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Effect of pesticide mixing on control of Anthracnose and *Spodoptera exigua* in shallot

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Inhoud

Abstract

In the dry season of 2015, a field experiment was carried out in Sumber Lor, West Java, Indonesia to test the effect of pesticide mixing on the presence of Anthracnose and *Spodoptero exigua* and yield of shallot.

The fungicides mancozeb and difenoconazole were applied with different combinations of the insecticides profenofos, lambda-cyhalothrin and chlorantraniliprole. The treatments were sprayed every five days.

Anthracnose was not observed in the experiment. Hence, no conclusions can be drawn with respect to the effect of mixing of insecticides and fungicides on the control of this fungal disease.

A mix containing both fungicides and the three insecticides gave a higher shallot yield than mixes with two fungicides and one or two insecticides, and the same insecticide mix and fungicide mix applied at different moments. This may indicate that the insect *Spodoptera* has developed resistance against insecticides in the study area, because single products were less effective in controlling the pest. Especially, Lambda-cyhalothrin was less effective in controlling *Spodoptera*.

The mix of two fungicides and three insecticides applied simultaneously showed the best control of *Spodoptera exigua.* Therefore, it may be concluded that there is no need to spray insecticides and fungicides separately.

1. Introduction

Shallot (*Allium cepa* group *aggregatum*) is an important crop in Indonesia especially in the lowland areas between Cirebon and Pekalongan. Farmers use high amounts of pesticides to control the fungal disease Anthracnose (*Colletotrichum gloeosporioides*) and the insect pest *Spodoptora exigua*.

In practice farmers spray at least one type/brand of fungicide and one type/brand of insecticide each week using knapsack sprayers. Combining fungicides with insecticides in one spray tank is a common practice of farmers to save labour and thus costs. Combining different types of pesticides in one spray application also reduces the time of exposure of the farmer/sprayer to pesticides.

However, the general advice is not to mix pesticides and to apply single products unless the label of the pesticide states otherwise. This is to avoid any risks of physical and/or chemical incompatibility of agro-chemical products.

To protect shallots from pests and diseases, farmers mostly apply a mix of a contact fungicide, a more translaminar active fungicide and one or two broad spectrum insecticides.

An experiment was carried out in West-Java in 2015 to test the effect of different pesticide mixes on controlling the fungus anthracnose and the insect pest *Spodoptora exigua*, shallot yield and the associated pesticide cost price per unit produce (shallot) of applying different pesticide mixes.

2. Materials and methods

An experiment was carried out in Sumber Lor village of Eastern Cirebon, West Java, Indonesia to assess the efficacy of pesticide mixes in controlling Anthracnose and *Spodoptera exigua* in shallot.

Different pesticide mixes with fungicides and insecticides were tested (Table 2.1). Eight mix treatments were tested with an interval of five days between the applications. The mix treatments differed in the type of pesticides and the concentration of application. Spraying started 12 days after planting on September 2, 2015, and the last spray took place on October 7, 2015. During the first two applications, a volume of 462 l/ha was used while for the following applications a volume of 556 l/ha was used.

Table 2.1 Pesticides applied in shallot (ml or gram per liter) and costs per hectare of the different treatments.

Product		Dithane M45 80 WP	Explore 250 EC	Matador 25 EC	Curacron 500 EC	Prevathon 50 SC	Total costs (IDR/ha)
Active ingredient [1)]		M	D	L	P	C	
Price (IDR/g or ml)		87	400	208	234	500	
Code							
P1	MDLPC	3	1	1	1.4	2	9,357,516
P2	MDP	3	1		1.4		4,211,436
P3	MDL	3	1	1			3,701,940
P4	MDLP	3	1	1	1.4		5,097,516
P5	MDC	3	1			2	7,075,860
P6	MD	3	1				2,815,860
P7 day 1	MD /	3	1				9,357,516
P7 day 2	LPC			1	1.4	2	
P8	UTC[1)]						0

[1)] M=mancozeb; D= Difenoconazole; L= Lamda-cyhalothrin; P=Profenofos; C= Chlorantraniliprole; UTC = untreated control.

