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# Effect of co-formulated fungicides on late blight management in seed and ware potatoes

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**Abstract.** Late blight caused by *Phytophthora infestans* (Mont.) de Bary is the most important potato disease in Cameroon. Three co-formulated fungicides (Anteor Super, Galben Plus and Ridomil Plus) were evaluated in 2000 for efficacy in suppressing late blight development in seed and ware potato fields. The trial was conducted at Upper-Farm, Bambui (2000 masl). A randomised complete block design was used with four replicates. Three potato varieties (Desirée, Cipira and Tubira) were treated twice with the fungicides at manufacturers' recommended rates. The first treatments were applied at the appearance of the first late blight symptoms (35 DAP) and the second sprays were applied 21 days later. Control plots were not sprayed. Late blight severity varied with fungicide treatment and variety. Low disease intensities and high seed and ware potato yields were obtained in sprayed plots. The highest yields and net returns were obtained generally in plots treated with Ridomil Plus, followed by Galben Plus. Tuber yields and net returns from fungicidal control varied with fungicidal treatments and variety. Ridomil Plus was the most profitable fungicide, while Anteor Super was the least. Net returns to Ridomil Plus applications varied from US$ 1,649.27 to 6,949.27/ha for seed potatoes and US$ 1,400.70 to 2,494.98/ha for ware potatoes. Results show that the co-formulated fungicides used have a potential to suppress potato late blight severity and increase seed and ware potato yields and consequently net farm incomes.

## Introduction

Potato (*Solanum tuberosum* L.) plays an important socio-economic role because of its high productivity and nutritional quality (Hakiza, 1999). It is currently the fourth largest food provider in the world, after cereal crops like maize, rice and wheat. World potato production in 2002 was estimated at 308 million metric tons produced on 19 million hectares of land (FAOSTAT, 2003). Africa accounts for only 4% of this production on 6% of total world hectarage (FAOSTAT, 2003). Of the 34 African potato producing countries yield in, 22 is less than 10 t/ha and this is attributed to biotic and abiotic constraints (Hakiza, 1999). The most important biotic constraint of potato production in the world is late blight, caused by *Phytophthora infestans* (Mont.) de Bary. It limits the potential of the crop in fulfilling its role as a global food provider.

Five promising potato varieties were released in Cameroon in 1992 (Martin *et al.*, 1995) and about 37 metric tons of sprouted basic seed tubers were distributed to more than 735 farmers (Deffo *et al.*, 1998). Two of the five varieties, Cipira (CIP 381381.13) and Tubira (CIP 381406.6), were widely adopted by potato farmers (Deffo *et al.*, 2003) for their high productivity and resistance to late blight. However, the level of late blight resistance in both varieties has been decreasing in recent years (Demo *et al.*, 1999; Fontem and Tsopmbeng, 2003; Njualem *et al.*, 2001). Consequently, farmers started using

fungicides intensively and indiscriminately to control this disease (Fontem and Tsopmbeng, 2003; Fontem *et al.*, 1998). Studies conducted in the western highland agro-ecological zone of Cameroon revealed that two applications of a co-formulated fungicide, Ridomil Plus (12 % metalaxyl + 60 % copper oxide), at a relatively low rate are more effective in late blight management than six weekly applications of contact fungicides, such as maneb, mancozeb or cupric hydroxide (Fontem and Aighewi, 1991; 1993). Further studies also indicated that two applications of Ridomil MZ (12 % metalaxyl + 60 % mancozeb) or Ridomil Plus were effective in potato late blight management (Fontem, 1995a,b; 2001; Fontem *et al.*, 2001a). Samoucha and Cohen (1989) also reported that co-formulations of systemic and contact fungicides are more effective in reducing potato late blight severity than the individual fungicide components.

The main purpose of this study was to assess the effects of the applications of co-formulated fungicides, Anteor Super, Galben Plus and Ridomil Plus, on late blight severity and yield of seed and ware potatoes.

