An evaluation of some systemic fungicides for the control of *Septoria* leaf spot of tomato

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SUMMARY

Three systemic fungicides *viz.* Thiophanate Methyl (Topsin M 70WP), Benomyl (Benlate 50WP) and Carbendazim (Bavistin 50WP) and a protectant, Mancozeb (Dithane M-45), were tested at Akomadan in Ghana for their efficacies and cost effectiveness against *Septoria lycopersici* Speg., which causes *Septoria* leaf spot of tomato. The optimal spray schedule for the most cost effective and most readily-available fungicide was also studied. In the dry season, when leaf spot was generally absent, no differences in efficacies of the fungicides could be detected. In the wet season, *Septoria* leaf spot severity was high and the three systemic fungicides were generally superior to the protectant, Dithane M-45. Among the systemics, Benlate and Topsin M performed similarly and were generally more efficacious than Bavistin. The cost effectiveness of the systemic fungicides in the wet season (indicated by benefit:cost indices (BCI) was highest for Topsin M (0.22-0.32 per cent) followed by Bavistin (0.11-0.23 per cent) and lowest for Benlate (0.07-0.13 per cent). Use of Topsin M (413 g a.i. /ha) at 1, 2 and 3-weekly applications, commencing 5 weeks after transplanting and terminating in the 9th week, resulted in area under disease progress curve (AUDPC) values of 26.83, 29.16 and 31.82 per cent wk, respectively. These values were all significantly lower (P=0.05) than the value of 38.73 per cent wk associated with the no fungicide treatment. Judicious pesticide-use and possible measures for increasing tomato yields in the area are discussed.

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RÉSUMÉ

AWUAH, R. T.: *Une évaluation de quelques fongicides systémiques pour le contrôle de Septoria - Une tache à feuille de tomate.* Trois fongicides systémiques, à savior Thiophanate Méthyle (Topsin M 70 WP), Bénomyle (Benlate 50 WP) et Carbendazine (Bavistin 50 WP) et un protectant, Mancozeb (Dithane M-45), étaient testés à Akomadan au Ghana pour leurs efficacités et rentabilités contre *Septoria lycopersici* Speg., qui est à l' origine de *Septoria* - une tache à feuille de tomate. La prévision optimale de pulvérisation pour le fongicide le plus rentable et le plus aisément disponible était également étudiée. Pendant la saison sèche, lorsque la tache à feuille était absente dans l' ensemble, des différences d' éfficacités des fongicides ne pourraient pas être découvertes. Pendant la saison humide la sévérité de *Septoria*, la tache à feuille était élevée et les trois fongicides systémiques dans l'ensemble, étaient supérieures aux protectants, Dithane M-45. Parmi les systémiques, Benlate et Topsin M performaient d' une manière semblable et dans l'ensemble, étaient supérieures aux protectant, Dithane M-45. Parmi les systémiques, Benlate et Topsin M performaient d'une manière semblable et dans l'ensemble étaient plus efficace que Bavistin. La rentabilité des fongicides systémiques au cours de la saison humide (indiquée par les indices de bénefice: coût; IBC) pour Topsin M était la plus élevée (0.22-0.32 pour cent) suivi par Bavistin (0.11-0.23 pour cent) et le plus bas pour Benlate (0.07-0.13 pour cent). L'utilisation de Topsin M (413 g a.i./ha) aux applications par 1,2 et 3 semaines, commençant 5 semaines' aprés le repiquage et terminant dans la 9ème semaine résultait en une courbe d' aire sous le progrés de maladie (CASPM) de valeur de 26.83, 29.16 et 31.82 pour cent/semaine respectivement. Toutes ces valeurs étaient considérablement plus basses (P=0.05) que la valeur de 38.73 pour cent par semaine liée au traitement de sans-fongicide. L'utilisation judicieuse de pesticide et de mesures possibles pour l'augmentation des rendements de tomate dans ce territoire sont discutées.

