa, fungicide, general resistance, growth parameters, late blight, yield

RÉSUMÉ

Les effets d'application des fongicides et le développement du mildiou sur les variétés de pomme de terre ayant des niveaux différents de résistance au mildiou ont été quantifiés au Kenya lors des saisons culturales de 1999.

Les expériences en blocs complètement randomisés avec 3 répétitions en 2 sites, Loreto et Kabete, ont été mises en place. A chaque site d'expérimentation, les parcelles en rangées de 4m avec des plants espacés de 0,75 x 0, 3m. Les traitements étaient de 3 variétés de pomme de terre et quatre intervalles d'application du Dithane M-45 arrangés en combinaison factorielle. L'aire sous les courbes du progrès de la maladie (AUDPC) était significativement petite dans les parcelles arrosées de fongicides que dans celles non arrosées. Les niveaux d'infection étaient bas sur des parcelles arrosées à 7 jours d'intervalle et très sévères sur des parcelles arrosées à 21 jours d'intervalle. Les rendements étaient élevés sur des parcelles arrosées à 7 jours d'intervalle et bas sur celles à 14 et 21 jours d'intervalle ainsi que celles non arrosées Le poids des tubercules frais et celui de ceux qui sont séchés était plus élevé sur des parcelles arrosées et plus bas chez celles non arrosées. A Kabete, Kerr's Pink a eu la plus grande valeur AUDPC de 2139,3 et l'infection était moindre pour Asante avec une valeur AUDPC de 409,4. Les valeurs AUDPC correspondantes aux parcelles de contrôle étaient 671,5, 945,6 et 2367,8 pour respectivement Asante, Tigoni et Kerr's Pink. A Loreto, l'infection était également très sévère sur Kerr's Pink avec une valeur AUDPC de 2076,3 et moins sévère sur Tigoni qui eut une valeur AUDPC de 444,8. Les valeurs AUDPC correspondantes sur les parcelles de contrôle étaient de 840,4, 1000,2 et 2740,0 pour respectivement Tigoni, Asante et Kerr's Pink. Le rendement le plus élevé en tubercules de 41,3 t/ha enregistré à Kabete pour Asante fut significativement plus élevé que celui de Kerr's Pink (22 t ha^{-1}) mais pas différent de celui de Tigoni (39,9 t ha^{-1}). A Loreto, Tigoni a eu le rendement le plus élevé de 34,6 t/ha et qui fut significativement différent de celui de Kerr's Pink (6,2 t ha^{-1}) sur des parcelles arrosées aux fongicides. A Kalengyere, l'infection était significativement petit dan les parcelles arrosées de fongicide qua dans celles non arrosées et l'infection était moindre pour Rutuku avec une valeur AUDPC de 17.9 à 7 jours d'intervalle. Le rendements était significativement plus éleve dans les parcelles arrosées de fongicides et le rendement le plus éleve pour Kabale était 39,5 t ha^{-1} sur dans parcelles arrosées aux fongicides à 7 jours d'intervalle.

Mots Clés: East Africa, fongicide, résistance générale, paramètres de croissance, mildiou, rendement

INTRODUCTION

Late blight has become one of the most expensive diseases world wide, both in terms of disease control and yield and post-harvest losses (Fry and Goodwin, 1997). This is particularly true for many of the major producing areas in tropical highlands of East Africa (Haverkort, 1986). For certain diseases the use of race-specific resistance governed by one or a few host genes has been ineffective as a control procedure because of the rapid appearance of new races of the pathogens which are virulent to cultivars containing such genes. Late blight of potato (*Solanum tuberosum* L.) caused by *Phytophthora infestans* (Mont.) De Bary is among these diseases. Consequently, plant breeders have concentrated on the development of resistance described variously as field, horizontal or polygenic resistance (Simons, 1972). Collectively, the effects of polygenic resistance reduce the rate of epidemic development (Van der Plank, 1963). Periodic application of a protective fungicide for control of a compound interest disease also reduces the rate of epidemic development (Van der Plank, 1967). Presumably, polygenic resistance and the periodic application of a protective fungicide should be useful combination (Simons, 1972; Shitienberg, 2001). It should be possible to reduce the rate of epidemic development (apparent rate of infection) to a given level with less fungicide on a cultivar with a high level of polygenic resistance than on a cultivar with less resistance.

