EFFECT OF DIFFERENT TYPES OF FUNGICIDES ON EARLY BLIGHT AND YIELD OF TOMATO

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ABSTRACT

*Early blight (*Alternaria solani*) is an important foliar disease of tomato in Papua New Guinea. A trial was conducted to evaluate four broad-spectrum fungicides for their efficacy on Early blight disease and yield of tomato. Plots treated with three contact curative fungicides; Chlorothalonil (Bravo, 50% EC, 0.15% a.i.); Mancozeb (Dithane M-45, 80% WP, 0.16% a.i.) and Copper oxychloride (Champion copper 50% WP, 0.10% a.i.) effectively reduced the intensity of Early blight and yielded significantly higher than the systemic fungicide, Benomyl (Benlate 50% WP, 0.10% a.i.) and the unprotected. Yield from Benomyl treated plots were much lower than the untreated. The yield loss in unprotected plots was estimated to be 65.3%. There was a positive relationship between coefficient of disease index (CODEX) and yield. Thus, the highest yields were obtained where the CODEX were the lowest.*

Key words: *Tomato, early blight* Alternaria solani, *fungicidal control*

INTRODUCTION

Tomato (*Lycoperiscon esculenta*. Mill) is an introduced vegetable in Papua New Guinea (PNG) where it initially was grown as a minor crop in backyard gardens. Its cultivation has now increased with available market facilities, especially near big cities and towns where the demand is high (Dodd 1979, Clarkson and Tomlison 1982).

Alternaria blight or Early blight of tomato caused by *Alternaria solani* Sarauer is the most serious disease that attacks the plant at any stage of development (Ellis and Gibson 1975; Datar and Mayee 1981; Sherif and Macnab 1986). The disease can affect the seedlings, stems, leaves and both ripe and unripe fruits. Organs at the ground level are usually affected first then the disease eventually spreads upwards. The pathogen is seed borne, spreads by wind and rain splash and survives in infected plant debris in the soil as long as three years (Basu 1971; Ellis and Gibson 1975; Howe 1983, Sherif and Macnab 1986). The disease was rated as very serious in India (Datar and Mayee 1981; Choulwar and Data 1988), in America (Sherif and Macnab 1986; Brammall 1993) and in PNG (Dodd 1979; Clarkson and Tomlinson 1982). The disease was first recorded in this country in 1963 (Shaw 1984).

The pathogen's inoculum spores can be reduced culturally by roughing and garden practice, chemically by fungicides, through quarantine by avoidance or restriction and genetically through the use of resistant or highly tolerant varieties. These varieties reported in other countries (Gardner 1988; Brammall 1993) are not available in PNG. Roughing has been reported to be effective on highly tolerant varieties (Brammall 1993). This method is not suitable for the susceptible varieties that PNG farmers are exposed to. Therefore, chemical control is seen as the most effective short term control method for aspiring farmers who grow tomatoes on a large scale near big cities where market is accessible and the disease is endemic.

Broad spectrum fungicides such as Chlorothalonil, Copper oxychloride, Mancozeb, Maneb and Captafol at manufacturers recommended rates have proved effective in Early blight control in other parts of the world (Datar and Mayee 1981; Howe 1983; Sherif and Macnab 1986, Choulwar and Datar 1988). In this country, Preston and Kowor (1988), used some of these fungicides to control Early blight on potato where the disease was very

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serious. Clarkson and Tomlinson (1983) recommended carbarnate fungicides (Maned, Zebeb abd Nabcizeb) at 150 g per 100 litres of water per hectare for the control of tomato Early blight disease in this country for large scale growers. This recommendation was made without any field trials under PNG conditions. Fungicides on the market need to be screened under local environmental conditions and only effective ones should be recommended.