Introduction

Septoria leaf spot caused by *Septoria lycopersici* (Speg.) has recently been reported as a major disease of tomato (*Lycopersicon esculentum* Mill.) in the Akomadan tomato-growing area of Ghana (Awuah, 1995b). Previously, the disease was noted as common in the country especially in the Ashanti and Northern regions (Leather, 1959). Barksdale, Good & Danielson (1972) reported *Septoria* leaf spot to be very damaging to tomato culture especially in the middle Atlantic and central states of the United States of America. The disease has also been reported to be important in Bermuda (Waterston, 1940), Uganda (Hansford, 1944), Zimbabwe (Hopkins, 1945), Palestine (Reirhert, Palti & Minz, 1944), Brazil (Kurozawa & Balmer, 1978), Nigeria (Iloba & Achor, 1989) and possibly wherever tomato is grown.

Management of *Septoria* leaf spot in Akomadan traditionally has been with protectant fungicides, notably Dithane M-45, Kocide 101, Champion and Caocobre-Sandoz. In the wet season, about eight applications of these fungicides, either singly or in various combinations with each other, commencing 3 weeks after transplanting, is common among farmers (Awuah, 1995b). These fungicides and similar modes of application are also utilized on the dry/semi-dry season crop. However, the level of disease control obtained with the fungicides in the wet season is low, despite the high application intensity adopted (Awuah, 1995b). This is so partly because protectant fungicides are easily washed off treated surfaces after rains. Thus, systemic fungicides which are absorbed and transported through plant tissues, making them fungitoxic, would be better alternatives in the control of *Septoria* leaf spot in a high rainfall area such as Akomadan.

Benomyl (Benlate 50WP), Carbendazim (Bavistin 50WP) and Thiophanate Methyl (Topsin M 70WP) are three systemic fungicides that have been introduced to the Ghanaian market. Critical studies on their performance, especially against *Septoria* leaf spot of tomato, however, have not been made. Besides, these fungicides, especially Benlate and Bavistin, are relatively expensive and evidence regarding their cost effectiveness must first be established before being recommended to farmers. Elsewhere, these systemic fungicides have proven effective against deuteromycetous fungal pathogens affecting aerial plant parts (Smyly & Filler, 1973; Singh & Singh, 1986; Spencer, 1977; Mourik, 1985).

The objectives of this study were to evaluate in the field different application rates of the three systemic fungicides against *Septoria* leaf spot of tomato, to ascertain the costs associated with the use of these fungicides, and to determine an optimum spray schedule for the most cost effective and most readily available of the fungicides.

Materials and methods

Experiment 1: An evaluation of the efficacies of Benlate, Bavistin and Topsin M

The study was conducted between December 1991 and March 1992 (dry season) and repeated between April and July 1992 (wet season) in Akomadan which is located in the transitional forest zone of Ghana. The dry season trial was located at the Akomadan Tomato Irrigation Project (ATIP) site but the wet season trial was conducted on a plot of land belonging to the Ministry of Agriculture and located outside the ATIP area. Both plots had been planted continuously to tomato for several years and had previous histories of *Septoria* leaf spot.

A randomized complete block design with 14 treatments (Table 1) and four replications was used for both experiments. In the dry season, plots (equivalent to ridges or rows) were 12 m long and 0.75 m apart but 6 m long rows (0.75 m apart) were used in the wet season. Four-week-old tomato transplants (cultivar Laurano 70) were planted on the rows at 0.3 m spacings. Normal cultural practices for tomato culture were followed. These included fertilization (N:P:K 25:15:15, 247 kg/ha at 3 wk) followed by an ammonium sulphate side dress (247 kg/ha) 4 wk later, hand weeding/reridging (at 3, 7 and 10 wk) and, in the case of the dry season trial, artificial irrigation (rotating sprinkler type, 10-14 days cycle, usually 30 min per cycle).