In Uganda, under good management but without fungicide sprays, yield losses due to late blight are estimated at 40-50% for the moderately resistant varieties Cruza and Rutuku, and 50-70% for the more susceptible varieties. On average yield losses range from 40-60% (FAO, 1996). Farmers' experience shows that two or three applications of fungicides at a rate of 2.5t ha^{-1} reduce losses down to an economically acceptable level. The impact of fungicide application on disease development in relation to variety susceptibility and fungicide application on yield under the tropical highlands of Africa has not been adequately addressed. Knowledge of the interaction of fungicides and commonly grown genotypes is essential in adjusting fungicide sprays to complement level of resistance to late blight. Sexual reproduction of the late blight fungus generates greater genetic diversity in population that may lead to genotypes that are aggressive and difficult to control (Fry *et al.*, 1993; Goodwin *et al.*, 1995). Characterisation of the *Phytophthora infestans* populations in Kenya and Uganda revealed populations that are resistant to metalaxyl (Vega-Sanchez *et al.*, 2000). As part of the integrated management of late blight, there is need to complement general resistance in available varieties with reduced amount of fungicide application. The objectives of this research were to determine the impact of fungicide application and late blight development on yield of potato cultivars with different levels of resistance to *Phytophthora infestans*.

MATERIALS AND METHODS

Field plot establishment in Kenya and Uganda. Experiments and field plots were established at the International Potato Centre (CIP) late blight testing sites at the University of Nairobi, Kabete field location (1, 800

m) and at Loreto (2, 200 m) in Kenya. In Uganda, field plots were established at Kalengyere Research Station in Kabale (2, 525 m). At the three sites, plot sizes consisted of 4 row plots each measuring 3 x 5 m (W x L). At both sites, a 3 x 4 factorial experiments (varieties by fungicide application intervals) were established in a randomised complete block design with 3 replications. Three fungicides spray intervals (7, 14, and 21days) and a control (no fungicide spray) were tested in the two sites. The test fungicide used in the study was Dithane M-45 (Mancozeb). Potato varieties with different levels of resistance to late blight were used in this study. In Kenya, varieties Kerr's Pink (highly susceptible), Cruza 148 (moderately resistance) and Tigoni (moderately resistant) were used while in Uganda, varieties Rutuku (moderately resistant), Kabale (moderately tolerant) and Victoria (susceptible) were used. Experiments were conducted at Kabete during the 1999 short-rain (Season B) and long-rain (Season A). At Loreto, experiments were only conducted in the 1999 B season. The variety Asante (moderately susceptible) was used instead of Cruza 148 during the 1999 B season. In Uganda the experiments were conducted only during the short rain season of 1999.

In all field plots, normal agronomic practices such as adequate field and seedbed preparation, weeding, and hilling were followed. Fertilisers (175 N, 175 P) were also applied at the rate of 500 kg DAP per hectare. Application of insecticides (metasystox) for control of aphid and leafhoppers was done when necessary. Beginning at 50 days after emergence, tuber weights were quantified 4 times during the cropping season at two weeks interval. A single potato plant was randomly sampled from each plot (36 plant samples) at each assessment period. From the plant samples obtained, fresh leaves, stems, roots and tubers were weighed and recorded. Similarly, a sub-sample of 100-g fresh weight from tubers was placed in paper bags, dried in an oven at 82°C for 3 days. Subsequently, oven dried weights of samples were recorded. At harvest, tubers from each experimental plot were weighed and converted to tons per hectare for subsequent analysis.

