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Potential of seed treatment fungicides for the control of foliar diseases of tomato under late short growing season conditions of a tropical derived savanna

M.M. Abang [1*] and C. Iloba [1]

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Abstract
Improved adapted varieties of tomato were used to test the efficacy of prophylactic seed treatment with the fungicides benomyl and thiram, in the late short growing season of a tropical derived savanna. The blotter technique was used to evaluate the effect of the fungicides on seed mycoflora and seed germination. Laboratory tests revealed seed infection by Fusarium spp. and showed that treated seeds performed better than those of the control. Despite the high incidence and severity of Septoria leaf spot and Alternaria leaf blight in the field, the number of severely infected leaves recorded 28 days after transplanting (DAT) was significantly (P″0.01) lower in the fungicide-treated than in the control plots. The fungicides were effective in maintaining considerably lower disease levels in treated plots up to flowering. However, early differences in disease severity did not translate into yield differences, because by the time of fruit set and fruit filling disease levels were the same. Our results suggested limited translocation of fungicides in time to control polycylic infection of new growth, and emphasized the necessity to combine seed treatment with other control options. Use of seed treatment in combination with limited spraying with an appropriate fungicide could potentially reduce the high costs and hazards of frequent fungicide application in tomato grown during the wet season.

1 Introduction
Tomato (*Lycopersicon esculentum* Mill.) is day-length neutral and thus can be grown at any time of the year provided that climatic and edaphic conditions are suitable (GRUBBEN, 1977). Tomatoes grown in the southern part of Nigeria are, however, seasonal and erratic in their yield. Despite a potential for tomato production, which can be more profitable than most other agricultural enterprises, only a few local farmers engage in the activity.

[1] Department of Crop Science, University of Nigeria, Nsukka, Nigeria.
[*]Author for correspondence; Present address: German Collection of Microorganisms and Cell Cultures (DSMZ), c/o BBA, Messeweg 11/12, 38104 Braunschweig, Germany.
Email: m.abang@t-online.de

A survey of markets south of Nigeria showed that most of the tomato fruits in the market were from the northern part of Nigeria (ILOBA and ACHO, 1989).

ASIEGBU and NWOSU (1990) reported the detrimental effects of high rainfall and humidity on field-grown tomatoes in the south due to the high incidence of various fungal diseases, most of which are seed-borne and cause economic losses (NEERGAARD, 1977). Alternaria leaf blight and Fusarium wilt cause significant yield reduction (BENHAMOU *et al.*, 1989) while Septoria leafspot is considered the most widespread and economically damaging foliar disease of rainy season tomato in Nigeria (OKPALA, 1977; ERINLE, 1989, ILOBA and ACHO, 1989).

The risk of crop failure and the inability to afford fungicides has discouraged many resource-poor local farmers from engaging in commercial tomato production (ILOBA and ACHO, 1989). As in other parts of the world, commercial growers rely heavily on the intensive use of fungicides (GEISEN, 1999). Improper spraying techniques and poor handling of fungicides expose these farmers to dangerously high levels of toxic chemicals. Often, fungicides are applied at very short intervals, and farmers do not observe prescribed pre-harvest intervals, apply higher than recommended doses, and mix chemical 'cocktails', causing considerable health hazards for themselves, consumers and the environment alike (GEISEN, 1999).

The ease, efficacy and economy of chemical seed treatment or "seed dressing" makes it a viable option whenever disease can be controlled in this way (HISLOP and CLIFFORD, 1975; ASSCHE and LEUVEN, 1988; ILOBA and ACHO, 1989). The efficacy of the fungicides benomyl and thiram against seed-borne mycopathogens, and their contribution to crop yield and quality is well documented (MARSH, 1977; ILOBA and ACHO, 1989). The exotic tomato varieties, Roma VFN and Ronita VFN are well adapted and widely grown in Nigeria (ILOBA and ACHO, 1989; ASIEGBU and NWOSU, 1990), and have been found to show great promise for use in the Nigerian tomato paste industry (QUINN, 1974).

