Efficacy of fungicides on the progress of early blight and yield of potato in Cameroon.

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Keywords: Potato — Early blight — *Alternaria solani* — Fungicidal control.

Summary

Five fungicides were evaluated during the 1990 and 1991 growing seasons in two locations in Cameroon for efficacy on the progress of early blight and yield of potato. Disease-progress curves fitted the logistic transformation better than the Gompertz. Fungicidal treatments reduced the rate of early blight progress and area under disease-progress curve (AUDPC). Early blight was more severe in the 1991 season and yields recorded in this season were lower than those in 1990. In both seasons, high yields were obtained in plots receiving six sprays maneb or mancozeb. Two sprays of Ridomil plus (12% metalaxyl + 60% cuprous oxide) and six of cupric hydroxide also produced appreciable yields, while fosetyl-Al (three sprays) provided the least yield increase. Yield losses in non-sprayed plots were estimated at 15.7-53.6%. Yields were negatively correlated to AUDPC.

Résumé

Cinq fongicides ont été testés pendant les saisons de culture de 1990 et 1991 pour leur efficacité sur l'intensification de l'alternariose et le rendement de pomme de terre en deux localités au Cameroun. Les courbes d'intensification de la maladie ont été mieux décrites par la transformation logistique que par celle de Gompertz. Les traitements fongicides ont réduit le taux d'intensification de l'alternariose et les aires sous la courbe de progression de cette maladie (ASCPM). La sévérité de l'alternariose était plus élevée en 1991 et les rendements enregistrés dans cette saison étaient inférieurs à ceux obtenus en 1990. Dans les deux saisons, des hauts rendements ont été obtenus dans les parcelles qui ont reçu six traitements au manèbe ou mancozèbe. Deux pulvérisations du Ridomil plus (12% métalaxyl + 60% d'oxyde cuivreux) et six d'hydroxyde cuivrique ont aussi donné des rendements appréciables tandis que le fosétyl-Al (trois pulvérisations) était le moins efficace. Les pertes de rendement dans les parcelles non traitées étaient estimées à 15.7-53.6%. Les rendements étaient négativement correlés avec ASCPM.

1. Introduction

Potato (*Solanum tuberosum* L.) is the main tuber crop of the highland areas of the West and North West provinces of Cameroon. These areas account for more than 90% of the potatoes produced in Cameroon (11). Early blight, caused by *Alternaria solani* Sorauer is one of the most important diseases of potato in Cameroon (4). The disease appears on the foliage and sometimes on tubers. Leaf infection causes defoliation and reduces tuber yields (2,9,19).

Early blight is commonly controlled with crop resistance or protectant fungicides (2,9,18,19). Resistant cultivars, though inexpensive, are not always available to growers. In the West province of Cameroon, farmers practice intensive fungicide sprays in the rainy season in order to control both early and late blight (*Phytophthora infestans* (Mont.) de Bary) infections. Most of the chemicals used are being supplied by cooperative institutions for use on cocoa or coffee diseases and had not been tested on early blight of potato.

In this study, some of the fungicides used by potato growers were tested for their effect on early blight progress and yield of potato in two locations of the West Province of Cameroon.

2. Materials and methods

2.1. Field plot design.

Field experiments were conducted in 1990 and 1991 at the university farms in Dschang (1400 m) and Bansoa (1440 m, located about 30 km from Dschang). The soil types of these sites are typic paleustult or dystric nitrosol (pH-H_2O 5.0, CEC 33.7 meq/100 g soil, 13% sand, 35% loam, and 52% clay) in Dschang and andeptic eutrorthox or alfisol (pH-H_2O 6.0, CEC 16.4 meq/100 g soil, 29% sand, 47.3% loam, and 23.7% clay) in Bansoa (3). A randomized complete block design was used with three blocks and six treatments per block. Each plot had four rows spaced 0.8 m apart and each row was 4.8 m long. Plots were separated by a potato-free zone 3-4 m wide in order to limit interplot interference.

