Original Research Article

Efficacy of three doses of fungicide Ridomil Gold 66 WP in the control of *Phytophthora* spp., agent of cocoa tree black pod disease in Côte d'Ivoire

ABSTRACT

Black pod disease is a major constraint to cocoa production in Côte d'Ivoire. Varietal selection and fungicide treatments are the principal means of control. Fungicide Ridomil Gold 66 WP (6% Metalaxyl and 60% copper oxide) is commonly used. This study aimed at evaluating the effectiveness of three doses of Ridomil Gold 66 WP in the control of black pod disease. An experiment on the rates of this fungicide was conducted in two localities (Aboisso and Duékoué). The experimental design was a randomized complete block with four treatments, replicated four times. The treatments comprised untreated or controlled, single dose (3.3 g/l) or recommended dose, double dose (6.6 g/l) or 2×recommanded dose and triple dose (9.9 g/l) or 3×recommanded dose. All data collected were subjected to ANOVA with the test of Student and Newmann-Keuls at the 5% threshold. As result, no significant difference was observed between the treatments of the three doses of Ridomil. But, a significant difference was observed between the fungicide treatments and the control. In Duékoué, black pod rates ranged from 4.5 to 9.52% in fungicide treated plots against 33.8% in control plots. In Aboisso, black pod rates ranged from 7.11 to 13.83% for fungicide treated plots against 30.83% for the control plots. Fungicide treatments increased healthy cocoa pod yields in both localities. The yields were increased by 51.35 to 89.63% in treated plots of Aboisso and by 34.63 to 101.06% in treated plots of Duékoué. This study confirmed the efficacy of the recommended dose (3.3 g/l) of Ridomil Gold 66 WP in the management of black pod disease. Yet, even if high doses of Ridomil Gold 66 WP improved yield, it could also be led to the development of resistant strains of *Phytophthora* spp. and increase production costs.

***Keywords**: Efficacy, Dose, Ridomil Gold 66 WP, Phytophthora spp. Black pod disease*

1. INTRODUCTION

Throughout its growing range, cocoa (*Theobroma cacao* L.) production is subject to high pest pressure, including fungal attacks by the genus *Phytophthora* spp., [1]. Two main species (*P. palmivora* and *P. megakarya*) are responsible for black pod disease in Côte d'Ivoire. *P. megakarya* species are more aggressive [2, 3]. Black pod disease causes about 30 to 60% of production losses depending on the region and the absence of phytosanitary intervention [2]. Several control methods have been used against this disease. Mainly the breeding of resistant varieties and chemical control [4]. However, the use of phytosanitary pesticides remains the main control method with the application of systemic and contact copper fungicides [5, 7]. The most commonly used fungicides in cocoa production are formulated with Metalaxyl and copper oxide [5, 6, 7]. Crop protection firms and researchers proposed several formulations of these active ingredients [8; 9]. Ridomil Gold 66 WP (6% Metalaxyl and 60% copper oxide) is a systemic fungicide whose action inhibits the

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germination of *Phytophthora* spores [10]. This study aimed at evaluating the effectiveness of three doses of Ridomil Gold 66 WP in the control of black pod disease.

2. MATERIAL AND METHODS

2.1 Experimental sites

The study was carried out in two localities, where high rates of black pod disease were often recorded. Aboisso and Duékoué were selected because of their high annual rainfall (Fig. 1). This rainfall is favorable to the development of the black pod disease causal agent, *Phytophthora* spp. The plots chosen for the trials, were those soils best represented the usual cocoa growing conditions (Table 1). The minimum size of each trial plot was 1.5 hectare. The plant material was traditionally cocoa varieties. The trial was carried out in a farming environment, in orchards where cocoa trees were in production.