Mancozeb and difenoconazole are fungicides to control anthracnose in shallot (Table 2.2). Lamda-cyhalothrin and profenofos are both broad spectrum insecticides to control all kinds of insects in shallot. Chlorantraniliprole is a selective insecticide targeting insects of the order *Lepidoptera*, which include butterflies and moths, such as *Spodoptera exigua*.

Table 2.2 Characteristics of applied pesticides.

Active ingredient	Type	Mode of action	FRAC/IRAC group		
Mancozeb (M)	fungicide	broad spectrum / contact	M3	Multi-site contact activity	dithiocarbamates
Difenoconazole (D)	fungicide	broad spectrum / Translaminair [1)]	3	Demethylation in sterolbiosynthesis	triazoles
lambda-cyhalothrin (L)	insecticide	broad spectrum / contact and ingestion action	3A	Sodium channel modulators. Nerve action	pyrethroids
Profenofos (P)	insecticide	broad spectrum / contact and ingestion action. Translaminair	1B	Acetylcholinesterase (AChE) inhibitors. Nerve action	organophosphates
Chlorantraniliprole (C)	insecticide	selective / contact and ingestion action. Translaminair	28	Ryanodine receptor modulators. Nerve and muscle action	diamides

1) Translaminair: ability of the active ingredient of the insecticide to penetrate the leaf cuticle and move into the leaf tissue.

Shallot var. *Bima Curut* was planted on August 21, 2015. The experiment was done as a randomized block design with three blocks. Plot size was 13.5 m^2. A total of 250 kg/ha N, 101 kg/ha P_2O_5 and 102 kg/ha K_2O was applied in the growing season. Two days before planting a basal fertilization was applied with NPK 15-15-15, Superphosphate 36 and KCl 60. A second fertilizer application with urea (85 kg N/ha) was 10 days after planting. The third application with ammonium sulphate (85 kg N/ha) was given

30 days after planting. Crop management, weeding and irrigation were performed according farmers' practice.

Harvest was on 13 October, 53 days after planting. Bulbs were then dried and cleaned in the open air till 16 October. Further drying and cleaning was carried out on 22 October. Total marketable bulb yield was determined at each step.

During the growing period, observations on the occurrence of *Spodoptera exigua* and anthracnose were performed. Starting September 8, randomly 10 selected plants per plot were weekly assessed on the number of *S. exigua* egg packages, the number of plants with *S. exigua* larvae, the number of total leaves per plant, and the number of leaves with *S. exigua* caterpillars. Also the intensity of anthracnose infection per plot was weekly recorded.

Based on field observations the Area Under the Disease Progress Curve (AUDPC) or Area Under the Pest Progress Curve (AUPPC) was calculated with the following formula:

$$A_k = \sum_{i=1}^{N_i-1} \frac{(y_i + y_{i+1})}{2}(t_{i+1} - t_i)$$

Where Y_i is the disease (Anthracnose) or pest (*Spodoptera E.*) level at a certain date (t_i) and Y_{i+1} at the following observation date (ti+1) (Madden et al. 2007).

Prices of the used pesticides in this experiment were collected at local agro-shops. The pesticide costs for each treatment were calculated based on the applied pesticide quantities. The costs do not include the costs of labour required for applying the pesticides. Based on the dried and cleaned yield of shallot the pesticide cost per kilo produced shallot was calculated.

3. Results

3.1 Temperature and precipitation

No precipitation was observed during the shallot experiment in Cirebon. Maximum temperature was about 40°C during the whole period from planting till harvest (Fig. 3.1). Minimum temperature was mostly about 25°C with some lower temperatures towards 20°C at the end of September.