The efficacy of chemical seed treatment depends on the planting season, climatic conditions during germination and type of fungicide (LOUGHMAN *et al.*, 1991). The incidence and severity of the fungal disease complex of tomato is generally low under conditions of low rainfall and low relative humidity (OKPALA, 1977; PARKER *et al.*, 1995), and seed treatment is usually adequate for controlling disease under such conditions. For instance, ILOBA and ACHO (1989) showed that yield of dry season tomato was significantly increased following seed treatment with systemic benomyl-based fungicides. In contrast, despite the potential to grow tomato all-year-round, little is known regarding the efficacy of seed treatment for the control of fungal diseases of tomato in the wet season when disease pressure is high. In view of the lack of resistant varieties, such knowledge could potentially contribute towards developing sustainable management strategies for fungal diseases of tomato (PARKER *et al.*, 1995; GEISEN, 1999).

The objective of this study was thus to evaluate the efficacy of seed treatment with thiram and benomyl as a cheap and safe disease management option in tomato grown under the late short growing season conditions of Nsukka, in the tropical derived savanna zone of southeastern Nigeria.

2 Materials and methods

2.1 Laboratory tests

The two improved adapted varieties of tomato used in the study were, Roma VFN and Ronita VFN (J.E. Ohlsens Enke, Denmark). The two fungicides investigated were: thiram (tetramethylthiuram disulphide, BDH Chemicals Ltd, England), which is non-systemic and Benlate (a.i. benomyl 50%, methyl 1-(butylcarbamoyl)-2-benzimidazole carbamate, Du Pont de Nemours S.A., Switzerland), which is systemic. A suspension of each of the fungicides was prepared in sterile distilled water (SDW) at a concentration of 0.25%, and both fungicides were applied as soak treatments. Sterile distilled water served as control.

The direct effect of the fungicides on seed germination and seedling vigour was studied in the laboratory using a blotter technique (DE TEMPE, 1953). Seeds of the tomato varieties were shaken in conical flasks containing the different fungicide suspensions on a mechanical shaker for 20 minutes and allowed to stand for 30 minutes. Sets of three sterile germination blotters were placed in each of 9 cm-diameter clear plastic sterile Petri dishes and moistened with 10 ml of the fungicidal suspension and SDW, for the treated and control variants respectively. All possible combinations of the two tomato varieties and three seed treatments were tested out in a completely randomized design (2x3 factorial). For each treatment combination, 10 seeds of the particular tomato variety were randomly picked and almost equidistantly plated on the sterilized moist blotting papers. Each Petri dish constituted a plot for each treatment combination, which was replicated 40 times, giving a total of 400 seeds (ISTA, 1966). Incubation was done on laboratory benches at 26°C+/-2°C under near natural conditions of 12 h light period for 12 days. Evaluation was based on the presence or absence of essential seedling features according to Agrawal and DADLANI (1987). Records were made on percentage germination and number of lateral roots. Germination speed indices were computed by dividing the number of normal germinated seedlings removed each day by the day on which they were removed (AGRAWAL and DADLANI, 1987). The mycoflora on the seeds were also identified.

2.2 Field trial

The field experiment was conducted in the research farm of the Department of Crop Science, University of Nigeria, Nsukka, Nigeria, during the rainy season of 1995. The experimental site was situated at latitude 06° 25'N, longitude 07° 24'E, and at 447.2 m above sea level. The soil was texturally a sandy loam with pH (H_20) 6.17, 1.31 % organic matter and 0.1 meq/100 g exchangeable Ca. Ten year average precipitation for the farm site is 1547 mm, of which 1455 mm is recorded between April and October. All possible combinations of the tomato varieties and fungicides including the control were tested out in a randomized complete block design with four replications.

The plant spacing was 60cm x 60 cm with a plant population of 10 plants/plot, giving a total of 27,777 plants/ha.

