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REDUCED FREQUENCY OF FUNGICIDE APPLICATION IN THE MANAGEMENT OF PAPRIKA (*CAPSICUM ANNUUM* L.) DISEASES UNDER DRYLAND CONDITIONS IN ZIMBABWE

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Abstract: In order to assess the economic benefits of reduced fungicide application for the control of paprika diseases under dryland conditions, on-farm experiments were conducted in the Chinyika Resettlement Area in the Eastern province of Zimbabwe in the 2000/2001 and 2001/2002 seasons. The six fungicide application regimes that were assessed include: weekly interval sprays; Sulphur at 2 weeks after transplanting (WAT) and copper oxychloride-Mancozeb mixture at 6 WAT; spraying after scouting; alternating Sulphur and copper oxychloride- Mancozeb every two weeks; Acibenzolar-s-methyl and unsprayed check. Parameters recorded were disease severity and yield; after harvest an economic analysis was performed. The highest added profit of Z$ 75 930/ha was recorded in the weekly sprayed plots which was not statistically different ($p > 0.05$) from Z$ 59 410/ha achieved by alternating copper oxychloride and Mancozeb fortnightly at Dengedza site in 2000/2001 season. There were no statistical differences ($p > 0.05$) between spraying after scouting and Acibenzolar-s-methyl application treatments as they added the least profits of Z$ 990/ha and Z$ 17 250/ha respectively at the same site in the same season. These have serious implications for smallholder farmers in terms of cost savings. Neither were there differences ($p > 0.05$) in added profits from different spraying regimes at Dengedza site in the 2001/2002 rainy season.

Key words: *Capsicum annuum* L., diseases, fungicide and economic benefits

INTRODUCTION

Paprika (*Capsicum annuum* L.) yields obtained in Zimbabwe vary from less than one tonne per hectare in the smallholder farms to around six tonnes per hectare in the commercial farming sector (Hyveld Seed 1996). These low yield figures recorded in the smallholder sector have been attributed to a number of production-related problems which include disease and weed management. Diseases of economic importance in Zimbabwe on paprika are powdery mildew, bacterial leaf spot, anthracnose, cercospora, damping off, stemphylium leaf spot, phytophthora blight, alternaria rot, sclerotium rot and bacterial soft rot (Paprika Zimbabwe 1998). Management of these diseases has been a problem in the smallholder-farming sector due to the prohibitive cost of chemicals. This is prevalent largely because the control of paprika diseases, such as leaf spot disease and powdery mildew, usually demands an intensive spray schedule. Therefore, as a result of chemical combinations and the campaign for limited Maximum Residual Level (MRL) in paprika, a viable management option that involves minimum fungicide input needs to be developed, at least to cut down on production cost.

Integrated pest management among growers must be supported and promoted as a means of significantly reducing the amount of synthetic pesticides applied to a crop (Bolkan and Ranert 1994). Apart from the economic benefits that would be associated with this, certainly its environmental considerations are also enormous. In a test of 10 fungicides against paprika disease caused by *Phytophthora* nicotianae var. *nicotianae*, six sprays of copper oxychloride (0.3%) at 10-day interval proved the most effective in checking infection and increasing yield (Bhardwaj and Sharma 1985). Dithane M-45 (mancozeb) and 0.3% Blitox (copper oxychloride) at 0.25% and 200 ppm, respectively, reduced bacterial leaf spot and fruit rot diseases of chilli caused by *Xanthomonas campestris* pv. *vesicatoira* and *Colletotrichum capsici* (Raju and Rao 1984). Application of both pesticides revealed that although fruit yield increased with decreasing spray interval, the net profit was highest with 15-day interval (Raju and Rao 1984).

The overall objective of this study, therefore, was to assess the economic benefits of a minimum fungicide application programme to manage bacterial leaf spot (*Xanthomonas campestris* pv. *vesicatoria*), cercospora leaf spot [*Cercospora unamunoi* (Cast.)], grey leaf spot (*Stemphylium solani*), powdery mildew [*Leveillula taurica* (Lev.)] and alternaria leaf spots (*Alternaria alternata*) in paprika in the smallholder farming sector of Zimbabwe.