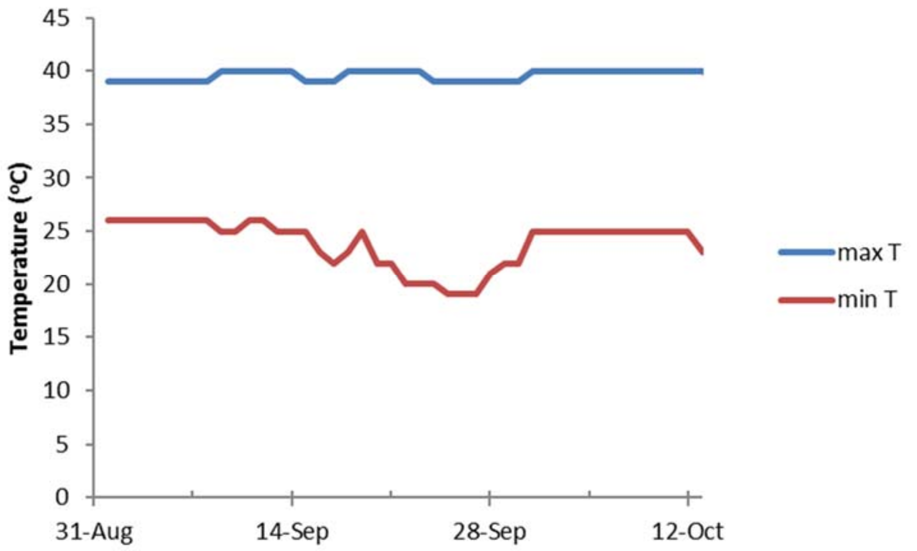

Figure 3.1 Daily minimum and maximum temperature (°C) at Cirebon, 2015.

3.2 Crop development

From the start, treatment P1 had more leaves, an indication of plant size, than other treatments (Fig. 3.2). Until 20 September, the untreated control (P8) showed a similar number of leaves as the treatments P2 - P7, but after that date the number of leaves was reduced.

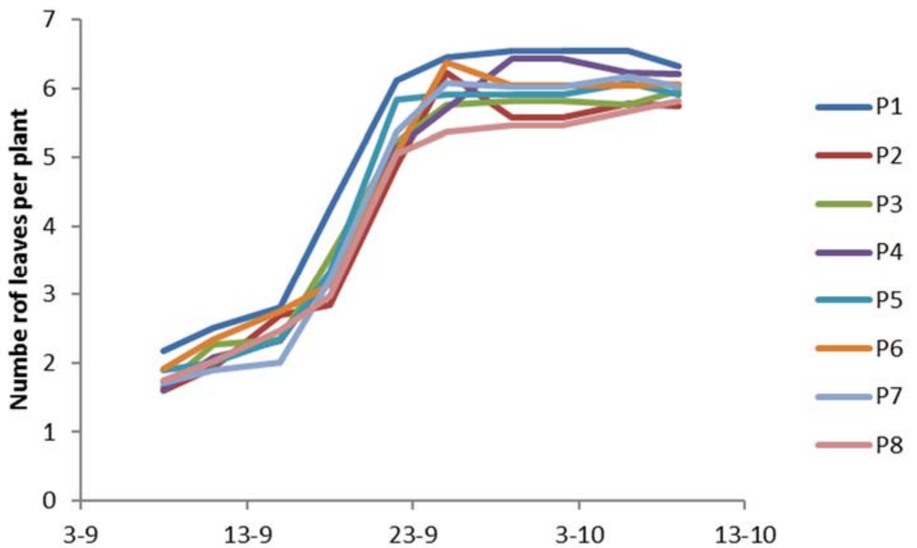

Figure 3.2 Development of the average number of leaves per plant in shallot.

The area under the progress curve for number of leaves of P1 showed the highest number of leaves of 1589 (Table 3.1). No significant differences were observed between the other pesticide treatments P2 to P7. The untreated control was not significantly different from the pesticide treatments of P2 to P7 with exception of P1 and P6, fungicides only.

Table 3.1 Area Under Progress Curve (AUDPC) of the number of shallot leaves per plant.

Pesticide treatment	Active ingredients [1)]	AUDPC	Statistical difference
P1	MDLPC	1589	c
P2	MDP	1352	ab
P3	MDL	1393	ab
P4	MDLP	1433	ab
P5	MDC	1424	ab
P6	MD	1442	b
P7	MD/LPC	1403	ab
P8	UTC	1319	a
Average		1419	
p		0.007	
$LSD_{0.05}$		119	

[1)] M=mancozeb; D= Difenoconazole; L= Lamda-cyhalothrin; P=Profenofos; C= Chlorantraniliprole; UTC = untreated control.