Disease assessment and environmental monitoring. Beginning at the onset of late blight symptoms, weekly assessments of disease incidence and severity were quantified in all treatment plots. Assessment for disease incidence and severity was based on visual symptoms and using late blight assessment scale (0-100%). At least seven disease assessments were recorded. Area Under Disease Progress Curve (AUDPC) was calculated from disease severity values as described by Campbell and Madden (1990). Units for AUDPC are % days-proportion. At crop maturity, plots were harvested; tuber numbers and tuber weight (yield) were recorded for all treatments. Incidence of tuber blight was also quantified by visual observation of tuber blight symptoms. In the two sites, weather equipment (Hobo Pro Series, Massachusetts, USA) for monitoring environmental parameters were deployed. Ambient temperatures, relative humidity, rainfall and hours of sunshine were recorded in the two sites.

Data analysis. Data on disease (AUDPC), yield (t ha^{-1}) and plant growth parameters (fresh and dry tuber weights) from both Kenya and Uganda sites were analysed by using Proc Means of the Statistical Analysis Systems (SAS, 1987). However, only data on plant growth parameters from Loreto and Kabete are presented in this paper. Environmental parameters (relative humidity, rainfall, temperature, hours of sunshine were analysed by using Proc Summary of the Statistical analysis System (SAS, 1997) to generate mean values for each parameter per assessment periods. The effects of the interval of fungicide application on late blight development on potato varieties were computed by using an analysis of variance (Proc Anova, SAS, 1997). Development and progress of late blight in sprayed and unsprayed plots were compared among potato varieties graphically after computing Areas Under Disease Progress Curves (AUDPC - % disease days).

RESULTS

In Kenya and Uganda, fungicide interval and variety x fungicide significantly affected late blight incidence and severity, fresh and dry tuber weights and tuber yields (**Table 1**). In the two sites, late blight development also differed significantly. Among the varieties tested, highest levels of late blight severity were observed on Kerr's Pink and Kabale in Kenya and Uganda, respectively. For all the varieties tested in Kenya and Uganda, AUDPC values were generally higher in the control plots than in the fungicide sprayed plots. Tuber yield, fresh and dry tuber weights were higher in the sprayed plots and lower in the unsprayed plots for all the three varieties studied.

Kabete. Late blight severity recorded as area under disease progress curve (AUDPC) in the sprayed plots was least on Asante (409.4) and highest on Kerrs' Pink (2139.3), while Tigoni had AUDPC value of 463.0. The corresponding AUDPC values for the unsprayed plots were 671.5, 945.6 and 2367.8 for Asante, Tigoni and Kerrs' Pink, respectively (**Table 2**). On average disease levels in the sprayed plots were less severe in plots with a 7 days application interval and most severe in 21 days application interval. This was true for all the three varieties. Disease was more severe in the unsprayed plots than in the plots with fungicide application. Late blight progress was much faster on variety Kerrs' Pink than Tigoni and Asante. Highest tuber yields were recorded in the sprayed plots with variety Asante having the highest tuber yields of 41.3 t ha^{-1} followed by Tigoni (39.9 t ha^{-1}) and least in Kerrs' Pink with a yield of 22.0 t ha^{-1} (**Table 2**). Generally, tuber yields were higher in 7 and 14 days spraying interval and lower in 21 day application interval plots, but there was no significant difference in yield between the 21 day interval and the control plots. The corresponding tuber yields of the control plots were 32.9, 31.5 and 24.9 t ha^{-1}, for Asante, Tigoini and Kerr's Pink, respectively (**Table 2**). Average fresh tuber weight was highest for Tigoni (715 g m^{-2}) compared to 600 g m^{-2} for Asante and 510 g m^{-2} for Kerrs' Pink. Generally, fresh tuber weight increased with increase days after planting and decreased at 82 days after planting for all the three varieties. Tuber dry weights were dependent on variety with Kerrs' Pink having the highest tuber dry weight of 16.0 g m^{-2} compared to 14.0 g m^{-2} for Tigoni.