MATERIALS AND METHODS

Site description and experimental design

The field trials were conducted in Chinyika Resettlement Area located in the Eastern province of Zimbabwe. It lies between lat 18°12''–18°17'' S and long. 32°09'' and 32°24'' E; with an altitude ranging from 700–1200 m above sea level. Field trials were conducted at two sites, namely Dengedza and Mhiripiri, in the 2000/2001 and 2001/2002 seasons. The six fungicide spray regimes that were compared included: (**A**) spraying after scouting (Sulphur at 3 weeks after transplanting (WAT) and copper oxychloride-Mancozeb mixture at 13 WAT), (**B**) commercial weekly recommended spray (Sulphur at 3, 5, 7, 9, 11 and 15 WAT, Mancozeb at 4, 8, and 12 WAT and copper oxychloride-Mancozeb mixture at 6, 10, 13, 14 and 16 WAT), (**C**) spraying Sulphur at 2 WAT and a copper oxychloride-Mancozeb mixture at 6 WAT, (**D**) alternating Sulphur and copper oxychloride-Mancozeb mixture at 2-week interval, (**E**) spraying Acibenzolar-s-methyl (3, 5, 7, 9 and 11 WAT), and (**F**) unsprayed treatment (check).

The treatments were laid out in a Randomised Complete Block design (RCBD) with three replications; each plot measuring 22.5 m^2.

Field management

Paprika seedlings were raised for 8 weeks in a standard nursery. Transplanting of paprika seedlings was done onto ridges, which were spaced 0.9 m apart and the seedlings planted 0.2 m apart along the ridges. Compound "L" fertilizer (7% N, 14% P_2O_5, 7% K_2O) was applied at the rate of 1 000 kg/ha before transplanting was done. Top dressing of ammonium nitrate (34.5% N) was done as a side dressing in 2 splits at the rate of 350 kg/ha at 4 WAT and 8 WAT. Muriate of potash (65% K_2O_5) applied in 2 splits at the rate of 350 kg/ha at 4 WAT and 8 WAT. Major diseases which were targeted for management in the two seasons were bacterial leaf spot (*Xanthomonas campestris* pv *vesicatoria*), cercospora leaf spot [*Cercospora unamunoi* (Cast.)], grey leaf spot (*Stemphylium solani*), powdery mildew [*Leveillula taurica* (Lev.)] and alternaria leaf spot (*Alternaria alternata*).

Data collection and analysis

Disease severity data were collected fortnightly beginning 2 WAT and continued until harvest time. Data on disease severity of bacterial leaf spot (*Xanthomonas campestris* pv *vesicatoria*), cercospora leaf spot [*Cercospora unamunoi* (Cast.)], grey leaf spot (*Stemphylium solani*), powdery mildew [*Leveillula taurica* (Lev.)] and alternaria leaf spots (*Alternaria alternata*) were collected using scoring scale of 0–5; where 0 represents no disease, 1 – very low severity, 2 – low severity, 3 – moderate severity, 4 – high severity, 5 – very high severity or plant dead. The disease severity data collected were used to calculate the area under disease progress curves (AUDPC) by the trapezoidal integration programme of a Sigma Plot 2000 computer package. Yield data were collected at 18 WAT and subjected to analysis of variance (Snedecor and Cochran 1980). To deduce the effectiveness of the various fungicides the areas under the disease progress curve (AUDPC) were compared.

Economic analysis

All production-related operations were costed and the economic analysis carried out on yield figures with significant differences to compare the profitability of treatments according to the procedure described by CIMMYT (1988) and the modified method of Ward et al. (1997). The data were then subjected to analysis of variance and Fisher's Least Significant Difference (LSD) was used for mean separation where the F-test was found to be significant (Steel and Torrie 1980). The gain in marketable yield (G) attributed to fungicide treatment is the difference between yield with fungicide treatment (Yc) and yield of the non-sprayed treatment (Yo), as shown in equation (i):

$$G = Yc - Yo \tag{i}$$

The added profit due to fungicide treatment (Pa) was calculated from the gain in yield (G) multiplied by the paprika price per tonne (R) less the costs of fungicide (F), fungicide application (A) and the extra cost of harvesting the gain in yield (H), as shown in equation (ii):

$$Pa = (G \times R) - (F + A + H) \tag{ii}$$

Added profit (Pa) reflects the estimated economic benefits of fungicide use as it shows the extra income less increased costs associated with fungicide treatment.