2.2. Cultural techniques.

A late blight-resistant, early blight-susceptible potato cultivar 'Romano' was planted manually in April 1990 and 1991 in Dschang and Bansoa. Plants were spaced 0.3 m within rows. In both seasons, plots in both sites were fertilized with 144-72-300 kg/ha N-P-K in bands at planting. A foliar fertilizer Fertigofol 313 (4 l/ha) was applied on leaves one month later.

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A herbicide, linuron (Calin 50 WP, 1.0 kg a.i./ha), was applied immediately after planting. An insecticide-nematicide, carbofuran (Furadan 10 G, 3 kg a.i./ha), was broadcast after planting but before emergence. In 1991, an insecticide, methyl parathion (40 WP, 1.6 kg a.i./ha), was applied when necessary to control ants. Plots were weeded and hilled as needed.

In 1990, harvesting was made on day 92 and 91 after planting in Dschang and Bansoa, respectively, while in the 1991 season it was made on day 98 in both locations. Tubers in each experimental unit were hand-harvested from the two centre rows, counted and weighed in bulk. Marketable (≧ 50 g) and diseased tubers were sorted, counted, and weighed. Tuber yields were expressed as kg/ha.

Rainfall and temperature data were obtained from the Institute of Agronomic Research meteorological station in Dschang. Mean monthly rainfall figures for the growing seasons were 229.1 mm in the 1990 season and 248.6 mm in 1991. Mean daily temperature readings ((minimum + maximum)/2) were 19.9 - 21.6 C and 20.2 - 21.2 C in both seasons, respectively.

2.3. Fungicide applications.

Disease control was made with five fungicides initiated when plants were approximately 15-20 cm in height (8). All fungicides were applied with a knapsack sprayer delivering about 1000 l/ha at a maximum pressure of 7 kg/cm² using a single flat fan nozzle. Maneb (Manessan 80WP, 1.6 kg a.i./ha), mancozeb (Mancozan 70WP, 2.8 kg a.i./ha), and cupric hydroxide (Kocide 101 77WP, 3.8 kg a.i./ha) were applied six times in a weekly schedule. Fosetyl-Al (Aliette 80WP, 3.2 kg a.i./ha) was applied thrice in a 2-week interval while Ridomil plus (12% metalaxyl + 60% cuprous oxide, 72WP, 2.4 kg a.i./ha) was applied twice in a 3-week interval. Control plots were not sprayed.

2.4. Disease evaluation.

Inoculation was achieved by naturally-occurring inocula in the field. Disease severity (proportion of leaf area diseased) was determined weekly on four randomly-selected plants in the centre rows of each plot with the aid of the Horsfall-Barratt (10) rating scale. Seven weekly observations were made in both sites starting from day 46 after planting in 1990 and day 38 in 1991 The Horsfall-Barratt severity ratings were converted to disease proportions with conversion tables (12).

2.5. Data analyses.

Progress of early blight in sprayed plots was compared with epidemic rate and area under disease-progress curve (AUDPC) (14). The efficiency of fungicidal control, defined as percent disease control per application, was used to compare the different scheduling methods. It was calculated according to the formula used by Shtienberg and Fry (15). The effect of fungicides on yield was compared with mean weight and yield of tubers as well as with the proportion of marketable tubers. Data for each location in each year were analyzed by analysis of variance and means were separated by the Duncan's multiple range test (P = 0.05).

3. Results

3.1. Disease progress.

Disease progress curves were plotted for each experimental unit. Eighteen disease-progress curves (corresponding to six fungicidal treatments in three blocks) were generated in each location in the 1990 season. The curves were compared with the logistic (17) and Gompertz (1) transformations for goodness of fit. All the progress curves fitted the logistic transformation (R^2 = 91-99%) better than the Gompertz (R^2 = 67-85%). Infection rates were then calculated with the logistic transformation: logit(y2) = logit(y1) + kt where k is the epidemic rate (or apparent infection rate *sensu* Vanderplank, 17), t is the time period during which disease increases from y1 to y2, and logit(y) = ln (y/(1 – y)).