Because of increased growing of tomato, the wide spread and endemic situation of the disease and the unavailability of information on effective fungicides for tomato early blight control in PNG highlands conditions, four broad spectrum fungicides were screened for their efficancy. The main objectives were to determine the best fungicides that reduce disease incidence and increase yield, to estimate the yield loss due to the disease and to predict whether there was any relationship between disease incidence/severity and yield.

MATERIALS AND METHODS

The trial was carried out at Aiyura at about 1650 m altitude. The long term average monthly rainfall between the months of April to September is between 125-140 mm. Long term average daily temperatures and relative humidity are between 20-30°C and 80-96% respectively. The soil type used was friable, clay loam and high in organic matter. The trial was planted on the 22nd of April and completed harvesting on the 2nd of September 1993.

The food variety, Grosse Lisse seeds were sown in steam sterilized soil mixture of 2:1:1 parts of top soil, chicken manure and river sand respectively. Seed trays were watered twice everyday from sowing until before transplanting. Prior to transplanting at 31 days after sowing (DAS), seedlings were hardened 3-4 hours in the afternoons under moderate sunlight for 7 days. Seedlings were planted in holes that had 20 gram of inorganic fertilizers NPK (12 parts nitrogen, 12 parts phosphorus, 17 parts potassium and 2 parts magnesium) and triple super phosphate (TRSP) were mixed in the ratio of 2:1. A 5x5 Latin square design was used for the trial. Plants were spaced at 0.6 m between plants and 1.0 m between rows. Plots and blocks were spaced at 1.5 m and 2.0 m respectively. A sample of four plants out of eight were used from each plot to assess the disease incidence and severity of leaves, fruit and yield. Plants were staked at 21 days after planting (DAP). Branches and shoots seen to be excessive were removed leaving standard two shoots per plant for fruit bearing. Weeds were removed manually by spade every week.

Foliar pests of tomato, especially larvae of Lepidoptera species, *Helicoverpa armigera* and *Spodoptera litura* were controlled by a broad spectrum insecticide (Orthene) at 3 g/L. First application was at 48 DAP, second was at 72 DAP and the third at 100 DAP. The insecticide was applied to reduce insect population in all plants.

Fungicide application

Three non-systemic and one systemic fungicides were screened for their efficacy in tomato early blight control. The systemic fungicide was Benomyl (Benlate, 50% WP, 0.1% a.i., 200 g/100 L/ha) and the non-systemic fungicides were; Chlorothalonil (Bravo, 50% EC, 0.15% a.i. 300 ml/100 L/ha), Mancozeb (Dithane M - 45, 80% WP, 0.16% a.i. 200 g/100 L/ha) and Copper oxychloride (Champion copper, 50% WP, 0.10% a.i. 200 g/100 L/ha). The fungicides were applied bi-monthly, starting first application at 29 DAP and ending 104 DAP before the last harvest. Four hand pump knapsack sprayers were used for each fungicide. The spray volume of 10 litres was increased to 15 litres at 63 DAP to compensate for the increase in foliage. Control plots were not sprayed.

Disease evaluation

Inoculation was achieved by naturally occurring inoculum. The field assessment of the disease was done first on the leaves at 83 DAP and on fruit at each picking. Pest damage on the fruits was also noted.

Leaf assessment

Four innermost plants were taken as a sample for each treatment and were assessed for the disease incidence and severity. Leaves, 70 cm from ground level were scored for early blight infection using modified disease rating scale of Singh and Shulka (1986). A scale between 0 and 4 was used, 0 for no lesions on leaves and 4 for 76-100% necrotic

area. Percent disease incidence (PDI) and percent disease severity (PDS) on the plants were determined using the formula by Datar and Mayee (1981). PDI is the number of affected plants or plant organs over the total. PDS is the extent of damage of the affected plant organ according to the above scale,
PDS vix; = where:

$$PDS = \frac{\text{Sum of ratings of leaves affected} \times 100}{\text{Number of Leaves observed} \times 4}$$

The Coeffecient of Disease Index (CODEX) was calculated to quantify the amount of infection, where:

$$CODEX = \frac{PDI \times PDS}{100}$$

Fruit assessment

Ripe fruits were first harvested at 96 DAP (27 July 1993) and continued weekly for five weeks, ending at 121 DAP (2 September, 1993).