Apart from farmers' practice (re-bagged Dithane M-45 at 353 g a.i./ha; total of 7 weekly sprays) which was initiated 3 wk after transplanting, all other fungicide treatments were initiated at 7 and 8 wk, respectively, for the wet and dry season trials. All sprays were terminated in the 9th week. Thus, 7-weekly sprays were applied in the case of farmers' practice for both wet and dry season trials but 3- and 2-weekly applications of the other treatments were, respectively, made during the wet and dry season trials. All fungicides were applied with lever operated knapsack sprayers fitted with cone nozzles. Three days after termination of sprays, 10 innermost plants on experimental rows (wet season) and 20 plants (dry season) were rated for *Septoria* leaf spot severity.

Experiment 2: Determination of an optimal spray schedule

Because Topsin M proved most cost effective and most readily available of the three systemic fungicides (Experiment 1), its optimum frequency of application was determined during the wet season of 1993 (May - July). The trial was conducted on the same piece of land used for the 1992 wet season trial. Experimental plots (each equivalent to a 6-m long ridge (row) 0.75 m apart) were arranged in a randomized complete block design with four replications per each of the five treatments. The treatments were 1, 2 and 3 - weekly applications of Topsin M (413 g a.i./ha), a weekly applications of Dithane M-45 (583 g a.i./ha) and a no fungicide control. Four-week-old transplants of tomato (cultivar Laurano 70) were planted on rows at spacings of 0.3 m. The necessary cultural practices were adopted as in the 1991 and 1992 trials.

Sprays were initiated 5 weeks after transplanting (i.e. onset of leaf spot development) and terminated at the end of the 9th week. At the initiation of sprays and weekly subsequently, 18 innermost plants from each treated ridge were marked out and assessed for *Septoria* leaf spot severity until the 10th week.

Data collection and statistical analysis

In all trials, a rating scale of 0 to 11 (Table 1) modified after Horsfall & Barratt (1945) was used to rate individual plants for leaf spot severity. Disease ratings were converted into percentages (Redman, King & Brown, 1962) and the percentages subjected to arc sine transformations (Little & Hill, 1978). In Experiment 1, ANOVA was directly performed on the transformed leaf spot values and mean separations accomplished with the Least Significance Difference Test. In Experiment 2, the arc sine transformed leaf spot values were used to draw disease progress curves. Additionally, the areas under the various disease progress curves (AUDPC) (Shaner & Finney, 1977) were estimated and the values statistically analyzed.

Costs of the various fungicide sprays were estimated from the prevailing retail prices of each fungicide as well as labour costs during the 1991, 1992 and 1993 cropping seasons. From these cost values, BCI associated with each fungicide application was calculated as follows:

$$BCI = \frac{\text{Disease level (no fungicide) - Disease level (fungicide)} \times 100}{\text{Cost of fungicide application}}$$

TABLE 1

Rating Scale for Leaf Spot Severity

Scale	*Percent disease severity*
0	0
1	0-3
2	3-6
3	6-12
4	12-25
5	25-50
6	50-75
7	75-88
8	88-94
9	94-97
10	97-100
11	100

Rainfall data:

Data for the 1991 dry season trial was obtained from the Cocoa Services Division station located about 3 km from the experiment site. During the wet season, such data were supplied by the Ministry of Food and Agriculture station located about 500 m from the experiment site.

Results and discussion

In the dry season, no significant differences could be detected among the fungicide treatments with respect to *Septoria* leaf spot control. Leaf spot severity during the season was low, the disease being absent from most plots (Table 2). Spots, if any, were observed as late as 8 weeks after transplanting.

In the wet season, differences in the efficacies of the various fungicide treatments were detected. All fungicide treatments resulted in significantly less disease ($P = 0.05$) than the no fungicide control treatment. In general, all three systemic fungicides were superior to the protectant, Dithane M-45. Among the systemics, Topsin M and Benlate particularly were effective. The lowest application rates i.e. 206.5 g a.i./ha tested for both fungicides kept the disease at low levels of 34.45 and 36.17 per cent, respectively (Table 2). These values are contrasted with farmers' practice and the no fungicide treatment with which leaf spot severity values of 53.24 and 76.44 per cent, respectively, were associated (Table 2).