Loreto. Unlike Kabete, disease was most severe on Kerrs Pink that had a mean AUDPC value of 2111.0 and least on Tigoni that had a mean AUDPC value of 444.8 in the sprayed plots, while the variety Asante had a moderate level of disease with an AUDPC value 602.5. Disease levels were significantly higher on Kerrs' Pink than on Tigoni and Asante. The corresponding AUDPC values for the unsprayed plots were 840.4, 1000.2 and 2740 for Tigoni, Asante and Kerrs' Pink, respectively (**Table 3**). Disease levels were generally lower in plots with a 7-day spray interval and higher in plots with a 21-day fungicide application interval (**Table 3**) and disease levels were significantly higher in unsprayed plots than plots with fungicide application. As was the case at Kabete, late blight progress was faster on Kerrs' Pink than on Tigoni and Asante. Generally, Tigoni had the highest yield of 34.6 t ha^{-1} in the sprayed plots and this yield was significantly higher than yields of Kerr's Pink which was 6.6 t ha^{-1} (**Table 3**). Tuber yields were significantly higher in plots with 7 days fungicide application (34.6 t ha^{-1} for Tigoni, 30.1 t ha^{-1} for Asante and 6.6 t ha^{-1} for Kerr's Pink) than in the 21 days application interval (28.1 t ha^{-1} for Tigoni, 27.8 t ha^{-1} for Asante and 5.7 t ha^{-1} for Kerr's Pink). The corresponding tuber yields of the unsprayed plots were 27.5, 25.8 and 5.0 t ha^{-1}, for Tigoni, Asante and Kerr's Pink, respectively.

Fresh tuber weights (FTWT) in the sprayed plots and unsprayed increased upto 68 days after emergence and then declined afterwards for all the varieties tested. Fresh tuber weights were significantly higher in the sprayed plots than in the unsprayed plots. For the moderately susceptible variety Asante, FTWT in the sprayed plots increased to 840.0 g m^{-2} and then decreased onwards, while in the unsprayed plots FTWT increased upto 590.5 g m^{-2} and decreased afterwards at Loreto (**Fig. 1**). As was the case with fresh tuber weights, dry tuber weights (DTWT) for variety Asante in the sprayed plots increased upto 21.5 g at 68 days after planting and decreased afterwards. In the unsprayed plots, DTWT increased upto 15.0 g at 54 days after planting and decreased afterwards during the short rains at Loreto (**Fig. 2**).

Kalengyere Research Station. Fungicide application and variety significantly (P = 0.01) affected late blight severity (**Table 1**) and disease was significantly (P = 0.05) lower in the fungicide sprayed plots than in the control (fungicide unsprayed plots). Within the sprayed plots, disease was least in plots with 7 day fungicide application intervals (AUDPC value of 17.9 for variety Rutuku). The AUDPC values for variety Rutuku in plots with 14 and 21 days spray intervals were 28.5 and 84.4, respectively. The corresponding AUDPC value for variety Rutuku in the control plots was 1256.7 (**Table 4**). Within the sprayed plots, disease was consistently lower on variety Rutuku compared to varieties Kabale and Victoria and a similar trend in disease levels was observed in the control plots. Tuber yields were also significantly (P = 0.05) affected by fungicide and variety. Tuber yields were higher in plots with 7 day fungicide application interval (39.5 t ha^{-1} for variety Kabale) compared to 35.0 and 34.7 t ha^{-1} for variety Kabale in plots with 14 and 21 days spray intervals, respectively. The corresponding tuber yield for variety Kabale in the control plots was 16.2 t ha^{-1} (**Table 4**).