RESULTS

The trial located at the Mhiripiri site had its yield bulked by the farmer before measurements were taken for individual treatments, hence yield data was missing in 2000/2001 season, however for other measured variables, it was not influenced by fungicide treatments in the 2000/2001 season (Table 1). The standardised AUDPC, actual marketable yield, yield gain over non-sprayed and added profits were significantly influenced by fungicide treatments at Dengedza during the same season (Table 1). Clearly, the highest actual marketable yield, yield gain and added profit came from the treatment involving alternating Sulphur, Mancozeb + copper oxychloride mixture fortnightly. The actual marketable yield and added profit that accrued from this treatment were 268.4, 325.0 and 340.0 per cent higher than those for the least effective treatments, respectively. Among the five spray treatments, the least effective was Acibenzolar-s-methyl at the rate of 5 g/100 litres of water 10 days after transplanting and thereafter every 14 days. With respect to SAUDPC values, the treatment which gave the highest figure was spraying of fungicides only after scouting (Table 2).

In the case of Mhiripiri site in the 2001/2002 season, it was the only case of standardised AUDPC and actual marketable yield that fungicide treatments had significant influence (Table 3). Similary to results obtained in the case of Dengedza site in the previous season, the highest actual marketable yield was from the treatment involving alternate spraying of sulphur, Mancozeb+copper oxychloride while the highest SAUDPC value was from spraying of Acibenzolar-s-methyl. The actual marketable yield for the best treatment was 48.5 per cent higher than that for the worst treatment. Dengedza site was not influenced by fungicide treatments in the 2001/2002 season (Table 1).

DISCUSSION

There were generally lower disease severity levels in 2001/2002 than in 2000/2001 season as reflected by the SAUDPC values for the respective seasons. Consequently, this resulted in a generally low disease pressure than would normally be present during the course of production. Thus, in terms of amount rainfall received, the 2000/2001 wet season was a better one than the 2001/2002 wet season. This can then be attributed to significant differences among the various fungicide treatments. The difference between unsprayed plots and sprayed ones was very clear cut as the marketable yield for unsprayed plots was reduced by the disease. This then explains the observed clear-cut differences in yield gains and consequent differences in added profits at Dengedza site in 2000/2001 wet season. These, of course, have serious implications for smallholder farmers in terms of cost savings and margins of profit. The relatively low disease severity at Mhiripiri site in 2001/2002 season resulted in a very small difference between the values of marketable yield for the unsprayed and sprayed plots, which were not significantly ($p > 0.05$) different from each other. As was expected, non-significance in yield gains resulted in non-significance in added profits. The prevailing weather conditions were vital to disease severity in both

Table 1. Total paprika fruit yield and area under disease progress curve (AUDPC) as influenced by frequency of fungicide sprays at Dengedza and Mhiripiri, Zimbabwe in 2000/2001 and 2001/2002 seasons

Fungicide treatment	2000/2001			2001/2002			
	Total yield [t/ha]	AUDPC		Total yield [t/ha]		AUDPC	
	Dengedza	Dengedza	Mhiripiri	Dengedza	Mhiripiri	Dengedza	Mhiripiri
A	0.20	29.1	24.8	0.38	0.43	26.5	8.0
B	0.70	23.6	38.8	0.49	0.48	13.3	6.8
C	0.50	24.8	27.6	0.45	0.36	15.4	5.6
D	0.59	25.8	32.4	0.55	0.69	18.7	5.4
E	0.31	27.0	28.0	0.39	0.36	19.5	7.9
F	0.19	26.5	28.0	0.33	0.37	29.9	8.1
LSD (0.05)	0.15	1.82	NS	0.13	NS	5.43	NS
CV (%)	20.2	3.8	12.6	16.1	38.1	14.5	31.4

(**A**) spraying after scouting (Sulphur at 3 weeks after transplanting (WAT) and copper oxychloride-Mancozeb mixture at 13 WAT), (**B**) commercial weekly recommended sprays (Sulphur at 3, 5, 7, 9, 11 and 15 WAT, Mancozeb at 4, 8, and 12 WAT and copper oxychloride-Mancozeb mixture at 6, 10, 13, 14 and 16 WAT), (**C**) spraying Sulphur at 2 WAT and a copper oxychloride-Mancozeb mixture at 6 WAT, (**D**) alternating Sulphur and copper oxychloride-Mancozeb mixture at 2 week intervals (**E**) spraying Acibenzolar-s-methyl (3, 5, 7, 9 and 11 WAT), and (**F**) unsprayed plot treatment (Check)

NS – not significant

Table 2. Standardised area under disease progress curve (SAUDPC), actual paprika marketable yield [t/ha], yield gain and added profit as influenced by frequency of fungicide sprays at Dengedza, Zimbabwe in 2000/2001 season