The same two parameters used to quantify the amount of infection on leaves were used on fruits at each picking since the fungus causes severe rots on ripe fruits. Fruits were classified as marketable and non-marketable according to appearance in size and health. They were scored zero (0) for no rots and a plus (+) sign with measured diameter in centimeters of necrotic lesions for rots. A score range of 0-4 was used to group infected fruits into classes. A score of 0 was given for fruits without lesion, a score of 1 for fruits with lesion diameter between 0.1 - 1.0 cm and a score of 4 was given where the lesion diameter was greater than 3 cm. Weights of both marketable and non marketable fruits were measured with an electronic top-pan balance.

Data analysis

Fruits were divided into four groups after weighing. The groups were non-diseased and not attacked by insect pest (NDNP); non-diseased but attacked by pest (NDP); diseased but not attacked by pest (DNP) and both diseased and attacked by pest (DP). The percentage of fruits in each group was calculated. To determine the efficacy of fungicides, total yield of NDNP group of marketable fruits expressed in tonnes per hectare were compared with CODEX of both leaves and fruits. For comparisons, yield of sprayed plots were compared with unsprayed. The yiel loss was determined as the difference between the highest yield of sprayed plots and the control over the highest yield expressed in percentage. Other comparisons made were between systemic and non-systemic and the cheapest and expensive fungicide(s). The cheapest being Copper oxychloride and the most expensive being Chlorothalonil. Yield of NDNP was analysed by analysis of variance and means seperated by Duncan's multiple range test. Total NDNP yield was regressed against CODEX to quantify the effect of disease on yield.

RESULTS

Fruit

Diseased fruit caused by tomato early blight was highest in Benomyl treated plots and lowest in Chlorothalonil sprayed plots (Table 1). Non-diseased marketable fruits affected by pest was higher in the second and third harvests in all treatments and declined in the last harvest. The number of diseased marketable fruits affected by pest decreased after the first harvest in all treatments. Plots treated with Chlorothalonil and Mancozeb had substantially lower number of diseased fruits affected by pests than the other treatments in all harvests. The CODEX of fruits was higher on Benomyl treated plots in the first three harvest and decreased in latter harvests (Table 2). Generally the CODEX of fruits on Chlorothalonil and Mancozeb treated plots were lower than the other treatments.

Leaves

Benomyl and untreated plants were severely affected and therefore the CODEX measured was 100% for each treatment, followed by copper oxychloride with 73%. The CODEX score for Chlorothalonil and Mancozeb were 52% and 38% percent respectively. These measurements were done after the 5th spray schedule.

Yield

In the analysis of variance of non-diseased non-pest infested group of marketable yield, significant

Table 1. *Number of marketable and non-marketable fruits as influenced by fungicidal sprays grouped into respective classes at each harvest.*