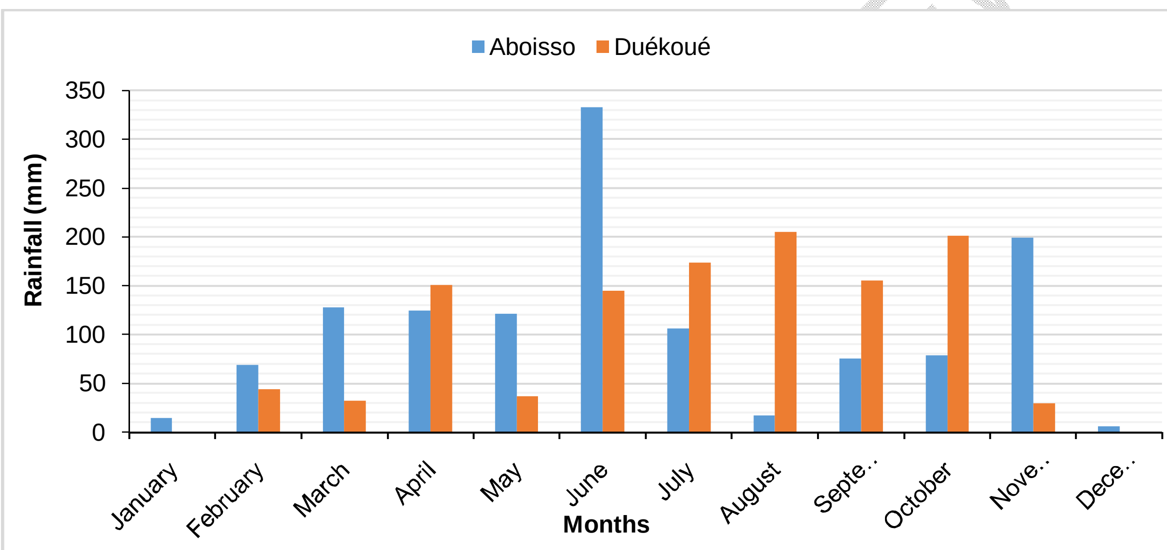

Fig. 1. Rainfall in Aboisso and Duékoué

Table 1. Organic, acid-base and nutrient status of soils from the 02 study sites

Sites	Organic status				Acid-base status		Nutrient status				
	(g kg^{-1})				Exchangeable Acidity	Current Acidity	Exchangeable bases (mgkg^{-1}) and cations exchange capacity (cmol kg^{-1})				
	C	**MO**	**N**	**C/N**	**Al^{3+}**	**pH eau**	**Ca^{2+}**	**K^+**	**Mg^{2+}**	**CEC**	**P_2O_5ass**
Aboisso	17,57	30,39	1,68	10,43	< 5	5,72	1,01	0,10	0,23	74,78	0,05
Duékoué	19,80	34,24	1,90	10,36	< 5	5,75	1,18	0,14	0,25	78,25	0,06

2.2 fungicide treatments

Three treatments of fungicide Ridomil Gold 66 WP, were done during the rainy season from Jun to November. These treatments were done with a sprayer at the rate of one application every 21 days. These fungicide treatments were applied entirely on the whole tree in order to ensure complete wetting of all pods and flower pads:
- Treatment 0: untreated or control;
- Treatment 1: 200 g / ha or a mixture ratio of 3.3 g/l (Single dose);
- Treatment 2: 400 g / ha or a mixture ratio of 6.6 g/l (Double dose);
- Treatment 3: 600 g / ha or a mixture ratio of 9.9 g/l (Triple dose).

2.3 Experimental design

The trial was set up in a randomized complete block design with four (04) repetitions in the two localities. Each block was made up of 4 elementary plots, each plot containing 25 cocoa trees or a total of 100 cocoa trees per block. On this basis, 400 cocoa trees were selected to assess the four treatments of the trial. The cocoa trees selected for the same treatment were marked with the same color.