In terms of cost effectiveness of the systemic fungicides during wet season tomato culture (indicated by BCI, Topsin M was generally the most cost effective to use (BCI = 0.22-0.32 per cent), followed by Bavistin (0.11-0.23 per cent) and Benlate (BCI = 0.07 - 0.13 per cent)(Table 2). The BCI for farmers' practice in the same season was a low 0.08 per cent. In general, all the fungicide treatments were more cost effective to use in the wet season (BCI = 0.07 - 0.32 per cent; average = 0.17 per cent) than in the dry season (BCI = 0.001-0.006 per cent; average = 0.004 per cent).

Topsin M, applied even once in 3 weeks at 413 g a.i./ha resulted in significantly less AUDPC than the no fungicide control treatment (Table 3). In general, leaf spot progressed more slowly on plants receiving the systemic fungicides than on untreated plants (Fig. 1).

The average monthly rainfall values during the dry season trial, i.e. January, February and March, respectively, were 10.50, 10.05 and 14.65 mm. There was a total of only 10 rainy days during the period. In the wet season trial, the monthly rainfall values representing April, May, June and July, when the plants were in the field, respectively, were 250.70, 163.66, 84.30 and 119.20 mm. Several rainy days were recorded during the period.

Traditionally, Dithane M-45 and other protectant fungicides have been utilized for controlling *Septoria* leaf spot of tomato in the Akomadan area. Owing to their nature, these fungicides do not offer durable control against the disease since they are easily washed off the crop after rains. The present study has amply shown that the systemics, *viz.* Topsin M, Benlate and Bavistin, could be replacement fungicides in managing *Septoria* leaf spot in Akomadan and the environs, especially during the wet season. The area lies within the transitional forest agro-ecological zone of Ghana, where rainfall is often frequent and intense. The total rainfall values from April to July when the study was in progress was 617.86 mm and was evenly distributed. In such high rainfall areas, systemic fungicides often perform better than protectants (Awuah, unpublished data).

There were no significant differences among the fungicides applied for control of *Septoria* leaf spot during the dry season primarily because incidence of the disease was generally low. With the onset of rain and availability of moisture (ideal for *Septoria* leaf spot development), differences in the efficacies of the test fungicides were evident. For example, the two systemic fungicides, Topsin M and Benlate, were equally effective in controlling *Septoria* leaf spot and were superior to Bavistin. Topsin M is generally efficacious against Deuteromycetes affecting aerial plant parts (Awuah, 1995a) and when utilized on a 3-weekly spray schedule it could significantly suppress *Septoria*

TABLE 2

Leaf Spot Levels and Cost Effectiveness Associated with Various Fungicide Applications

*Fungicide and a.i. used (g/ha)**	*Amount of product used (g/ha)*	*Leaf spot levels (%)*		*Cost of application in Cedis/ha***				*Benefit: cost index****	
				Dry season		*Wet season*			
		Dry season	*Wet season*	*Fungicide*	*Labour*	*Fungicide*	*Labour*	*Dry season*	*Wet season*
Dithane M-45 80 WP									
291.5	364.38	0	59.26	2915.04	6916	4372.56	10374	0.006	0.12
583	728.76	0	41.09	5830.08	6916	8745.12	10374	0.005	0.18
1166	1457.50	0.06	58.20	11660.16	6916	17490.24	10374	0.003	0.07
Bavistan 50 WP									
72.87	152.74	0	42.27	3054.8	6916	4582.2	10374	0.006	0.23
145.74	291.48	0.09	35.70	6109.6	6916	9164.4	10374	0.004	0.21
291.48	582.96	0	43.47	12219.2	6916	18328.8	10374	0.003	0.11
Benlate 50 WP									
206.5	413	0	34.45	9911.9	6916	14868	10374	0.004	0.12
413	826	0	23.67	19823.8	6916	29736	10374	0.002	0.13
826	1652	0	27.03	39647.6	6916	59472	10374	0.001	0.07
Topsin M 70 WP									
206.2	295	0.09	36.17	2360	6916	3540	10374	0.006	0.29
413	590	0	21.40	4720	6916	7080	10374	0.005	0.32
826	1180	0	21.99	9440	6916	14160	10374	0.004	0.22
Farmers' practice		0	53.24	4751.1	24206	4751.1	24206	0.002	0.08
No fungicide control	0	0.6	76.44	0	0	0	0	0	0
LSD (P=0.05)		NS	10.02						