Fungicide treatment	SAUDPC	Actual marketable yield [t/ha]	Yield gain over non-sprayed [t/ha]	Added profit [Z$[1] '000/ha]
A	2.43	0.20	0.01	0.99
B	1.97	0.70	0.51	75.93
C	2.07	0.50	0.30	45.33
D	2.15	0.59	0.40	59.41
E	2.25	0.31	0.12	17.25
Non-sprayed (check)	2.21	0.19		
LSD (0.05)	0.15	0.15	0.18	26.05
CV (%)	3.8	20.2	34.2	34.4

(**A**) spraying after scouting (Sulphur at 3 weeks after transplanting (WAT) and copper oxychloride-Mancozeb mixture at 13 WAT), (**B**) commercial weekly recommended sprays (Sulphur at 3, 5, 7, 9, 11 and 15 WAT, Mancozeb at 4, 8, and 12 WAT and Copper oxychloride-Mancozeb mixture at 6,10,13,14 and 16 WAT), (**C**) spraying Sulphur at 2 WAT and a copper oxychloride-Mancozeb mixture at 6 WAT, (**D**) alternating Sulphur and copper oxychloride-Mancozeb mixture at 2 week intervals and (**E**) spraying Acibenzolar-s-methyl (3, 5, 7, 9 and 11 WAT). SAUDPC is the area under disease progress curve, standardised by dividing AUDPC by the time duration (weeks). Added profit equals gain in yield multiplied by paprika price per tonne less costs of fungicides, fungicide application, and harvest of yield gain.

[1] 1 US Dollar = Z$ 5 500 at the time the research work was done

Table 3. Standardised area under disease progress curve (SAUDPC), actual paprika marketable yield [t/ha], yield gain and added profit as influenced by frequency of fungicide sprays at Mhiripiri, Zimbabwe in 2001/2002 season

Fungicide treatment	SAUDPC	Actual marketable yield [t/ha]	Yield gain over non-sprayed [t/ha]	Added profit [Z$[1] '000 /ha]
*A	1.11	0.38	0.05	12.67
B	1.28	0.49	0.16	32.34
C	2.21	0.45	0.12	32.26
D	1.56	0.55	0.22	57.89
E	1.63	0.39	0.06	16.83
Non sprayed (check)	2.49	0.33		
LSD (0.05)	0.45	0.13	NS	NS
CV (%)	4.4	16.1	63.1	67.2

(**A**) spraying after scouting (Sulphur at 3 weeks after transplanting (WAT) and copper oxychloride-Mancozeb mixture at 13 WAT), (**B**) commercial weekly recommended sprays (Sulphur at 3, 5, 7, 9, 11 and 15 WAT, Mancozeb at 4, 8, and 12 WAT and Copper oxychloride-Mancozeb mixture at 6,10,13,14 and 16 WAT), (**C**) spraying Sulphur at 2 WAT and a copper oxychloride-Mancozeb mixture at 6 WAT, (**D**) alternating Sulphur and copper oxychloride-Mancozeb mixture at 2 week intervals and (**E**) spraying Acibenzolar-s-methyl (3, 5, 7, 9 and 11 WAT). SAUDPC is the area under disease progress curve, standardised by dividing AUDPC by the time duration (weeks). Added profit equals gain in yield multiplied by paprika price per tonne less costs of fungicides, fungicide application, and harvest of yield gain.

[1] 1 US Dollar = Z$ 5 500 at the time the research work was done

seasons. This was so mainly because dry weather conditions are not favourable for the growth and development of causative pathogens (Agrios 1997). Under relatively wet conditions, the best disease management as a far pesticide spraying is concerned was alternating copper oxychloride and Mancozeb spraying fortnightly or weekly as they resulted in effective disease control, best marketable yield, yield gain and added profit.

Copper oxychloride is a broad-spectrum fungicide, which can also have some effects on bacteria. Its fortnightly alternation with Mancozeb ensured the effective control of pathogens while also reducing any chances of the pathogens developing partial resistance during the season as could have been the case if the two fungicides were not alternated. Spraying after scouting had the worst results, contrary to what was normally expected. This observation was attributed to the lack of a documented research-based threshold level required for deciding whether or not to spray. In the present research work, a threshold of an overall severity score of 3 of at least 25% of the total plants was required for a plot to justify being sprayed. The use of a lower threshold level than the one used in the present study is likely to result in the improvement of the effect of spraying when necessary, and the consequent increase in the total marketable and gained yield and added profit. Spraying after scouting was highly tipped as "the best bet" for paprika farmers as it is the case for some other crops, such as cotton. However, a major limitation is that most farmers are not familiar with paprika diseases, such that during scouting, they may not actually know the right disease symptoms to look for. Acibenzolar-s-methyl application consistently gave the least gain in yields over the two seasons and consequently produced the least added profits. This confirms some earlier findings on tobacco and pepper (Cole 1999), that the yields of plants treated with Acibenzolar-s-methyl were very similar to those of the untreated. Since paprika seedlings spend 8–10 weeks in the nursery, it may be necessary to induce resistance to diseases by applying treatments when the crop is in its final stages of life cycle.