3.3 Presence of Anthracnose and *Spodoptera exigua*.

During the growing season no Anthracnose was observed in the shallot experiment.

Spodoptera exigua was present in the experiment and differences among treatments were identified. On September 8, egg packages were found in all treatments (Fig. 3.3). The highest number of egg packages was found in P3 and the lowest number in P7 and P5. The number of egg packages in P3 was significantly higher than all other treatments. The next, but much smaller peak in the number of egg packages was observed in P3 and P4 at 22 September and in P6 and P8 (untreated control) at September 25 (Fig. 3.3).

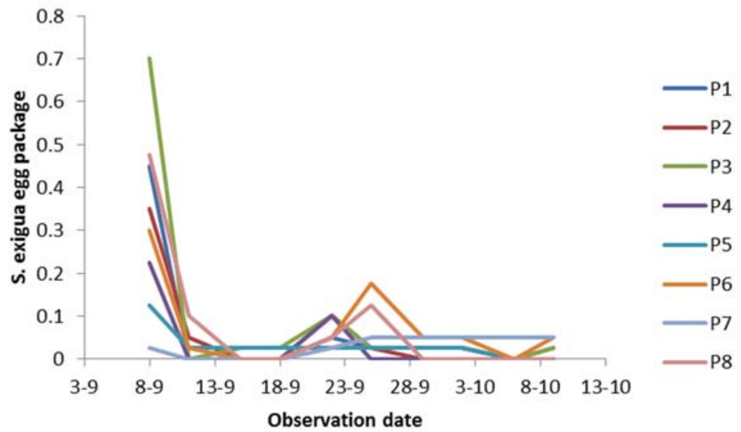

Figure 3.3 Number of Spodoptera exigua egg packages per plant. (Treatment x observation date: p=0.027, LSD 0.05 = 0.17).

On September 8 and September 25, peaks were observed regarding the number of larvae per leaf (Fig. 3.4). On September 8, treatment P6 had the highest number of larvae and on September 25 the untreated control P8. The treatments P2, P3, P5 and P7 had at some stage in the growing season more larvae than the treatments P1, P4, P6 and P8.

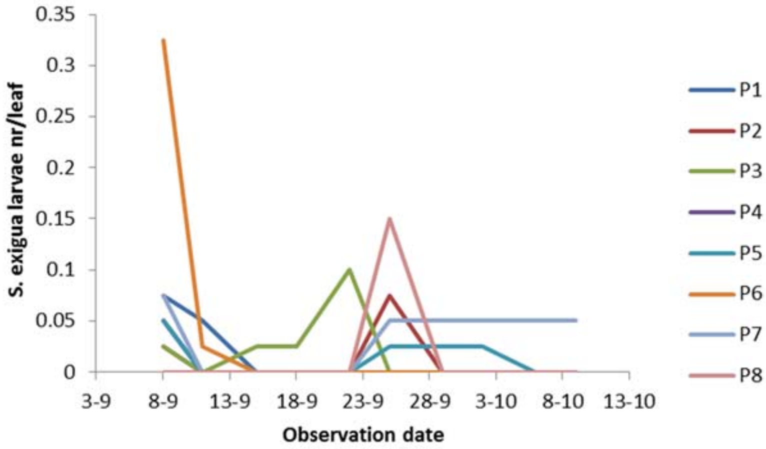

Figure 3.4 Number of Spodoptera exigua larvae per leaf.

There was no interaction between treatment and observation date in terms of the percentage of leaves with *Spodoptera exigua* larvae (p=0.18) (Fig. 3.5). A high percentage of leaves, i.e. 10 to 30% of the plant leaves had larvae on September 8. Then the infection percentage gradually decreased until it reached a lowest level on September 22. After this date, the percentage of leaves with *Spodoptera exigua* larvae increased in all treatments with the highest percentage observed in the untreated control (Fig. 3.5). On average, the untreated control showed the highest percentage (p <0.001) of leaves infected with *Spodoptera exigua* larvae while the treatment P1 showed the lowest percentage of infected leaves.