In analyses of variance of k and AUDPC, for both years, significant effects were location (L) and Fungicide (F) in 1990, and L, F, and L × F interactions in 1991. Early blight was generally more severe in 1991 than in 1990. In both seasons, the epidemic progress was relatively slower in sprayed plots than in the control. Differences in progress curves among fungicide treatments were better observed in Bansoa than in Dschang (Fig. 1).

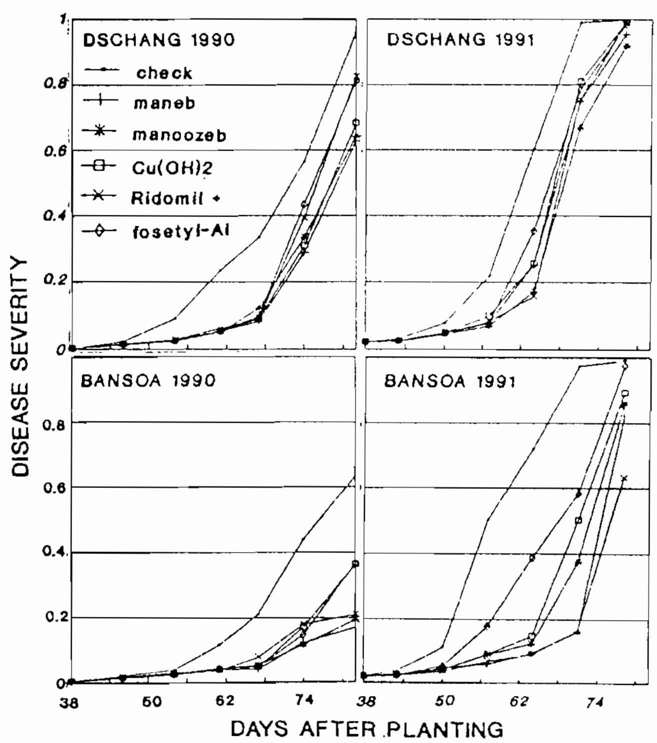

Figure 1 — Effect of fungicide sprays on the progress of early blight in Dschang and Bansoa for the 1990 and 1991 seasons.

Though epidemic rates did not vary significantly between both seasons, the rates were higher in Dschang than in Bansoa. Early blight progress was generally slower in all the plots treated with fungicides than in the control in both sites and in both seasons. In the 1990 season in Dschang, k was significantly slowest in plots exposed to six weekly applications of maneb, mancozeb, or cupric hydroxide. In Bansoa, however, all fungicide-treated plots had similar epidemic rates. In the 1991 season, k was slowest in plots sprayed with mancozeb in Dschang and maneb or Ridomil plus in Bansoa (Table 1).

TABLE 1

Epidemic rate (k), area under disease-progress curve (AUDPC), and percent disease control per application (PDC) as influenced by fungicidal sprays on early blight of potato in Dschang and Bansoa.