2.4 Data collection

The observations consisted to count all categories of pods in the different plots of the trial. All remarkable pods were observed and counted once every two weeks: healthy mature pods (HMP), pods with black pod symptoms (PBP), pods with moldy rot symptoms (PMR), wilted pods (WP), and gnawed pods (GP). The data were recorded on observation sheets. These data were used to calculate the black pod disease rate (BPR) of each treated plot according to the formula:

$$\text{BPR}\ (\%) = \frac{\text{PBP}}{\text{HMP} + \text{PBP} + \text{PMR} + \text{GP}} \times 100$$

The efficiency indices of fungicides treatments were calculated by using the slopes of epidemic curved according to the formula [11]:

$$\textbf{Efficiency index}\ (\%) = \frac{\text{A} - \text{B}}{\text{A}} \times 100$$

Where: A is the slope of the control epidemic curve and B is the slope of a fungicide treatment epidemic curve.

2.5 Statistical analysis of data

Data were subjected to analysis of variance (ANOVA) using SAS software version 6.12. Student and Newman-Keuls multiple means comparison test at the 5% threshold was used for the classification of homogeneous groups.

3. RESULTS AND DISCUSSION

3.1. Effect of fungicide treatments on the evolution of black pod disease

Three doses of fungicide Ridomil Gold 66 WP were evaluated by comparing the different means rates of black pod disease observed after the treatments. The results obtained during the study in both localities (Duékoué and Aboisso) were used to represent the evolution curves of black pod disease in these two localities (Fig. 2 and Fig. 3). Disease evolution curves slopes of the treated plots were largely lower than those of untreated plots. Black pod disease rates were less than 15% in treated plots and ranged from 30 to 35% in untreated plots. In addition, the slopes of disease evolution curves of the double dose and triple dose fungicide treatments were lower than those of the single dose treatments. Increasing the

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fungicide Ridomil Gold 66 WP dose therefore leads to a significant improvement in its effectiveness.

The statistical analysis showed no significant (p=0.2307; Table 2) difference between black pod disease rates in the two localities (33.38% in Duékoué and 30.83% in Aboisso,). However, a significant difference was noted between the plots which received the fungicide treatments and the control plots. The three applied doses of the fungicide Ridomil Gold 66 WP induced a significant reduction in cocoa pods number affected by black pod disease in the treated plots compared to the control plots. In Duékoué, disease rates ranged from 4.45% to 9.52% for the treated plots compared to a rate of 33.38% for the control plots. In Aboisso, black pod disease rates ranged from 7.11% to 13.83% for treated plots and 30.83% for untreated plots (Table 3 and Table 4). Similarly, the efficacy indices of the three fungicide doses were statistically identical in each locality. Efficiency indices of the fungicide doses ranged from 70.04 to 88.02% in Duékoué and from 51.61 to 72.90% in Aboisso. In Duékoué, efficacy indices noted, were: 70.04% for the single dose, 83.84% for the double dose and 88.02% for the triple dose (Table 3). In Aboisso, efficiency indices of 51.61% were noted with the single dose, 60.64% with the double dose and 72.90% with the triple dose (Table 4).

Increasing the dose of the fungicide Ridomil Gold 66 WP (6% Metalaxyl and 60% copper oxide) resulted in a significant decrease of black pod disease rates in Aboisso and Duékoué. No significant difference was observed between the efficiency indices of the three applied fungicide doses (Single or recommended dose, double doses, and triple doses). These results corroborate those of Despreaux et al [11], who compared the effect of the standard dose with that of the double dose of the fungicide Ciba-Geigy Ridomil Plus (0.4g metalaxyl+2g cuprous oxide per liter). Berry [12] also obtained similar results with the application of Ridomil Plus 72 PM (metalaxyl + cuprous oxide) at single and triple doses. According to these authors, increasing the fungicide dose reduced the number of phytosanitary treatments by half in the reference system. However, this technique requires high quantities of fungicide (50% higher). This could lead to the development of resistant strains and environmental pollution [10]. In addition, the use of large quantities of fungicide can be very expensive for farmers [13, 14].