## Materials and Methods

**Trial site.** Two field experiments were conducted at Upper Farm (10.04'E, 6.07'N, 2000 masl) in the North West province of Cameroon during May to August 2000. The site has a yearly rainfall of 1760 mm, a mean temperature of 12.3 °C and a total sunshine of about 1900 h. The major soil types are ferrous soils on slopes and hydromorphic soils in valleys.

**Experimental design and cultural practices.** The experimental design used for each trial was a 3 x 4 factorial involving three potato varieties (Desirée, Cipira and Tubira) and four fungicide treatments (Anteor Super, Galben Plus, Ridomil Plus and an unsprayed control) in four randomised complete blocks. A 2-m potato free zone separated experimental units from each other to avoid possible interactions. Experimental units consisted of four ridges of 3m long. Multiple sprouted tubers, each 50 g, of two late blight tolerant potato varieties (Cipira and Tubira) and a susceptible variety (Desirée) were planted on 6 May 2000. Plants were spaced 1.0 x 0.3 m, giving a plant density of 33,333 plants/ha. A fertiliser formulation of 60-180-100 of N, $P_20_5$ and $K_20$ from urea, triple super phosphate and potassium nitrate was applied at 720 kg/ha during planting. Urea was applied at 130 kg/ha during earthing up (36 days after planting, DAP). Plots were weeded during second earthing up at 50 DAP.

Fungicide protection was applied using a Solo knapsack sprayer (Solo Kleinmotoren GmbH, Sindelfingen, Germany) that delivers about 800 L/ha at a maximum pressure of 4 kg/cm$^2$ using a single flat fan nozzle. Three fungicides were applied at the first appearance of late blight symptoms (35 DAP). Plots were sprayed twice with Anteor Super, Galben Plus and Ridomil plus or left unsprayed (control). The first treatment was applied at first foliar symptoms; while the second was applied 21 days later (56 DAP). All treatments were applied at manufacturers' recommended rates (Table 1). The trial was carried out under nature inoculum. Late blight severity (proportion of leaf area diseased) was assessed at weekly intervals on five randomly selected plants in the centre rows of each plot using a modified Horsfall-Barratt (Berger, 1980) rating scale. Disease assessment were made weekly from the time the first foliar late blight symptoms were observed. A total of nine and eight assessments were made for ware potato and seed potato plots respectively. The Horsfall-Barratt severity ratings were converted to disease proportions with the conversion tables of Redman *et al.* (1967). Values for standardised area under disease-progress curves (SAUDPC) were calculated from the severity data according to the formula used by Campbell and Madden (1990).

Tubers in each inner rows of each plot were hand-harvested at 84 DAP for the seed production trial and 104 DAP for the ware potato production trial. Seed tubers were sorted and graded into grades I (tuber size ≤

Table 1: Fungicide treatments used for late blight protection in potato.

| Fungicide | Formulation | Active ingredients | Rate (kg/ha) |
|---|---|---|---|
| Anteor Super | 49.6 WP | 9.6% cymoxanil + 40% copper metal | 3.0 |
| Galben Plus | 78 WP | 18% benalaxyl + 60 % copper metal | 2.5 |
| Ridomil plus | 72 WP | 12% metalaxyl + 60% copper oxide | 2.5 |

25 mm diameter), II (tuber size 25 to 55 mm) and III (tuber size ≥ 55 mm). Ware tubers were also sorted but after discarding diseased tubers, healthy ones were graded into marketable (tuber weight ≥ 20g) and unmarketable (tuber weight < 20g) tubers. For both potato types, tubers in each grade were counted and weighed. All tuber yields were expressed in t/ha of fresh weight.

**Economic Appraisal of Fungicidal Control**. Economic analyses were computed for costs and returns to the different fungicidal treatments for both seed and ware crops as suggested by Horton (1982). The same cost items were considered for different cultural techniques carried out on the different fungicide treatment plots. What differed between the treatments was the cost of the fungicides used and their application. During a storage period of about seven months prior to planting, seed yields registered a weight loss of about 30% for grade II tubers and 60% for grade I tubers. Consequently, a seed weight of 70% or 40% of the initial seed weight was considered for both seed categories, respectively.