Year	Fungicide[X] (Rate in kg a.i./ha)	k		AUDPC		PDC[Y]	
		Dschang	Bansoa	Dschang	Bansoa	Dschang	Bansoa
1990	Maneb (1.6)	0.19 c[Z]	0.14 b	5.78 b	2.30 b	23.0 c	27.5 c
	Mancozeb (2.8)	0.20 c	0.15 b	6.40 b	2.41 b	21.9 c	27.3 c
	Cupric hydroxide (3.8)	0.20 c	0.16 b	6.15 b	3.33 b	22.3 c	25.0 d
	Ridomil plus (2.4)	0.22 ab	0.15 b	7.37 b	3.08 b	60.4 a	76.7 a
	Fosetyl-Al (3.2)	0.22 ab	0.16 b	7.53 ab	3.21 b	39.7 b	50.5 b
	Non-sprayed check	0.24 a	0.19 a	9.31 a	6.62 a	—	—
1991	Maneb (1.6)	0.19 e	0.11 e	12.59 bc	5.69 d	21.0 c	27.7 c
	Mancozeb (2.8)	0.18 f	0.13 d	11.42 c	7.71 c	22.2 c	26.0 c
	Cupric hydroxide (3.8)	0.22 b	0.14 c	12.91 bc	8.89 c	20.7 c	24.6 d
	Ridomil plus (2.4)	0.20 d	0.11 e	12.04 bc	5.00 d	64.7 a	85.2 a
	Fosetyl-Al (3.2)	0.21 c	0.17 b	12.10 b	13.56 b	40.1 b	42.9 b
	Non-sprayed check	0.27 a	0.22 a	16.96 a	17.03 a	—	—

[X]Maneb, mancozeb, and cupric hydroxide were applied six times in a weekly schedule; fosetyl-Al was applied thrice in a 2-weeks interval, while Ridomil plus was applied twice in a 3-weeks interval.

[Y]Percent disease control per fungicidal application was calculated according the formula used by Shtienberg and Fry (15).

[Z]Means for each year in a column followed by the same letter are not significantly different (P = 0.05) according to Duncan's multiple range test.

Values for AUDPC for either location were higher in the 1991 season than in the previous season because of higher disease severities. In either season, the values recorded in Dschang were significantly higher than those in Bansoa. Apart from fosetyl-Al-treated plot in Dschang in the 1990 season, all the fungicide-protected plots had significantly lower AUDPC than the control. In the 1990 season, the least values for AUDPC were obtained in plots protected with maneb, mancozeb, cupric hydroxide, or Ridomil plus in Dschang, while in Bansoa, all the protected plots had similarly low AUDPC's. In the 1991 season, the least AUDPC's were obtained in plots exposed to mancozeb in Dschang and to maneb or Ridomil plus in Bansoa. The highest values for AUDPC in sprayed plots were obtained from plots exposed to fosetyl-Al in both locations (Table 1).

In all treatments, the efficiency of fungicidal application was higher in Bansoa than in Dschang. The efficiency of control was inversely related to the number of applications made. Plots which received six fungicidal sprays (maneb, mancozeb, or cupric hydroxide) had a low efficiency of control compared to those treated with two applications of Ridomil plus or three sprays of fosetyl-Al (Table 1).

3.2. Yield.

In analyses of variance of total yield, tuber weight, and percent marketable tubers, for both years, significant effects were location (L) and Fungicide (F) in 1990, and L, F and L × F interactions in 1991. In either season, tuber weight and yields recorded in Bansoa were always higher than those obtained in Dschang. In the 1990 season, plots treated with maneb produced the largest tubers in both sites. However, those treated with other fungicides were not significantly different from the control. In the 1990 season, mean tuber weight in Dschang was 82.3 g in non-sprayed plots and 84.2-104.3 g in sprayed plots while in Bansoa, the values were 101.9 g and 105.6-129.3 g, respectively. In the following season, fungicide-treated plots had mean tuber weight in the range of 53.6-68.5 g and 70.6-96.8 g in Dschang and

TABLE 2

Tuber weight, total yield, and percentage of marketable tubers of potato as influenced by fungicide applications in Dschang and Bansoa.