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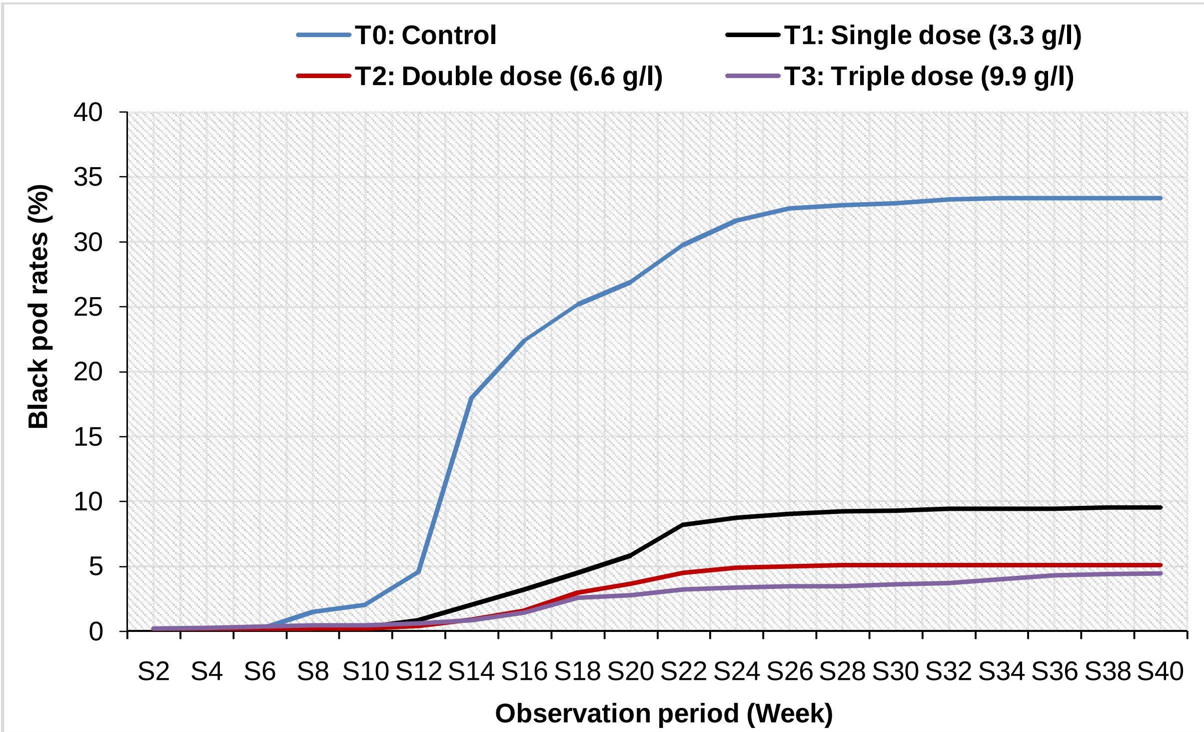

Fig. 2. Effect of treatments on the evolution of black pod disease in Duékoué locality