Total returns were the value of the seed or ware potato yield obtained in each treatment. A unit farm gate price of $ 1.43/kg for grade I tubers, $ 0.71/kg for grade II tubers and $ 0.14/kg for grade III tubers was applied on seed yields to estimate the total returns. For ware potato returns, a unit price of $ 0.14/kg was used for marketable tubers and $ 0.03/kg for unmarketable tubers. The cost of each fungicide and its application was also assessed. The cost of applying the fungicide with a knapsack sprayer was estimated at US$ 15/ha (US$ 5.0/manday x 3 mandays/ha).

Returns for the tuber grades were obtained by multiplying the yield of each fungicidal treatment by its farm gate price. The net return (NR) for each fungicide treatment was obtained by deducting total cost (TC) of fungicide protection from total return (TR), NR = TR-TC. Increase in net returns due to fungicide application in seed or ware potato farms was assessed by deducting the net return from the unsprayed plot from that obtained in sprayed plots to determine the most economically efficient fungicide spray regime.

**Data analysis**. Disease and yield data were analysed by analysis of variance (ANOVA) using an MSTAT-C statistical package (Michigan State University) and their means separated using the Duncan multiple range test at p = 0.05. Correlation analyses were performed between the SAUDPC and yield variables of seed and ware potatoes to determine the relationship between late blight severity and yield components. Economic analyses were performed for fungicidal control of potato late blight for both seed and ware potatoes. The fungicide treatment that yielded the highest increase in net return for seed or ware potato production was generally recommended for use by farmers.

## Results

**Late blight severity.** The first detection of late blight symptoms was recorded four weeks after planting on the lower leaf canopies of the three varieties and the severity progressed towards the upper leaf canopies. Disease progress into the upper leaf canopies was faster on Desiree than on Cipira or Tubira.

An analysis of variance revealed highly significant ($p<0.001$) varietal and fungicide effects on standardised area under disease-progress curve (SAUDPC) for both seed and ware potato fields. However, variety x fungicide interaction effects on disease severity were not significant ($p>0.05$) for both fields. Late blight was generally less severe in the seed potato field than in the ware potato field most likely because the former was harvested earlier than the latter.

Desirée was more susceptible to late blight than Cipira and Tubira in both seed and ware potato fields. The resistance level of Cipira and Tubira to late blight was not significantly different in the seed potato field (Table 2). Late blight was most severe in unsprayed control plots in both fields. Within the sprayed plots, SAUDPC values were lower on plots treated with Ridomil Plus than on those treated with Galben Plus or Anteor Super (Table 2).

**Effect of fungicide treatments on seed yield and yield components**. Potato yields included total and marketable or graded yields, while yield components were tuber number and tuber weight. An analysis of variance for potato seed tuber yield data revealed significant ($p\leq0.01$) variety x fungicide interactions for total yield, yield of grade II tubers and tuber number, while the interactions were not significant ($p>0.05$) for tuber weight and grades I and III seed tuber yields (Table 3). A significant increase in tuber weight was recorded in fungicide sprayed plots.

Total seed yield of the three varieties increased significantly with all fungicide treatments. Generally, the highest total yields for the three varieties were obtained in plots exposed to Ridomil Plus sprays and the lowest one on the unsprayed control plot (Table 4). Except for Tubira where Ridomil Plus-treated plants had the highest grade II yields, fungicide treatments did not generally affect the yields of this size of tubers. Conversely, except for Desirée where fungicide treatment did not significantly affect tuber number, this variable increased significantly with fungicide treatments for Cipira and Tubira (Table 4).

Table 2: Main effects of varieties and fungicides on standardised area under disease progress curve (SAUDPC) in seed and ware potato fields.

| Main effects | Seed potatoes | Ware potatoes |
|---|---|---|
| Varieties | | |
| Désirée | 0.214 a* | 0.315 a |
| Cipira | 0.157 b | 0.234 b |
| Tubira | 0.139 b | 0.201 c |
| Fungicides | | |
| Unsprayed Control | 0.230 a | 0.324 a |
| Anteor Super | 0.167 b | 0.257 b |
| Galben Plus | 0.161 b | 0.240 b |
| Ridomil Plus | 0.123 c | 0.180 c |

*Means in a column for the same main effect followed by the same letters are not significantly different according to Duncan's multiple range test ($p = 0.05$).