* Includes allowance for 18% waste; Farmers' practice = use of re-bagged Dithane M-45 at 353 g a.i. /ha, total of 7-weekly sprays; with all other treatments, two applications were made in dry season and three in the wet season.

** Based on average fungicide retail prices and labour costs in 1992 and 1993.

$$BCI = \frac{\text{Disease level (no fungicide) - Disease level (fungicide)} \times 100}{\text{Cost of fungicide application}}$$

leaf spot. However, the optimal cost effective spray schedule for use in the wet season is 2- and 3-weekly sprays; the longer spray schedule of 3 weeks may be ineffective and could give ample time of leaf spot development under favourable environmental conditions.

In order to compensate for redistribution of the fungicide during the unpredictable heavy rains in this area, the 2-weekly spray schedule with Topsin M at 206.5-413.0 g a.i./ha is recommended. If the spray is initiated 5 weeks after transplanting (i.e. when leaf spots are expected to appear) and terminated by the 10th week, not more than three applications would be needed in contrast with eight or more applications of the protectant fungicides currently in use in the Akomadan area. This is very desirable, not only because of the savings in labour cost and materials but also because of the potential for reducing environmental pollution.

It is almost superfluous to apply fungicides to

TABLE 3

AUDPCs and Cost Effectiveness Associated with Topsin M and Dithane M-45 Sprays for the Control of Septoria *Leaf Spot of Tomato in the Wet Season*

*Fungicides and spray schedules**	*AUDPCs***	*Application cost (Cedis/ha)****		*Benefit:cost index per cent*
		Fungicide	*Labour*	
Topsin M, weekly spray	26.83	11800	17290	0.041
Topsin M, 2-weekly spray	29.16	7080	10374	0.055
Topsin M, 3-weekly spray	31.82	4720	6916	0.059
Dithane M-45 (control)	34.25	14575	17290	0.014
No fungicide (control)	38.73	0	0	0
LSD (P=0.05)	4.15			

* Sprays were initiated 5 wk after transplanting and terminated at the end of the 9th week; Dithane M-45 schedule = total of 5 weekly applications at 583 g a.i./ha; Total Topsin M applications: weekly = 5; 2-weekly=3; 3-weekly; 3=weekly = 2.

** AUDPCs = Area Under Disease Progress Curves in per cent weeks.

*** Based on average fungicide retail prices and labour costs in 1992 and 1993.

$$BCI = \frac{\text{Disease level (no fungicide)-Disease level (fungicide)} \times 100}{\text{Cost of fungicide application}}$$

control *Septoria* leaf spot in the dry season since the disease is largely absent at this time of the year. However, if unexpected rains come within the period, the lower application rate of 206.50 a.i./ha and longer spray schedule (once in 3 weeks) may be worthwhile.

The incidence of fruit damage due to *Spodoptera littoralis* is generally low in both dry and wet season (Awuah, 1994). The current eight insecticidal applications made by farmers should be limited to either two or three at the fruiting stage based on the manufacturer's recommendation.