Treated and untreated seeds were sown in ground nurseries for four weeks before transplanting into the field plots. Routine field management practices such as weeding, staking and fertilization were carried out. Organic manure (poultry dropping) was applied at 11.4 t/ha (OIKEH and ASIEGBU, 1993) and N-P-K fertilizer (15:15:15) at the rate of 535 kg/ha (19 g per plant) by ring application (Asiegbu and Nwosu, 1990). Weeding was done manually, and a prophylactic dose of an insecticide, Vetox 85 WP, was sprayed on all field plots 21 days after transplanting (DAT), to prevent the incidence tomato leaf curl virus transmitted by whiteflies (*Bemisia tabaci*). Evaluation of varietal performance in response to fungicidal seed treatment was according to ILOBA and ACHO (1989), and included the following parameters:
(1) % germination, ten days after planting in the nursery; (2) Number of healthy leaves; (3) Number of severely infected leaves (>50 % leaf area infected) ; (4) Fruit count and total yield (kg/plot); (5) Plant population and fresh weight of whole plants at harvest.

2.3 Data analysis

The SAS statistical package (SAS INST. INC., 1987) was used for analysis of variance (ANOVA) tests in both the laboratory and field trials. Percentages of germination were subjected to arc-sine transformation before ANOVA was performed. When significant F values were obtained, treatment means were compared using Fisher's least significant difference (F-LSD).

3 Results

A summary of the weather record (Table 1) showed that rainfall amount and number of rain days during the crop establishment and vegetative growth periods in June and July were very high. During the fruit-set and fruit-filling stages (August and September), the amount of rainfall increased only slightly but there was a considerable increase in the number of rain days. The mean maximum day temperature appeared mostly moderate while the mean night temperature and relative humidity were rather high for tomato production.

The fungicides, benomyl and thiram, were similar in efficacy in all the parameters of evaluation. In both the laboratory and field experiments, fungicide-treated seed lots gave a higher percentage germination compared with the control, but this difference was not significant (data not shown). Treated seeds also appeared to produce more vigorous seedlings as indicated by their higher germination speed indices, and there was a significant difference in number of lateral roots produced by seedlings from treated compared to untreated seed lots (Table 2). Isolations from infected seeds and defective seedlings consistently revealed that *Fusarium* spp. were implicated. Termites identified as *Macrotermes* spp. (M.I. EZUEH, entomologist, University of Nigeria, pers. comm.) were found associated with 'felling' of some seedlings in all treatments in the nursery.

Table 1: Summary of weather records during the period of the experiment.

	May	June	July	August	September	October
Rainfall (mm/month) *	274.0 (193.2)	345.0 (277.9)	221.3 (219.7)	224.1 (193.6)	370.5 (308.2)	117.5 (201.4)
Raindays (days)	13	10	18	25	22	18
Mean pan evaporation (ml/day)	3407.1	3385.0	2056.5	1785.2	1404.7	2650.3
Mean max. day temp. (°C) *	30.1 (28)	28.9 (27)	27.8 (26)	26.7 (26)	27.5 (26)	28.3 (27)
Mean min. day temp. (°C) *	20.7 (20)	20.5 (20)	20.7 (20)	20.7 (20)	20.8 (21)	20.3 (20)
Mean daily rel. humidity (%) at 6.00 H *	80.8 (81)	80.7 (85)	80.7 (83)	80.6 (83)	80.8 (82)	80.4 (80)
(%) at 18.00 H *	72.4 (68)	73.1 (71)	75.7 (72)	76.7 (75)	75.7 (74)	74.3 (69)

Source: University of Nigeria, Nsukka, Meteorological Station.
* Values in parenthesis are 10 years average

Table 2: Mean number of lateral roots produced by seedlings of 2 tomato varieties in response to fungicidal seed treatment

	Tomato varieties		
Seed treatments	Roma VFN	Ronita VFN	Seed treatment means
Benomyl	3.83	3.73	3.78
Thiram	4.66	4.86	4.76
Control	2.96	2.83	2.90
Varietal means *	3.87	3.81	-

F-LSD0.05 for 3 seed treatment means = 0.53
* Non-significant mean difference

The number of leaves per plant was the same for all the treatments at 14 DAT (Fig. 1). However, significant differences in leaf count (P"0.01) were observed between the treated and control plants at 28 DAT. Also, leaf count was significantly higher (P"0.01) with Roma VFN than with Ronita VFN at this stage (Table 3). Leaf counts taken at 42 DAT indicated the lack of persistence of the fungicides and their inability to achieve sustained control of severe leaf spot and early blight symptoms (Fig. 1). *Septoria lycopersici* Speg. and *Alternaria solani* Sorauer were commonly isolated from infected leaves. Diseased leaves rapidly senesced and leaf abscission followed soon after. The number of severely infected leaves followed the same trend as the leaf count, being the same for all treatments at 14 DAT, with a significant difference (P"0.01) at 28 DAT. Failure of the fungicidal seed treatments to protect plants under conditions of high disease pressure was again observed at 42 DAT (Fig. 2).