**Effects of fungicides on ware potato yield and yield components**. The effects of fungicide treatments on ware potato yields are presented in Table 5. Unlike in seed potatoes, significant variety x fungicide interaction effects were noted for all the yield variables of ware potatoes. Consequently, the effects of the fungicide treatments differed according to the variety used. The highest total and marketable yields of each variety were recorded in Ridomil Plus sprayed plots. Except for Tubira where Galben Plus treated plots out-yielded Anteor Super-sprayed plots, Desirée and Cipira plots treated with both fungicides had significantly similar yields, tuber weight and tuber number (Table 5).

**Correlations between late blight severity and potato yields**. SAUDPC values were negatively correlated with seed and ware potato yields and yield components (Table 6). For seed potatoes, the correlations were highly significant ($p<0.001$) for tuber number, grade II tuber yields and total yields, and significant ($p\leq0.05$) for grade III tuber yields, while correlations with seed tuber weight and

grade I tuber yields were not significant. Similarly, for ware potatoes, highly negative ($p<0.001$) correlations were obtained between SAUDPC and tuber number, marketable yields or total yields, and significant ($p\leq0.05$) for tuber weight (Table 6).

**Economic analysis of fungicide control of potato late blight**. The costs of the fungicides needed to protect a hectare of seed and ware potatoes against late blight are shown in Table 7. Three mandays were needed to spray a hectare of seed or ware potato farm with each

Table 3: Main effects of varieties and fungicides on seed tuber weight and yield of grades I and III tubers.

| Treatments | Tuber weight (g) | Seed tuber yield (t/ha) | |
|---|---|---|---|
| | | Grade I | Grade III |
| Varieties | | | |
| Désirée | 43.0 a* | 0.29 b | 1.81 b |
| Cipira | 30.9 b | 0.86 a | 3.22 a |
| Tubira | 36.4 ab | 0.43 b | 1.11 b |
| Fungicides | | | |
| Unsprayed Control | 29.0 c | 0.63 a | 0.60 c |
| Anteor Super | 37.8 b | 0.49 a | 1.95 bc |
| Galben Plus | 35.5 b | 0.67 a | 2.03 b |
| Ridomil Plus | 44.7 a | 0.33 a | 3.60 a |

*Means for the same main effect followed by the same letters in each column are not significantly different according to Duncan's multiple range test (p = 0.05). Tuber size was ≤ 25 mm in diameter for grade I and ≥ 55 mm for grade III.

Table 4: Effect of fungicide protection on seed potato yields at Upper Farm, Cameroon.

| Variety | Fungicide | Total seed yield | Grade II tuber yield (t/ha) | Tuber number |
|---|---|---|---|---|
| Desirée | Unsprayed Control | 12.9 b | 11.8 a | 9.1 a |
| | Anteor Sup. | 13.4 b | 11.6 a | 8.0 a |
| | Galben Plus | 15.1 ab | 13.4 a | 9.2 a |
| | Ridomil Plus | 18.3 a | 14.5 a | 7.4 a |
| Cipira | Unsprayed Control | 13.7 b | 12.1 a | 12.2 b |
| | Anteor Sup. | 18.4 a | 14.2 a | 13.9 ab |
| | Galben Plus | 23.1 a | 17.9 a | 14.5 ab |
| | Ridomil Plus | 22.9 a | 17.8 a | 15.5 a |
| Tubira | Unsprayed Control | 13.3 c | 12.4 c | 10.4 c |
| | Anteor Sup. | 20.5 b | 19.4 ab | 13.6 b |
| | Galben Plus | 18.0 bc | 16.8 b | 13.6 b |
| | Ridomil Plus | 28.6 a | 25.7 a | 17.5 a |

*Means in a column for each variety followed by the same letters are not significantly different according to Duncan's multiple range test (p = 0.05). Tuber size was 25 – 55 mm in diameter for grade II.