Site	Fungicide[X] (Rate in kg a.i./ha)	1990			1991		
		tuber wt (g)	Yield (kg/ha)	% market. tubers[Y]	tuber wt (g)	Yield (kg/ha)	% market tubers
Dschang	Maneb (1.6)	104.3 a[Z]	23,820 a	71.1 ab	68.5 a	13,108 a	74.3 a
	Mancozeb (2.8)	95.2 ab	23,856 a	77.1 a	59.7 ab	13,631 a	74.5 a
	Cupric hydroxide (3.8)	89.2 ab	22,254abc	75.2 ab	53.6 ab	11,334 ab	75.3 a
	Ridomil plus (2.4)	91.9 ab	24,192 a	78.4 a	65.3 ab	12,486 ab	75.4 a
	Fosetyl-Al (3.2)	84.2 ab	20,117 bc	67.7 ab	57.8 ab	11,569 ab	75.4 a
	Non-sprayed check	82.3 a	19,535 c	65.0 b	48.1 b	9,482 b	65.2 b
Bansoa	Maneb (1.6)	129.3 a	29,560 a	65.7 a	94.0 a	20,658 ab	84.1 a
	Mancozeb (2.8)	124.7 ab	28,903 ab	66.5 a	85.5 ab	18,381 b	79.0 a
	Cupric hydroxide (3.8)	126.6 ab	28,379abc	65.9 a	70.6 b	17,123 b	77.9 a
	Ridomil plus (2.4)	123.4 ab	26,521abc	68.8 a	96.8 a	23,061 a	83.0 a
	Fosetyl-Al (3.2)	105.6 ab	25,655 bc	60.4 ab	74.4 b	13,164 c	76.2 a
	Non-sprayed check	101.9 b	24,929 c	52.7 b	51.2 c	10,695 c	62.4 b

[X]Maneb, mancozeb, and cupric hydroxide were applied six times in a weekly schedule; fosetyl-Al was applied thrice in a 2-weeks interval, while Ridomil plus was applied twice in a 3-weeks interval.

[Y]Marketable tubers were those that weighed at least 50 g.

[Z]Means for each location in a column followed by the same letter are not significantly different (P = 0.05) by Duncan's multiple range test.

Bansoa, respectively, compared to 48.1 g and 51.2 g in control plots in both sites, respectively. Though tubers harvested in the 1991 season were not as large as those in the previous season, plots exposed to maneb in Dschang or ot other fungicide treatments in Bansoa produced significantly larger tubers than the control (Table 2). In both years, the percentage of blighted tubers were not affected by fungicide treatment.

In all treatments, total and yields obtained in the 1991 season were lower than those recorded in the previous season. In either season, the yields recorded in Bansoa were generally higher than those in Dschang. In Dschang, significant increase in yields was obtained in plots exposed to maneb, mancozeb, or Ridomil plus in 1990 and to maneb or mancozeb in 1991. In Bansoa, however, significant increase in yields was obtained in plots receiving maneb, mancozeb, cupric hydroxide, or Ridomil plus protection in the 1991 season whereas, in the previous season, a significantly high increase in yields was only recorded in plots under maneb or mancozeb protection (Table 2).

In Dschang, mean yield in the first season was 19,535 kg/ha in control plots while in sprayed plots, the yields were in a range of 20,117-24,192 kg/ha. In the second season, the yields dropped to 9.482 kg/ha in control plots and to 11,334-13,631 kg/ha in sprayed plots. In Bansoa, mean yield in the first season was 24,929 kg/ha in control plots and was ranged 25,655-29,560 kg/ha in sprayed plots. In the second season, the yields dropped to 10,695 kg/ha in control plots and to 13,164-23,061 kg/ha in sprayed plots. Yields obtained in plots sprayed with fosetyl-Al in both locations were not significantly different from the control in the 1990 season (Table 2).

In the 1990 season, the proportion of marketable yields increased significantly in plots sprayed with mancozeb or Ridomil plus in Dschang and in those sprayed with maneb, mancozeb, cupric hydroxide, or Ridomil plus in Bansoa. In the following season, tubers harvested in plots exposed to fungicide treatments had significantly higher proportion of marketable tubers than the control (Table 2).

Yield losses in non protected plots were calculated as the difference between the plot yield and the highest yield for the location. In the 1990 season, yield losses in control plots were 18.1% in Dschang and 15.7% in Bansoa, while in the 1991 season, they were 30.4% in Dschang and 53.6% in Bansoa.