DISCUSSION

Application of the protective fungicide to the potato varieties infected with *P. infestans* significantly reduced disease severity and increased tuber yields. Application of the protective fungicide also affected fresh tuber weights and dry tuber weights of the varieties studied. This response was seen with varieties that differed in their susceptibility to late blight. The absolute impact of the fungicide treatment was influenced by the variety. The magnitude of the response was greater with variety Tigoni and Asante than on variety Kerr's Pink. Kerr's Pink is highly susceptible to late blight and attack by the disease early in the season significantly contributed to the lower yields observed. These results correspond well to informal reports by the national potato programmes in Kenya and Uganda. Fry and Shtienberg (1990) reported that complete suppression of yield is possible if the disease occurs early enough. The lack of consistency in results in some cases as observed in this study was due to the early occurrence of the disease before the spray programme was initiated to allow for adequate control of the disease. Adjustment of fungicide application rates to complement the general resistance of a particular variety is one method whereby fungicide efficiency is enhanced (Fry, 1977; Shtienberg, 2001). One of the principles of fungicide resistance management is that any factor which suppresses the growth rate of resistant individuals relative to sensitive ones, will also slow the selection for resistant individuals (Milgroom and Fry, 1988).

In his study with potato genotypes with low levels of resistance to late blight, Fry (1975) observed that greater reductions in the amount of fungicide required for adequate control were possible with introduction of varieties with high levels of polygenic resistance. In this case growers should be able to increase fungicide efficiency by adjusting the dosage of fungicide to complement the polygenic resistance of various varieties (Fry, 1977). The efficiency of fungicide use in this case is expected to increase especially where genotypes of high resistance are used. Niklaus *et al.* (2000) evaluated host resistance and fungicide application and managed late blight with weekly sprays using a contact fungicide. Where the contact fungicide was applied, resistance of a susceptible variety Alpha was increased by 20% of the final disease severity of a resistant genotype. Unfortunately, for all potato varieties grown in Kenya, general resistance has not been quantified to allow for reliable adjustment of fungicide dosage to complement resistance. Resistance of commonly grown cultivated potato varieties has been quantified elsewhere (Fry *et al*., 1983). There is thus need to quantify the levels of general resistance in available varieties to increase the efficiency of fungicide application. In the experiments reported here, the same concentrations of the fungicide were applied at different intervals. Further work is necessary to determine whether the same relationship would prevail if concentrations of the fungicide were varied rather than the interval of application.

ACKNOWLEDGEMENT

The International Potato Centre provided core funding for the study. The second author was funded by the Rockefeller Foundation's Forum for Agricultural Resource Husbandry as part of his MSc. study at Makerere University.

REFERENCES

Fry, W.E. 1975. Integrated effects of polygenic resistance and a protective fungicide on development of potato late blight. *Phytopathology* 65:908-911.

Fry, W.E. 1977. Integrated control of potato late blight - Effects of polygenic resistance and techniques of timing fungicide applications. *Phytopathology* 67:415-420.

Fry, W.E., Apple, A.E. and Bruhn, J.A. 1983. Evaluation of potato late blight forecast modified to incorporate host resistance and fungicide weathering. *Phytopathology* 73:1054-1059.

Fry, W.E. and Shtienberg, D. 1990. Integration of host resistance and fungicide to manage potato diseases. *Canadian Journal of Plant Pathology* 12:111-116.

Fry, W.E. and Goodwin, S.B. 1997. Re-emergence of potato and tomato late blight in the United States. *Plant Disease* 81:1349-1357.

Fry, W.E., Goodwin, S.B., Dyer, A.T., Matuszak, J.M., Drenth, A., Tooley, L.S., Sujkuwski, L.S., Koh, Y.J., Cohen, B.A., Spielman, L.J., Deahl, L., Inglis, D.A. and Sandlan, K.P. 1993. Historical and recent migrations of *Phytophthora infestans* - Chronology, pathways and implications. *Plant Disease* 77: 653-661.

Goowin, S.B., Sujkuwski, L.S., Dyer, A.T., Fry, B. and Fry W.E. 1995. Direct detection of gene flow and probable sexual reproduction of *Phytophthora infestans* in northern North America. *Phytopathology* 85:473-479.