fungicide. Ridomil Plus was the most costly fungicide, while Anteor Super was the least. Seed tubers are usually stored for up to 7 months under diffuse light conditions before sale because they would have to pass through a dormancy period and develop sprouts before planting. Ware potatoes and grade III (large) seed tubers are sold directly after harvest and no weight loss is considered for them. Grade III seed tubers were sold at harvest at $ 0.14/ kg as ware potatoes since large tubers are less efficient in converting their unit weight in tuber yield than smaller ones. However, seed grades I and II were sold at $ 1.43/kg and $ 0.71/kg, respectively. Ware potatoes were graded into marketable (tuber wt ≥20 g) and unmarketable (tuber wt < 20 g) tubers and sold respectively at $ 0.14/kg and $ 0.03/kg.

The returns to fungicide treatments in seed potatoes are presented in Table 8. The economic benefits of fungicide application depended on the variety planted. Net returns in sprayed plots varied from $ 6,142.85 to 13,363.56/ha. Ridomil Plus was the most

Table 5: Effect of fungicide protection on ware potato yields at Upper Farm, Cameroon.

| Variety | Fungicide | Total yield (t/ha) | Marketable yield (t/ha) | Tuber weight (g) | Tuber number |
|---|---|---|---|---|---|
| Désirée | Unsprayed control | 13.6 c* | 12.9 b | 35.9 b | 11.6 a |
| | Anteor Super | 16.4 b | 14.5 b | 39.1 b | 12.2 a |
| | Galben Plus | 17.2 b | 15.7 b | 44.2 b | 11.2 a |
| | Ridomil Plus | 25.3 a | 23.3 a | 60.3 a | 12.5 a |
| Cipira | Unsprayed control | 17.0 b | 14.9 b | 29.6 a | 16.5 b |
| | Anteor Super | 20.5 b | 19.0 b | 37.6 a | 16.5 b |
| | Galben Plus | 19.9 b | 18.8 b | 32.5 a | 17.8 b |
| | Ridomil Plus | 29.5 a | 28.4 a | 36.0 a | 26.0 a |
| Tubira | Unsprayed control | 14.2 d | 13.4 c | 30.8 b | 14.2 b |
| | Anteor Super | 18.6 c | 17.7 c | 38.3 b | 14.0 b |
| | Galben Plus | 27.1 b | 26.4 b | 37.0 b | 22.3 a |
| | Ridomil Plus | 32.6 a | 31.7 a | 51.4 a | 19.1 ab |

*Means in a column for each variety followed by the same letters are not significantly different according to Duncan's multiple range test (p = 0.05).

Table 6: Correlations between SAUDPC and yield variables for seed and ware potatoes.

| Character | Seed grade | Seed potatoes | Ware potatoes |
|---|---|---|---|
| Tuber number | | -0.55*** | -0.52*** |
| Tuber weight | | -0.24ns | -0.32* |
| Tuber yield | Grade I | -0.15ns | - |
| | Grade II | -0.67*** | - |
| | Grade III | -0.38* | - |
| Marketable yield | | - | -0.82*** |
| Total yield | | --0.71*** | -0.81*** |

Significant at *** p = 0.001 or * p = 0.05, ns = non significant.
*Seed tuber sizes were ≤ 25 mm for grade I, 25 – 55 mm for grade II and ≥ 55 mm for grade III.

efficient treatment for Desirée and Tubira, while Galben Plus was the most efficient for Cipira. The most cost-effective combination was Tubira-Ridomil Plus, followed by Tubira-Anteor Super and Cipira-Galben Plus treatments. The use of Anteor Super on Desirée resulted in negative returns (Table 8).

The returns to fungicide treatments in ware potatoes are presented in Table 9. The highest increase in net returns was obtained with Ridomil Plus sprayed plots of all varieties, followed by Galben Plus on Desirée or Tubira or Anteor Super on Cipira. Tubira–Ridomil Pus treatment was the most cost effective combination for ware potatoes (Table 9).