Figure 1: Leaf count from the benomyl, thiram and control treatments at 14, 28 and 42 days after transplanting (DAT)

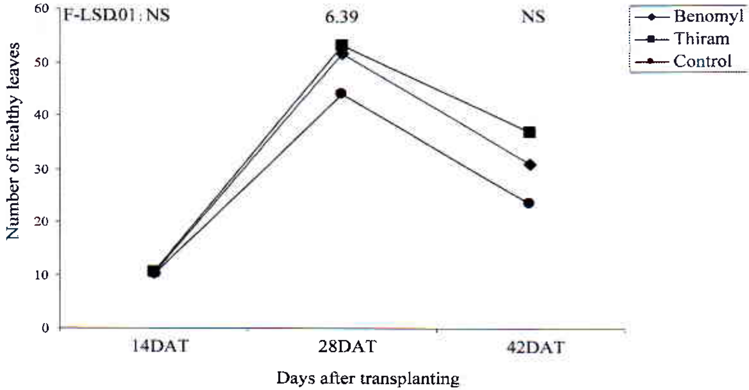

Figure 2: Number of severely infected leaves from the benomyl, thiram and control treatments at 14, 28 and 42 days after transplanting (DAT)

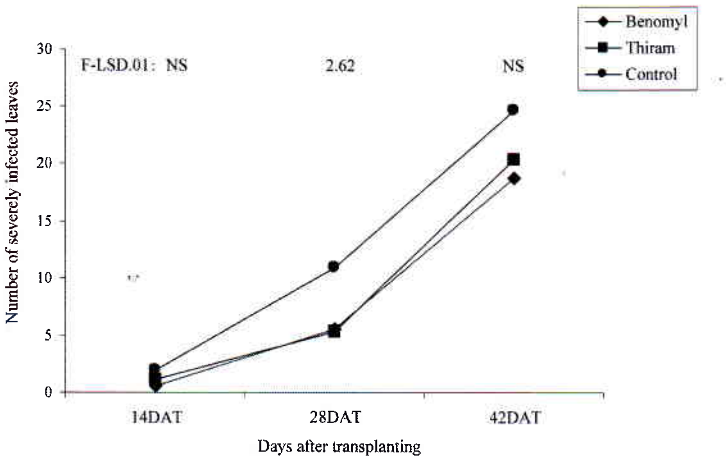

Table 3: Means and mean differences in number of healthy leaves produced by Roma VFN and Ronita VFN, 28 DAT.

Mean of Roma VFN	Mean of Ronita VFN	Difference of Means
54.99	44.22	10.77 **

** F-LSD0.01 for 2 Varietal means = 5.20

There were no significant differences between treated and control plants for all other parameters measured beyond 42 DAT (fruit count, total yield, plant population and fresh weight of whole plants at harvest) (data not shown). Many stands were wilted especially at the end of the growing period in spite of the wet conditions and this symptom was found to be associated with the presence of *Fusarium oxysporum*, which was commonly isolated from wilted plants. Despite the generally low yields due to high disease pressure, Roma VFN gave higher yield and appeared better adapted than Ronita VFN under the conditions of this study. There was no significant interaction between the tomato genotypes and the seed treatments in all the parameters of evaluation.

4 Discussion

The fact that fungicide-treated seed lots had higher germination and showed greater vigour than non-treated seeds is probably due to the well recognized fungicidal activity of thiram and benomyl (MAUDE *et al.*, 1969; NEERGAARD, 1977). SINHA *et al.* (1999) attributed improved germination in treated infected seed to elimination of fungi, and thus mycotoxins, which are responsible for the reduction in seed germination.