Reduced pesticide use in the area will not only be beneficial to farmers' health and the environment, but would also impact favourably on profit margins. For example, use of Topsin M at 413 g a.i./ha in the wet season (three applications) resulted in a cost of about ¢40,000 / ha and a BCI of 0.32 per cent. On the dry season crop, the cost of applying fungicides using farmers' practice is about ¢29,000 /ha with a low BCI of 0.002 per cent. This wasteful expenditure on fungicides in a season when *Septoria* leaf spot is not problematic certainly would depress farmers' profits.

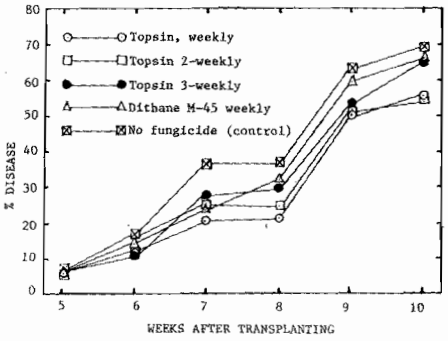

Fig. 1. Progress of *Soptoria* leaf spot on tomato plants receiving various spray schedules of Topsin M and Dithane M-45.

While the cost of fungicides has gone up considerably since the completion of the study, there has not been a parallel increase in the sale price of tomato, which generally has remained very low. Thus, fungicides and other pesticides must be used only when necessary in order to increase profit margins.

Some workers (Bollen & Scholten, 1971; Berger, 1973; Magie & Wilfret, 1974; Georgopoulos, 1979) have shown that intense use of systemic fungicides especially the benzimidazoles, to which Topsin M belongs, selects for resistant fungal strains in the subsequent years following application. Indeed, resistance to Topsin M by *Venturia*

inaequalis has been reported from Poland (Nowacka, 1992) and Romania (Stroe & Alexandri, 1992). It is, therefore, expedient to use Topsin M judiciously for the control of *Septoria* leaf spot in Ghana. The possible selection for strains of *Septoria lycopersici* resistant to Topsin M through the use of the fungicide could be avoided or minimized in three ways: (a) rotating the use of Topsin M with a protectant fungicide, e.g. Dithane M-45 at the rate of 880 g a.i./ha (Ferrandino & Elmer, 1992), (b) using a very low Topsin M application rate and frequency of application to reduce the selection pressure on the pathogen, and (c) substituting periodically the use of Topsin M with other types of systemic fungicides, e.g. Bavistin at the rate of 72.87 to 145.74 g a.i./ha on a 2-weekly spraying schedule.

Tomato culture in the Akomadan area also has attendant soil fertility problems. Several of the experimental plots had soil *p*H values ranging from *p*H 4.34 to *p*H 6.02 (average *p*H 4.71; data not shown). The acidic nature of the soil could be attributed to the application of sulphate of ammonia (Miller & Donahue, 1992), a fertilizer routinely used for tomato culture as a side dressing at the flowering stage. The practice of 'clean culture' used for tomato has also resulted in declining soil organic matter levels. Low organic matter and acid soils can reduce yields of tomato (Rice, Rice & Tindall, 1986). In the current study, very low tomato fruit yields were recorded on plots where stringent cultural practices were adhered to regarding weeding, fertilizer application and fungicide application. Prior to 1989, tomato yields as high as 8452-12265 kg/ha were common at Akomadan (Yeboah, 1989). Since the benefit of fungicide application to control *Septoria* leaf spot can be masked by soil infertility problems resulting in low fruit yield, it is expedient to tackle the soil problems in order to maximize the benefit derived from fungicide application.

Recent concerns regarding chemical pesticide use/misuse in agriculture makes it imperative to search for other environmentally friendly approaches to controlling *Septoria* leaf spot. Plant remains used as mulches have proved efficacious against some soil-borne pathogens whose inocula are disseminated primarily by soil splashing (Lewis & Papavizas, 1980; Galindo *et al.*, 1983; Yik, Lam & Wong, 1987). Experiments are in progress to determine the effectiveness of dry elephant grass (*Pennisetum purpureum* Schumach) mulch in the control of *Septoria* leaf spot of tomato. This will be reported in a subsequent paper.

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