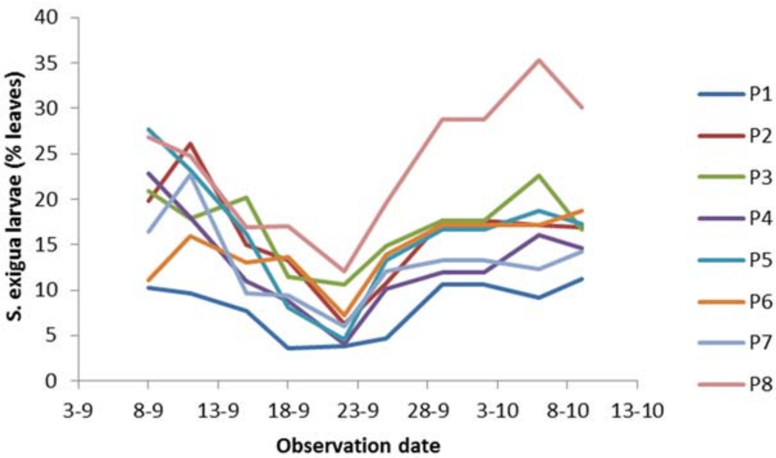

Figure 3.5 Percentage of leaves with Spodoptera exigua larvae.

The area under the pest progress curve (AUPPC) with *Spodoptera exigua* was 241 for treatment P1, which was significantly lower than the AUPPC for treatment P7 (Table 3.2). Treatment P1 was also significantly lower than treatment P4 with no chlorantraniliprole was applied. Among the treatments P2, P4, P5, P6, and P7 no significant differences were observed. Remarkably, the AUPPC of P3 with fungicides and the broad-spectrum insecticide lambda-cyhalothrin was not different from P6 with only fungicides. The AUPPC of the untreated control (P1) was significantly higher than the other treatments, including the fungicide only treatment P6.

Table 3.2 Average number of shallot leaves with Spodoptera exigua larvae (% of total number leaves per plant) of all observation dates and Area under the pest progress curve (AUPPC) of % leaves with larvae.

Pesticide treatment	Active ingredients [1)]	Average number of leaves with larvae (%)	AUPPC of % leaves with larvae
P1	MDLPC	8.1 a	241 a
P2	MDP	16.0 c	488 b
P3	MDL	17.0 c	520 c
P4	MDLP	12.9 b	378 b
P5	MDC	16.2 c	478 b
P6	MD	14.5 bc	448 bc
P7	MD / LPC	12.9 b	391 b
P8	UTC	24.0 d	726 d
Average		15.2	459
p		<0.001	< 0.001
$LSD_{0.05}$		2.5	113

[1)] M=mancozeb; D= Difenoconazole; L= Lamda-cyhalothrin; P=Profenofos; C= Chlorantraniliprole; UTC = untreated control.

3.4 Yield

The fresh shallot yield of P1 was significantly higher than that of the other treatments with the exception of P7 with the separate application of a fungicide mix and an insecticide mix (Table 3.3). The treatments of P2, P3, P5 and P6 were not significantly different from the untreated control P8. The treatment P1 had the highest dry yield which significantly higher than P7. The dry yield of treatment P7 was similar to P4, and the yield of the untreated P8 was not different from P3.

Dried and cleaned yield of treatment P1 was highest (Table 3.3). Yield of untreated (P8) and P3, fungicides plus lambda-cyhalothrin, was lowest. Treatment P2, fungicides only, and P6, fungicides plus profenofos, showed the same yield which were significantly higher than the untreated control P8. The treatment P7 in which all pesticides were mixed but applied at different dates (in two applications), showed a significantly lower yield than treatment P1 with the same pesticides but applied all at once in one mix.

On average, the weight loss of shallots was 33% with no significant differences between treatments (Table 3.3).

Table 3.3 Yield of shallots at harvest, after drying and after cleaning and weight loss of shallots between fresh and cleaned product.