Haverkort, A.J. 1986. Light interception and yield relations under the tropical highland conditions of Central Africa. *Potato Research* 29:257-258.

Milgroom, M.G. and Fry, W.E. 1988. A model for the effects of metalaxyl on potato late blight epidemics. *Phytopathology* 78:559-565.

Niklaus, N.J., Rubio-Covarrubias, O.A. and Fry, W.E. 2000. Potato late blight management in the Toluca Valley: Forecasts and resistant cultivars. *Plant Disease* 84410-416.

SAS (1988) *SAS/STAT User's Guide, Release 6.03*. SAS Institute, Cary N.C.

Simons, M.D. 1972. Polygenic resistance to plant disease and its use in breeding resistant cultivars. *Journal of Environmental Quality* 1:232-240.

Shitienberg, D. 2001. Integrated management of early and late blights of potatoes in Israel. *African*

Crop Science Journal 9:203-207.

Vega-Sanchez, M.E., Erselius, L.J., Rodrigues, A.M., Bastidas, O., Hohl, H.R., Ojiambo, P.S., Mukalazi, J., Vermeulen, T., Fry W.E. and Forbes, GA. 2000. Host adaptation to potato and tomato within the US-1 clonal lineage of *Phytophthora infestans* on tomato and potato in Uganda and Kenya. *Plant Pathology* 49:531-539.

Van der Plank, J.E. 1963. *Plant Disease: Epidemics and Control*. Academic Press, New York. 349 p.

Van der Plank, J.E. 1967. Epidemiology of fungicidal action. In: *Fungicides: An advanced treatise.*Torgeson, D.C. (Ed.), pp. 63-92. Academic Press, New York.

TABLE 1. Analysis of variance on the effect of fungicide (Dithane M-45) application intervals on late blight severity on three potato varieties at Loreto and Kabete during the short rains cropping season of 1999

Source	Df	M.S.	Pr > F
Loretoa			
Rep	2	690.00	0.0001
Variety	2	37428.33	0.0001**
Rep x Variety	4	6572	0.0023
Fungicide intervalb	3	90.91	0.0173*
DOAc	5	19495.93	0.0001**
Variety x fungicide	6	96.68	0.1054
Variety x DOA	10	2137.46	0.0001**
Fungicide x DOA	15	23.22	0.9681
Variety x fungicide x DOA	30	39.93	0.8325
Kabetea			
Rep	2	1807.55	0.0047
Variety	2	34771.64	0.0001**
Rep x Variety	4	8673	0.0032
Fungicide intervalb	3	261.72	0.0489*
DOAc	5	19382.16	0.0001**
Variety x fungicide	6	625.95	0.0797
Variety x DOA	10	2554.57	0.0001**
Fungicide x DOA	15	147.489	0.9353
Variety x fungicide x DOA	30	360.41	0.3355

Kalengyerea			
Rep	2	2295.72	0.1002
Variety	2	1095.11	0.0152*
Rep x Variety	4	476.2	0.0987
Fungicide intervalb	3	26630.32	0.0001**
DOAc	7	3890.42	0.0001**
Variety x fungicide	6	366.81	0.2068
Variety x DOA	14	37.266	0.9999
Fungicide x DOA	21	1351.78	0.0001**
Variety x fungicide x DOA	30	2416.34	0.2143

[a] Loreto and Kabete locations in Kenya are at 1,800m and 2,200m above seal level, respectively and Kalengyere Research Station in Uganda (2,525 m above sea level).
[b] Refers to 7, 14, 21 days interval and no application (control)
[c] Days of assessment
*, ** Significant at P= 0.05 and P=0.01, respectively

TABLE 2. Yield (t ha^{-1}) of three potato varieties treated with different fungicide (Dithane M-45) application at Kabete location during the short rains of 1999