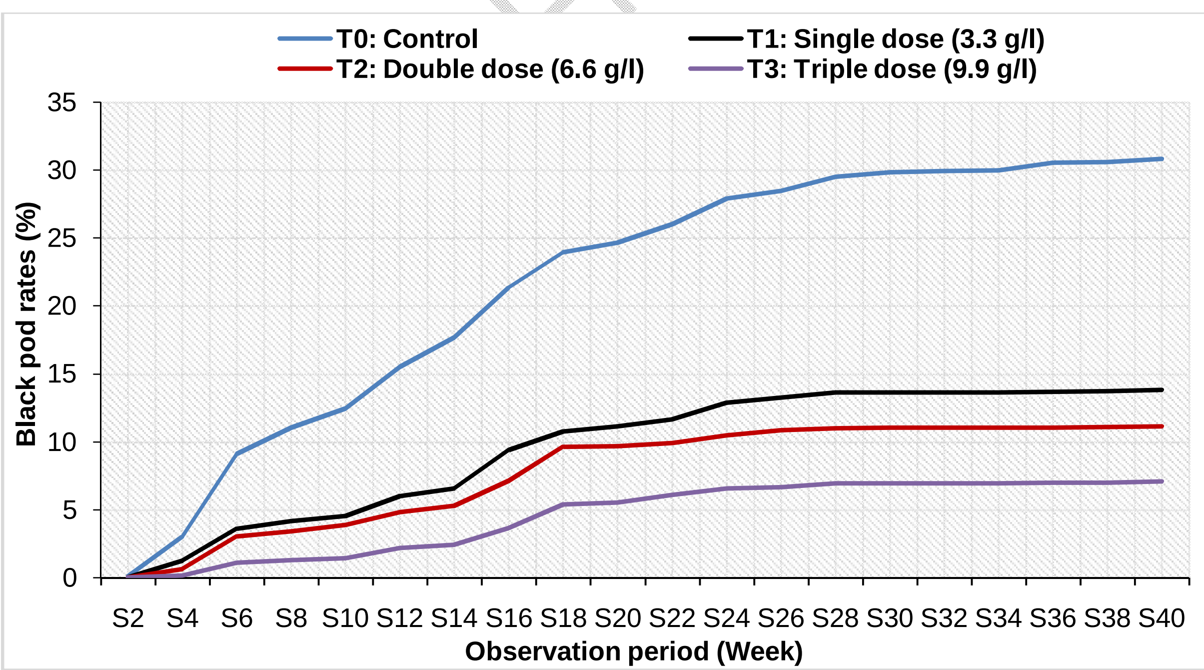

Fig. 3. Effect of treatments on the evolution of black pod disease in Aboisso locality

Table 2: ANOVA table of the black pod disease rates data collected according to the randomized complete block design

Source of variance	DF	Type III SS	Means Square	F-Values	Pr > F
Block	3	56.5341378	18.8447126	46.33	<.0001
Treatment	3	249.1837825	83.0612608	204.20	<.0001
Block*Locality	3	1.5105808	0.5035269	1.24	0.2988
Localitiy* Treatment	3	7.2069977	2.4023326	5.91	0.0008

Block (4 blocks or repetitions); **Treatment** (4 treatments: T0, T1, T2, T3); **Locality** (2 localities: Duékoué and Aboisso) p =5%

Table 3: Effect of treatments on crop losses due to black pod disease in Duékoué

Treatments	Black pod rates (%)	Epidemic curved slopes	Efficiency index (%)	Homogeneous group
T0: Control	33,38	2,17		A
T1: Single dose (3.3 g/l)	9,52	0,65	70,04	B
T2 : Double dose (6.6 g/l)	5,1	0,35	83,87	B
T3 : Triple dose (9.9 g/l)	4,45	0,26	88,02	B

Treatments affected in the same homogeneous group are not different according to Student and Newman-Keuls multiple means comparison test at the 5% threshold

Table 4: Effect of treatments on crop losses due to black pod disease in Aboisso

Treatments	Black pod rates (%)	Epidemic curved slopes	Efficiency index (%)	Homogeneous groups
T0: Control	30,83	1,55		A
T1: Single dose (3.3 g/l)	13,83	0,75	51,61	B
T2 : Double dose (6.6 g/l)	11,17	0,61	60,64	B
T3 : Triple dose (9.9 g/l)	7,11	0,42	72,9	B

Treatments affected in the same homogeneous group are not different according to Student and Newman-Keuls multiple means comparison test at the 5% threshold

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3.2. Effect of fungicide treatments on the yield of healthy cocoa pods production