Although a high water requirement of 8-10 mm/day is required for tomato (GRUBBEN, 1977) rainfall appeared too high in July and August resulting in very high relative humidity. High precipitations are detrimental to tomato production due to high incidence of Septoria leafspot, Alternaria blight and Fusarium wilt diseases (BENHAMOU *et al.*, 1989; ILOBA and ACHO, 1989; PARKER *et al.*, 1995). *S. lycopersici* and *A. solani* were not isolated from the seeds and must have come from other sources of inoculum, such as crop debris. *S. lycopersici*, for instance, is known to be the most widespread and damaging foliar disease of wet season tomatoes in Nigeria (OKPALA, 1977; ERINLE, 1989). Wilting of plants under very wet conditions and the isolation of *F. oxysporum* from infected plants were clear signs of pathological wilt and this symptom is widely known to be associated with serious losses in tomato fields (BENHAMOU *et al.*, 1989).

Crop productivity (grams per square metre) has been defined as the product of solar radiation interception (RI) and radiation use efficiency (RUE) (grams per megajoule) (KENNETH, 1987). Septoria leaf spot and Alternaria blight have an adverse effect on both RI and RUE, and consequently reduce the photosynthates that are needed for fruit set and fruit filling. The highly significant difference in leaf count and number of severely infected leaves between the treated and control variants observed 28 DAT must have been due to the efficacy of the seed treatment fungicides. Our results confirm those of ILOBA and ACHO (1989) who observed significant differences between tomato treated with benomyl-based fungicides and untreated plants. They first observed differences at 42 DAT indicating an earlier onset of epidemic in the present study due to the particularly favourable conditions for fungal disease development.

Early differences in disease severity did not translate into yield differences because by the time of fruit-set and fruit-filling disease levels were the same on treated and control plots. This is in agreement with the results of LOUGHMAN *et al.* (1991), who found that fungicidal seed treatments were significantly (P"0.01) less effective in high rainfall areas. The inability to sustain healthy foliage up to 42 DAT and beyond may be ascribed to limited translocation of the fungicides into new growth (HISLOP and CLIFFORD, 1977), and the rapid development of tomato leaf spot and blight symptoms under high rainfall conditions (OKPALA, 1977; PARKER *et al.*, 1995). ILOBA and ACHO (1989) evaluated benomyl-based seed treatment fungicides under dry season conditions and found that there was sustained control, and a significant increase in yield of treated tomatoes. The inability of the fungicides to perform similarly in this study emphasizes the need to test disease management options under different agroecological conditions.

The differences between Roma VFN and Ronita VFN appeared to be genetically controlled. ILOBA and ACHO (1989) reported similar differences among tomato cultivars in response to fungicidal seed treatment. They noted that Roma VFN was better adapted and out-yielded other less adapted exotic varieties. Our results show that Roma VFN has good potential for use in wet season tomato cultivation.

The common occurrence of *Fusarium* spp. in local and improved tomato seed lots (ILOBA and ACHO, 1989), the reluctance of farmers to produce organically because of a perceived increased risk of crop failure due to diseases (GEISEN, 1999), and the absence of acceptable tomato cultivars possessing resistance to Septoria leafspot and Alternaria leaf blight (PARKER *et al.*, 1995), means that farmers will continue to rely on sanitation and frequent fungicide application. Treatment of seeds with fungitoxic formulations remains 'a very important and economical facet of pesticide usage' (HISLOP and CLIFFORD, 1975). Prophylaxis with benomyl and thiram did not persist long enough to achieve sustained disease control and increase yield, but showed good potential to be combined with other control options in an integrated strategy. A single spray application of benomyl at 24 DAT may maintain the foliage healthy beyond fruit filling and thus ensure increased yield of treated plants. Such a measure could potentially supplement seed treatment so that sustained disease control is achieved throughout the growth period without the high costs and hazards of frequent fungicide application. In addition to developing resistant cultivars, further research should identify critical levels of rainfall and determine how environmental factors and cultural practices influence disease progress.

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