MARKETABLE					NON MARKETABLE				
Harvest date	Treat-ments	NDNP1	NDP2	DNP3	DP4	NDNP	NDP	DNP	DP
27/7/93	A	17(46)	0	6(16)	0	3(8)	0	9(24)	2(6)
	B	43(78)	0	4(7)	0	4(7)	0	3(6)	1(2)
	C	42(82)	0	3(6)	0	1(2)	0	5(10)	0
	D	56(71)	0	5(6)	0	3(4)	0	10(13)	5(6)
	E	36(48)	0	1(1)	0	7(9)	0	25(33)	7(9)
2/8/93	A	19(38)	1(2)	5(10	1(2)	0	4(8)	14(28)	6(12)
	B	34(58)	6(10)	2(3)	0	1(2)	12(20)	4(7)	0
	C	31(49)	7(11)	4(6)	3(5)	8(13)	2(3)	6(10)	2(3)
	D	35(54)	4(6)	5(8)	0	5(8)	7(11)	7(11)	1(2)
	E	18(47)	4(11)	4(11)	2(5)	0	5(13)	4(11)	1(2)
12/8/93	A	28(27)	1(1)	13(13)	1(1)	20(19)	8(8)	26(25)	6(6)
	B	148(73)	11(5)	7(3)	0	12(6)	6(3)	8(4)	10(5)
	C	75(67)	4(4)	5(5)	3(3)	7(6)	6(5)	7(6)	4(4)
	D	71(52)	10(8)	10(8)	5(4)	12(9)	7(5)	10(8)	8(6)
	E	17(32)	2(4)	4(8)	1(2)	10(20)	3(6)	5(9)	10(19)
19/8/93	A	10(20)	0	6(12)	0	11(23)	5(10)	14(29)	3(6)
	B	48(56)	3(3)	9(10)	3(3)	6(7)	2(2)	10(12)	6(7)
	C	47(63)	3(4)	2(3)	0	7(9)	6(8)	8(10)	2(3)
	D	18(33)	1(2)	8(15)	0	7(13)	1(2)	14(46)	5(9)
	E	21(47)	1(2)	8(18)	2(4)	7(16)	2(4)	1(2)	3(7)
26/8/93	A	4(12)	0	2(6)	0	14(43)	0	12(36)	1(3)
	B	25(46)	0	7(13)	0	7(13)	4(7)	10(19)	1(2)
	C	37(63)	1(2)	5(8)	1(2)	4(7)	0	10(16)	1(2)
	D	24(43)	2(4)	8(14)	0	13(24)	0	7(13)	1(2)
	E	8(33)	1(4)	0	0	4(17)	0	10(42)	1(4)

NB: Figures in parenthesis ( ) are expressed in percentage

A: Benomyl (Benlate)
B: Chlorothalonil (Bravo)
C: Mancozeb (Ditane M-45)
D: Copper oxychloride (champion copper)
E: Control (Unsprayed)

[1] Non-diseased and not attacked by pest
[2] Non-diseased but attacked by pest
[3] Diseased and not attacked by pest
[4] Diseased and attacked by pest

Table 2. *Coefficient of Disease Index (CODEX) of fruits at each harvest, leaves at 83 DAP and the yield as influenced by fungicidal sprays.*

	Benomyl	Chlorothalonil Mancozeb		Copper oxychloride	Control
CODEX Fruits at each harvest[a]					
27/7/93	41.5	4.5	0[6]	1.5	0
2/8/93	33.0	0	0	2.4	20.7
12/8/93	24.9	2.0	1.65	9.9	7.0
19/8/93	10.9	2.5	0	12.5	2.2
26/8/93	4.2	9.3	13.4	6.6	
CODEX of leaves at 83 DAP[b]	100.0	52.0	38.0	73.0	100.0
Total NDNP[9] Marketable Yield (t/ha)	5.79b	20.98a	20.94a	18.63a	7.27b

CV 15.8%
SE of mean 0.22
SE of difference 0.31
Figures in each row followed by the same letter do not differ signnificantly according to Duncans' multiple range test.

[a] **Disease severity rating : fruits**
0 = no lesions. 1=0.1-1.0 cm lesion diameter, 2 = 1.1-2.0 cm lesion diameter.
3 = 2.1 - 3.0 cm lesion diameter, 4 = > 3 cm lesion diameter.

[6] No diseased fruit

[7] No marketable fruits

[b] **Disease severity rating : leaves**
0 = no symptoms, 1=1-25% necrotic area, 2=26-50% necrotic area, 3=51-75% necrotic area, 4= 76-100% necrotic area and death.

[9] NDNP: Non-diseased and not attacked by pest.