## Discussion

Late blight was most severe in unsprayed plots than in sprayed plots. Desirée was the most susceptible variety, while Cipira and Tubira had the same level of disease resistance. Ridomil Plus was consistently the most effective fungicide for seed and ware potatoes, followed by Galben Plus and Anteor

Table 7: Cost of fungicides used in the production of one hectare of potato.

| Fungicide | Quantity (kg/ha)(a) | Unit cost (US $)(b) | Number of applications (c) | Labour for application (d) | Total cost [(axbxc) + d] |
|---|---|---|---|---|---|
| Anteor Super | 3 | 12.15 | 2 | 15.00 | 87.90 |
| Galben Plus | 2.5 | 20,00 | 2 | 15.00 | 115.00 |
| Ridomil Plus | 2.5 | 21,43 | 2 | 15.00 | 122.15 |

NB: All costs are in US $/ha, 1 US $ = 700 FCFA.

Table 8: Economic analysis for fungicidal control of late blight in one hectare of seed potatoes.

| Variety | Fungicide | Fungicide cost (TC) | Returns per tuber grade* | | | Total return (TR) | Net return (TR-TC) | Increase in NR |
|---|---|---|---|---|---|---|---|---|
| | | | I | II | III | | | |
| Desirée | Control | 0 | 171.43 | 5,857.14 | 114.28 | 6,142.85 | 6,142.85 | - |
| | Anteor Sup. | 87.90 | 171.43 | 5,785.71 | 214.28 | 6,171.42 | 6,083.52 | - 59.33 |
| | Galben Plus | 115.00 | 228.57 | 6,714.28 | 42.85 | 6,985.70 | 6,870.70 | 727.85 |
| | Ridomil Plus | 122.15 | 114.28 | 7,285.71 | 514.28 | 7,914.27 | 7,792.12 | 1,649.27 |
| Cipira | Control | 0 | 742.86 | 6,071.43 | 42.85 | 6,857.14 | 6,857.14 | - |
| | Anteor Sup. | 87.90 | 514.29 | 7,071.42 | 514.29 | 8,100.00 | 8,012.10 | 1,154.96 |
| | Galben Plus | 115.00 | 628.57 | 8,928.57 | 600.00 | 10,157.14 | 1,0042.14 | 3,185.00 |
| | Ridomil Plus | 122.15 | 171.43 | 8,928.57 | 685.71 | 9,785.71 | 9,663.56 | 2,806.42 |
| Tubira | Control | 0 | 171.43 | 6,142.86 | 100.00 | 6,414.29 | 6,414.29 | - |
| | Anteor Sup. | 87.90 | 228.57 | 9,714.28 | 114.28 | 10,057.13 | 9,969.23 | 3,554.94 |
| | Galben Plus | 115.00 | 342.86 | 8,285.71 | 85.71 | 8,714.28 | 8,599.28 | 2,184.99 |
| | Ridomil Plus | 122.15 | 285.71 | 12,857.14 | 342.86 | 13,485.71 | 13,363.56 | 6,949.27 |

NB: All costs and returns in US $/ha; US$1.00 = 700 FCFA. Seed prices were $ 1.43/kg for grade I tubers, $ 0.71 for grade II tubers and $ 0.14 for grade III tubers.
*Tuber size = ≤ 25 mm in diameter for grade I, 25 – 55 mm for grade II and ≥ 55 mm for grade III.

Table 9: Economic analysis for fungicidal control of late blight in one hectare of ware potatoes.