Pesticide treatment	Active ingredient [1)]	Fresh yield (t/ha)	Dried yield (t/ha)	Dried and cleaned yield (t/ha)	Weight loss (%)
P1	MDLPC	53 e	43 d	36 e	32
P2	MDP	42 abc	34 abc	28 b	32
P3	MDL	38 a	30 a	26 a	31
P4	MDLP	45 cd	36 bc	31 cd	32
P5	MDC	44 bcd	35 bc	30 c	32
P6	MD	42 abc	32 ab	28 b	33
P7	MD / LPC	49 de	38 c	32 d	35
P8	UTC	39 ab	30 a	26 a	34
Average		44	35	30	33
p		< 0.001	< 0.001	< 0.001	0.7
LSD		5.9	4.5	1.9	5.1

[1)] M=mancozeb; D= Difenoconazole; L= Lamda-cyhalothrin; P=Profenofos; C= Chlorantraniliprole; UTC = untreated control.

3.5 Economics

Pesticide costs per kg of dried and cleaned shallot product are shown intable 3.4. The treatment P7 had the highest pesticide cost price followed by P1 with mixed pesticides in one application. However, labour costs associated with the application of the pesticides was not accounted for in calculating the pesticide cost price.

Table 3.4 Pesticide cost per kg dried and cleaned shallot.

Pesticide treatment		Pesticide costs of dried and cleaned product (IDR/kg)	
P1	MDLPC	263	d
P2	MDP	151	c
P3	MDL	143	c
P4	MDLP	168	c
P5	MDC	240	d
P6	MD	100	b
P7	MD / LPC	299	e
P8	UTC	0	a
Average		170	
p		<0.001	
LSD		28.5	

4. Conclusions

- In the shallot experiment carried out in Sumber Lor, West Java, in 2015 the disease pressure of Anthracnose was low associated with the dry season. There was a moderate pressure of *Spodoptera exigua*.
- The average yield of dried and cleaned shallot was relatively high compared to average farmer yields in the region (15 to 20 t/ha). Also the yield of the untreated control (P8) was quite high.
- Considering the pesticide mixes that were assessed in the experiment the following conclusions can be drawn:
  - The used fungicides had no negative effect on the efficacy of the used insecticides. The treatment P1, a mix of two fungicides and three insecticides applied simultaneously, showed the best control of *Spodoptera exigua*.
  - P7 also gave a good control of *Spodoptera exigua* with the same mix of pesticides, but fungicides and insecticides applied at different dates. However, P7 did not give a better control than P1. Based on this observation and the previous point, it may be concluded that there is no need to spray insecticides and fungicides separately.
  - Since no Anthracnose was found, the effect of insecticides on the fungicide efficacy could not be established.
  - A mix of profenofos, lambda-cyhalothrin and chlorantraniliprole provided a better control of *Spodoptera exigua* than each of them applied separately. This might be an indication of some level of resistance of *Spodoptera exigua* against pesticides because single products seem less efficient in controlling this pest.
  - Lambda-cyhalothrin was less effective in controlling *Spodoptera exigua* compared to profenofos and chlorantraniliprole. The reason for the lower efficacy might be associated with resistance development of *Spodoptera* against lambda-cyhalothrin (see previous point).
  - Fungicides only also showed a controlling effect on the insect *Spodoptera*. This may imply that the spraying activity itself results in a reduction of the *Spodoptera* population or that the fungicide influences *Spodoptera*. Further study is needed to investigate the reason of the observed effect of fungicide application on *Spodoptera*.
  - The mix of all pesticides (mancozeb, difenoconazole, profenofos, lambda-cyhalothrin and chlorantraniliprole), either applied all together (P1) or applied in split applications with only insecticides or fungicides (P7), showed the best control of *Spodoptera*. However, they were also the most costly. In terms of costs per kg these treatments were almost twice as expensive as spraying with only Profenofos (P2) or Lamda-cyhalothrin (P3). In practice, however, farmers will save labour costs by applying pesticide mixes. But this was not the topic of this study, which focused on the effectiveness of pesticide mixes in controlling Anthracnose and *Spodoptera exigua.*