In order to quantify the effect of disease on yield, total yields were regressed on k or AUDPC using a linear or power equation. The best regression, based on R^2, was obtained with AUDPC in a power equation. In 1990, yields (Y in ton/ha) were predicted by the equations: $Y = 33.11 * AUDPC - 0.44$ ($R^2 = 0.51$, $P = 0.001$) in Dschang, and $Y = 36.31 * AUDPC - 0.42$ ($R^2 = 0.74$, $P = 0.0001$) in Bansoa. In 1991, the yields were predicted by the equations: $Y = 53.7 * AUDPC - 0.59$ ($R^2 = 0.30$, $P = 0.03$) in Dschang, and $Y = 69.2 * AUDPC - 0.67$ ($R^2 = 0.80$, $P = 0.0001$) in Bansoa.

4. Discussion

In Cameroon, cultivar Romano is resistant to late blight but very susceptible to early blight (4). Late blight lesions were only detected in the field during harvest.

The severity of early blight depended on the year, the location of the experiment, and the fungicide used. Though climatic conditions and overall k ratings were similar in both seasons, early blight was more severe in Dschang than in Bansoa. Moreover, in either location, plots set in 1991 had a higher disease pressure than those planted in 1990. Total yields obtained in the 1991 season were, therefore, lower than those recorded earlier in 1990 and yield losses in control plots were higher in 1991 than in 1990. Plots used in both years were established on the same piece of land and the significant increase in blight severity could be due to a higher level of initial disease in the second season. This suggested that there was some spread of inoculum from the previous season since the pathogen is known to overseason on crop debris and in soil (18,19). Shtienberg and Fry (16) reported that the history of potato production and the immediate preceding crop affect the earliness of early blight appearance. However, they did not report whether such earliness contributed to higher blight severities or lower yields.

There was a significant reduction in epidemic rate and AUDPC in sprayed plots. Both k and AUDPC were used to monitor yields. Tuber yields were better correlated to AUDPC than to k. This suggests that AUDPC is more useful to quantity fungicide effects than epidemic rate. In many epidemics, AUDPC was reported to be more reliable than k or disease severity to quantify the effects of fungicide or general resistance (5,7,14).

Although plots receiving six weekly applications of maneb, mancozeb, or cupric hydroxide produced significant reductions in AUDPC's, the efficiencies of early blight control recorded in these plots were lower than those obtained in plots exposed to two 3-weekly applications of Ridomil plus or three biweekly applications of fosetyl-Al. The highest efficiency of fungicidal control was obtained in plots treated with Ridomil plus. Only two applications of Ridomil plus were as effective in improving yields as six applications of the contact fungicides (maneb, mancozeb, cupric hydroxide). Ridomil plus (a prepackaged mixture of 12% metalaxyl and 60% cuprous oxide) will also control late blight infections in potato (13). Shtienberg and Fry (15) reported that reduced-sprays scheduling produced higher percent blight control per application than the conventional weekly spray method. Research has shown that proper timing of initial application requires relatively few fungicidal applications for early blight control (2,15,18,19).

In the western highlands of Cameroon, early blight is the second most important fungal disease of potato after late blight (4). Zachman (19) reported that the same fungicides used in late blight protection would also control early blight in potato. Protectant fungicides such as dithiocarbamates, fentin hydroxide, captafol, or chlorothalonil, have been recommended on early blight in potato (9,18,19). All fungicides used in this study had potential control for early blight. The fungicides increased both tuber weight and improved both total yields and the proportion of marketable tubers.

In both locations, six applications of maneb or mancozeb provided the best yield improvement than three sprays of fosetyl-Al although the latter fungicide had a better efficiency of disease control. Yields obtained in fosetyl-Al-sprayed plots were not significantly different from those obtained in unsprayed plots. Fosetyl-Al is not recommended on early blight control (18), although growers in Cameroon use it early and late blights of potato.

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