| Variety | Fungicide | Fungicide cost (TC) | Returns per tuber grade | | Total return (TR) | Net return(TR-TC) | Increase in NR |
|---|---|---|---|---|---|---|---|
| | | | < 20 g | > 20 g | | | |
| Desirée | Control | 0 | 20.00 | 1,842.86 | 1,862.86 | 18,62.86 | - |
| | Anteor Sup. | 87.90 | 25.71 | 2,071.43 | 2,097.14 | 20,09.24 | 146.38 |
| | Galben Plus | 115.00 | 14.29 | 2,242.86 | 2,257.15 | 21,42.15 | 279.29 |
| | Ridomil Plus | 122.15 | 57.14 | 3,328.57 | 3,385.71 | 3,263.56 | 1,400.70 |
| Cipira | Control | 0 | 31.43 | 2,128.57 | 2,160.00 | 2,160.00 | - |
| | Anteor Sup. | 87.90 | 42.86 | 2,714.29 | 2,757.15 | 2,669.25 | 509.25 |
| | Galben Plus | 115.00 | 31.43 | 2,685.71 | 2,717.14 | 2,602.14 | 442.14 |
| | Ridomil Plus | 122.15 | 31.43 | 4,057.14 | 4,088.57 | 3,966.42 | 1,806.42 |
| Tubira | Control | 0 | 22.86 | 1,914.29 | 1,937.15 | 1,937.15 | - |
| | Anteor Sup. | 87.90 | 148.57 | 1,914.29 | 2,062.85 | 1,974.95 | 37.80 |
| | Galben Plus | 115.00 | 20.00 | 3,771.43 | 3,791.43 | 3,676.43 | 1,739.28 |
| | Ridomil Plus | 122.15 | 25.71 | 4,528.57 | 4,554.28 | 4,432.13 | 2,494.98 |

NB: All costs and returns in US $/ha; US$1.00 = 700 FCFA. Tuber prices were $ 0.14/kg for size ≥ 20 g and $ 0.03/kg for < 20 g.

Super. The differences in the performance of these fungicides could be due to either the different systemic active ingredients which are metalaxyl for Ridomil Plus, benalaxyl for Galben Plus, and cymoxanil for Anteor Super or to the differences in percentage of protectant copper oxide (60, 60 or 40, respectively). Although Ridomil Plus was the most effective fungicide, metalaxyl resistant isolates of *P. infestans* have recently been reported in Cameroon (Fontem *et al*., 2001b), suggesting that resistance to this fungicide can be expected in future. However, these results show that Ridomil Plus is still the best available treatment against late blight. Galben Plus was inferior to Ridomil Plus, but was efficient on Cipira seed production. Anteor Super may not be suitable especially on Desirée, where negative returns were obtained.

Tuber number, total yield and grade II seed tuber yields were highly negatively significantly correlated to SAUDPC, suggesting that the higher the disease intensity on potato, the lower the above-yield components. The highest seed and ware potato yields were obtained in plots treated with Ridomil Plus, indicating that this fungicide was more effective than the two other fungicides. It is important to note that overall yield results from multiplicative effects of mean tuber number and mean tuber weight (Mendoza, 1995). It appears, therefore that these two components play a major role in the superior performance of Cipira and Tubira. Both varieties had a significantly higher mean tuber number than Desirée, although the mean tuber weight for Desirée was significantly higher than those of Cipira or Tubira. Since tuber number and weight were highly linked to disease pressure in the field, then a mean number of 15 to 18 tubers of 50 – 60 g would provide a potential yield of 30 t/ha or more (Mendoza, 1995).

Although Ridomil Plus was more costly than Galben Plus or Anteor Super, it significantly provided the highest returns in seed and ware potato crops. However, Galben Plus registered the highest increase in net return for Cipira ($ 3,185.00/ha), closely followed by Ridomil Plus ($ 2,806.42/ha). Consequently a farmer who treats his/her farm with Ridomil plus may have an increase net return ranging from $ 1,649.27 to 6,949.27/ha

for seed potato or $ 1,400.70 to 2,494.98/ha for ware potato depending on the variety used. Moreover, a farmer who treats his/her farm with Galben Plus, may register an increase in net return between $ 727.85 and 3,185.00 for seed potatoes or $ 279.29 and 1,739.28 for ware potatoes. These returns are similar to those reported earlier for the susceptible potato variety (Fontem, 2001).

## Conclusion

This study shows that late blight is significantly more severe in unsprayed potato plots than in fungicide-sprayed seed or ware potato plots. Although a significant reduction in late blight severity with subsequent improvement in seed and ware potato yields was obtained in all the sprayed plots, these attributes varied with variety and the fungicide used. Ridomil Plus was the most cost-effective co-formulated fungicide against late blight infection in seed and ware potatoes. Results show that late blight infections may decrease potato yields and consequently net farm returns if appropriate management measures are not undertaken. Tubira produced the highest seed and ware potato yields, while Desirée produced the least.

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