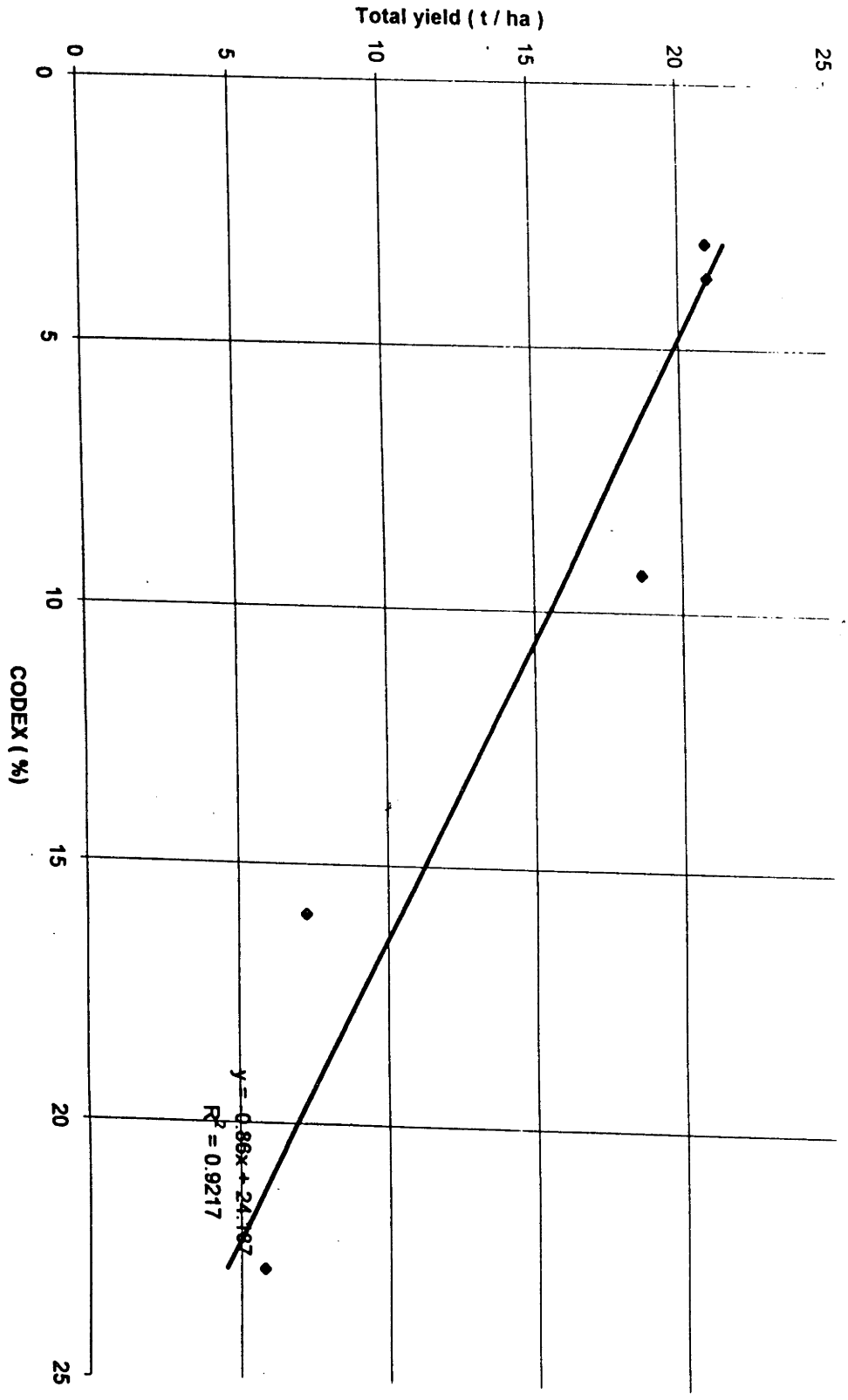

Figure 1. *Total yield (t/ha) of tomato against CODEX (%) as influenced by fungicidal sprays*