In order to verify the effect of fungicide treatments on healthy cocoa pod production, production gains were evaluated based on the number of healthy pods obtained for each treatment. Results showed a significant variation in healthy cocoa pods number produced per treatments (Tables 5). All plots treated with the different doses of Ridomil Gold 66 WP produced more healthy cocoa pods 34 to 100% compared to the untreated plots (Tables 6 and 7). In Duékoué, the treatments increased pod production by 34.98% with the single dose, 71.48% with the double dose, and 101.06% with the triple dose compared to the control (Table 6). In Aboisso, pod production increased by 51.36% with the single dose, 59.17% with the double dose, and 89.63% with the triple dose compared to the control (Table 7). The use of high doses of fungicide Ridomil Gold 66 WP increased cocoa pods production in both localities. Similar results were obtained by Norgrove [15]. According to his results, the application of high doses of Ridomil Plus 72 WP fungicide increased by 2.5 times the annual yield of cocoa pods in high spray treatment than in low spray treatment. Adomako *et al*. [16], showed that a weekly application of fungicide Ridomil Plus 66 WP (12% metalaxyl-M oxide and 60% copper oxide) against taro leaf blight (a *Phytophthora* disease) increased yield by 33.0 to 44.0% compared to one application four weeks apart. Khan *et al*. [17], also showed that application of an insecticide (Methamidophos) on *Vigna radiata* L. crops, at doses of 1000 and 1250 ml/ha increased grain yield per hectare by 45% over the single recommended dose of 500 ml/ha.

Table 5: ANOVA table of healthy cocoa pod number collected according to the randomized complete block design

Source of variance	DF	Type III SS	Means Square	F-Values	Pr > F
Block	3	113719.8997	37906.6332	535.02	<.0001
Locality	1	475.7551	475.7551	6.71	0.0107
Treatment	3	5007.0799	1669.0266	23.56	<.0001
Block*Locality	3	3494.3294	1164.7765	16.44	<.0001
Localitiy* Treatment	3	149.7298	49.9099	0.70	0.5511

Block (4 blocks or repetitions); **Treatment** (4 treatments: T0, T1, T2, T3); **Locality** (2 localities: Duékoué and Aboisso) p =5%

Table 6: Effect of treatments on the production of healthy pods in Duékoué

Treatments	Total number of pods	Gain of pods	Production gain (%)	Homogeneous groups
T0: Control	852			C
T1: Single dose (3.3 g/l)	1150	298	34,97	B
T2 : Double dose (6.6 g/l)	1713	861	101,05	A
T3 : Triple dose (9.9 g/l)	1461	609	71,47	A

Treatments affected in the same homogeneous group are not different according to Student and Newman-Keuls multiple means comparison test at the 5% threshold

Table 7: Effect of treatments on the production of healthy pods in Aboisso

Treatments	Total number of pods	Gain of pods	Production gain (%)	Homogeneous groups
T0: Control	1254			C
T1: Single dose (3.3 g/l)	1996	742	59,17	B
T2 : Double dose (6.6 g/l)	1898	644	51,35	B
T3 : Triple dose (9.9 g/l)	2378	1124	89,63	A

Treatments affected in the same homogeneous group are not different according to Student and Newman-Keuls multiple means comparison test at the 5% threshold

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4. CONCLUSION

In this study the use of fungicide Ridomil Gold 66 WP at a single dose (3.3 g/l), double dose (6.6 g/l) and triple dose (9.9 g/l) was found to be efficient against black pod disease. However, no significant difference was observed between the fungicide protections obtained with the two high doses (double dose and triple dose) and the single dose according to the efficiency indices recorded. These results proved that the recommended dose (3.3 g/l) of the fungicide Ridomil Gold 66 WP is effective in the management of cocoa black pod disease. The use of Ridomil Gold 66 WP at high doses resulted in an improvement of healthy cocoa pods yield in treated plots. But the risk of development of *Phytophthora* spp., resistant strains remains high and the cost of these fungicides treatments is expensive for small cocoa farmers.

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