Total pod yield was statistically the same across treatments in both seasons. However, significant ($p < 0.05$) differences were noted for total marketable yield in the 2001/2002 wet season, implying that there was disease effect on the quality of paprika pods. Probably, disease severity did not harm the quantity of paprika produced such as from each separate disease management practice but rather the quality. Marketability of paprika is mainly based on the state of the pods in terms of blemish and colour. The disease management practices that farmers employ should not only focus on maintaining the high quantity of paprika pods but on the quality as well. It was the ability of a disease management practice to control diseases that affects the quality of pods and that mattered in 2001/2002 season.

CONCLUSIONS

Smallholder paprika farmers can adopt the alternation of copper oxychloride and Mancozeb fortnightly for the effective control of paprika diseases and the best added profits as this will be as good as the weekly spraying with other pesticides. The cost implications of these to the farmers are obvious. Under dry weather conditions, with their associated low disease pressure, smallholder paprika farmers can adopt the least costly spraying regime, which would be the most cost-effective disease management practice. Under wet conditions, smallholder paprika farmers should not adopt a no-spray disease management practice as this may result in very low economic yields. Alternating the spraying of sulphur and copper oxychloride-Mancozeb mixture fortnightly gave the same disease control effect and total marketable yield as the weekly recommendation for commercial fungicide spraying.

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POLISH SUMMARY

OGRANICZONA CZĘSTOTLIWOŚĆ STOSOWANIA FUNGICYDÓW DO ZWALCZANIA CHORÓB PAPRYKI (*CAPSICUM ANNUUM* L.) NA SUCHYCH TERENACH ZIMBABWE

W celu określenia korzyści ekonomicznych wynikajacych z ograniczenia częstotliwości stosowania fungicydów do zwalczania chorób papryki na suchych terenach Zimbabwe, przeprowadzono w sezonach 2000/2001 i 2001/2002 doświadczenia na farmach w rejonie Chinyika Resettlement we wschodniej prowincji Zimbabwe.

Oceniano sześć programów zwalczania: (1) cotygodniowe opryskiwanie fungicydami; (2) siarka 2 tygodnie po wysadzeniu roślin i mieszanina tlenochlorku miedzi +Mankozeb 6 tygodni po weryfikacji stanu uprawy; (3) opryskiwanie fungicydami po dokonaniu weryfikacji stanu uprawy; (4) siarka i mieszanina tlenochlorku miedzi +Mankozeb przemiennie co 2 tygodnie; (5) Acibenzolar-s-methyl; (6) nieopryskiwana kontrola.

Zebrano dane o nasileniu porażenia i wysokości plonu, a uzyskane wyniki poddano analizie ekonomicznej. Najwyższy kumulatywny zysk w wysokości Z$ 75 930/ha stwierdzono na cotygodniowo opryskiwanych poletkach, który nie różnił się statystycznie ($p > 0,05$) od zysku wynoszącego Z$ 59 410/ha, uzyskanego w kombinacji z przemiennym stosowaniu co 2 tygodnie tlenochlorku miedzi i Mankozebu w lokalizacji Dengezda, w sezonie 2000/2001. Nie było statystycznych różnic pomiędzy kombinacją uwzględniającą opryskiwanie po dokonaniu weryfikacji stanu uprawy i kombinacją, w której stosowano Acibenzolar-s-methyl, na tym samym terenie i w tym samym roku, a kumulatywny zysk był najniższy i wynosił odpowiednio Z$ 990/ha i Z$ 17 250/ha. Wyniki te mają duże znaczenie dla małych gospodarstw w aspekcie ograniczania kosztów.

Nie było różnic ($p > 0,05$) w kumulatywnym zysku odnotowanym przy wykorzystaniu różnych programów opryskiwania w lokalizacji Dengedza w deszczowym sezonie roku 2001/2002.