difference between treatments occurred at $p < 0.001$. Yield of treated plots, except Benomyl were significantly higher than the control (unsprayed). Yield of the contact fungicides *viz*; Chlorothalonil, Mancozeb and Copper oxy chloride were significantly higher than the systematic, Benomyl at $p < 0.001$. There was no significant difference in yield between the cheapest (copper oxy chloride) and the most expensive (Chlorothalonil) fungicides at $p < 0.001$ although there was marked difference of CODEX on leaves and fruits. Total yield was highest in Chlorothalonil treated plots with 20.98 t/ha followed by Mancozeb with 0.04 t/ha less, Copper oxychloride with 18.63 t/ha, unsprayed with 7.27 t/ha and the least being Benomyl with 5.89 t/ha (Table 2). Yield loss in non-protected plots were predicted as the difference between the control and the highest yield over the highest yield expressed in percentage. Yield loss in non protected plots in this trial was 65.3%. To quantify the effect of disease on yield, total yield (t/ha)(y) was regressed on the mean CODEX (x) of fruits. Yield (t/ha) was predicted by the equation, where: $y = 24.14 - 0.86 x$. $R^2 = 0.9217$ (Figure 1).

DISCUSSION

The tomato variety, Grosse Lisse, is very susceptible to Early blight. The disease has been reported to be very serious on tomato (M. Kanua, pers. comm) and potato (*Solanum tuberosum*) (Preston and Kowor 1988) in the Highlands of PNG. It is also reported to be serious in many other parts of the world. Although serious, conflicting reports exist on the effect of the disease on yield. In North America, control of early blight was not recommended because fruit load was established before the disease became established and thus the disease had little effect on the yield (Horsfall and Heuberger (1942). In Ontario, USA, most cultivars treated with fungicides did not improve yield although leaves were severely defoliated by Early blight (Brammall 1993). He mentioned that the local weather had an influence on the disease development. However the time blight became established and rate of subsequent disease progress were considered more important.

At Aiyura the fungicide treatments yields were significantly higher than the control except for one. Aiyura experiences annual rainfall of more than 2000 mm, average daily temperatures of between 20 - 30°C and relative humidity between 80-96%. The weather pattern here is ideal for early blight disease development and spread as reported by Ellis and Gibson (1975). Several workers have reported that fungicides have proven to reduce early blight severity and increase yield in places where they experience similar weather like Aiyura (Datar and Mayee 1981; Choulwar and Datar 1988; Preston and Kowor 1988 and Brammall 1993). Some of these workers also mentioned that under such weather regimes, proper timing of initial application of fungicides resulted in reduction of inoculum, and consequently reduced disease severity and increased yields.

In this investigation, Mancozeb, Chorothalonil and Copper oxychloride gave twice the yield of the control treatment. The fungicides were reported to be effective against Early blight disease control (Datar and Mayee 1984, Choulwar and Datar 1988). The three contact fungicides gave longer protection on the plants thus more marketable fruits were harvested in the last harvests than the systemic and control groups. By that time Benomyl and untreated plots had only a few heavily infested leaves remaining on the plants. Mancozeb and Chlorothalonil were effective in Early blight control and gave similar higher yields with Copper oxychloride being the next best. The yield loss due to early blight on tomato in this trial was estimated to be 65.3%. The yield loss estimated here is less than that observed by Datar and Mayee (1981) (78% loss) and greater than that reported by Sherif and Macnab (1986) (30% loss). There was a positive relationship between CODEX and yield. Highest yield were obtained where the CODEX were lowest indicating the efficacy of the tested fungicides.

Although Mancozeb is as effective as Chlorothalonil in controlling Early blight, tomato processors in Ontario, have questioned the regisration of Mancozeb and were not accepting tomatoes with Mancozeb which would not be recommended until it is cleared. So based on this trial, Chlorothalonil and Copper oxychloride could be recommended for Early blight control on tomato. Benomyl did not have any effect on the disease.

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