Application[a] interval	Variety[b]	Sprayed		Unsprayed	
		AUDPC[z]	Yield	AUDPC	Yield
7 days	Asante	409.4	41.3	671.5	32.9
7 days	Kerr’s Pink	1965.5	27.1	2367.8	24.9
7 days	Tigoni	463.0	39.9	945.6	31.5
14 days	Asante	492.3	34.3	671.5	32.9
14 days	Kerr’s Pink	2139.3	26.5	2367.8	24.9
14 days	Tigoni	546.0	36.1	945.6	31.5
21 days	Asante	540.6	32.5	671.5	32.9
21 days	Kerr’s Pink	2292.3	22.0	2367.8	24.9
21 days	Tigoni	761.5	34.4	945.6	31.5
Mean		1054.7	32.7	1266.7	29.8
LSD 0.05		199.3	2.3	90.8	2.1

[a]Duration at which fungicide treatments were applied beginning 45 days after emergence
[b]Variety Kerr's Pink is highly susceptible, Asante moderately susceptible and Tigoni tolerant to late blight
[c]Area under disease progress curve (% - disease days)

TABLE 3. Yield (t ha^{-1}) of three potato varieties treated with different fungicide (Dithane M-45) application at Loreto location during the short rains of 1999

Application[a] interval	Variety[b]	Sprayed		Unsprayed	
		AUDPC[z]	Yield	AUDPC	Yield
7 days	Asante	602.5	33.2	1000.2	25.8
7 days	Kerr's Pink	1940.0	6.6	2740.0	5.0
7 days	Tigoni	444.8	34.6	840.4	27.5
14 days	Asante	702.4	30.1	1000.2	25.8
14 days	Kerr's Pink	2003.2	6.2	2740.0	5.0
14 days	Tigoni	524.3	31.6	840.4	27.5
21 days	Asante	870.4	27.8	1000.2	25.8
21 days	Kerr's Pink	2111.0	5.7	2740.0	5.0
21 days	Tigoni	744.7	28.1	840.4	27.5
Mean		1148.0	24.9	1827.6	21.4
LSD 0.05		170.5	5.5	150.6	2.1

[a]Duration at which fungicide treatments were applied beginning 45 days after emergence
[b]Variety Kerr's Pink is highly susceptible, Asante moderately susceptible and Tigoni tolerant to late blight
[c]Area under disease progress curve (% - disease days)

TABLE 4. Yield (t ha^{-1}) of three potato varieties under different fungicide spray schedules at Kalengyere Research Station, Uganda, during the second (B) season of 1999

Application[a] interval	Variety[b]	Sprayed		Unsprayed	
		AUDPC[c]	Yield	AUDPC	Yield
7 days	Kabale	36.6	39.5	1749.3	16.2
7 days	Rutuku	17.9	32.2	1256.7	19.6
7 days	Victoria	24.4	36.4	2062.5	8.2
14 days	Kabale	268.3	35.0	1749.3	16.2
14 days	Rutuku	28.5	31.0	1256.7	19.6
14 days	Victoria	132.8	29.9	2062.5	8.2

21 days	Kabale	294.4	34.7	1749.3	16.2
21 days	Rutuku	84.4	30.1	1256.7	19.6
21 days	Victoria	203.8	27.8	2062.5	8.2
Mean		129.0	33.0	1689.5	14.7
LSD 0.05		400.8	6.1	920.5	4.3

[a]Duration at which fungicide treatments were applied begining 45 days after emergence.
[b]Variety Victoria is highly susceptible, Kabale moderately susceptible and Rutuku tolerant to late blight
[c]Area under disease progress curve (% - disease days)

Figure 1. Fresh tuber weights (g m^{-2}) of three potato varieties with differing levels of resistance to late blight obtained from Dithane M-45 sprayed and unsprayed treatment plots during the short rains of 1999 at Loreto.

Figure 2. Percent dry tuber weights of three potato varieties with differing levels of resistance to late blight obtained from Dithane - M45 sprayed and unsprayed treatment plots during the long rains of 1999 at Loreto.

The following images related to this document are available:

Line drawing images

[cs01052a.gif] [cs01052b.gif]