Fate of Insecticide Acephate and Metabolite in Vegetable and Soil

by
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Green mustard

Green mustard (Sawi hijau or Cai sim) is a vegetable crop widely grown and consumed in Malaysia and other Asian countries. It is grown throughout the year with a very short crop rotation cycle of about one month. Different types of insecticides are used on green mustard; the choice depends partly on the time interval between insect attack and crop harvest, and the pre-harvest interval (PHI) of the insecticides. Frequency of spray depends on size and nature of insect populations, and on climatic and other site characteristics.

Insecticide acephate

Acephate is commonly used to control insects in vegetable production systems. It quickly degrades to methamidophos which is more toxic to human than acephate. Acephate is hydrophilic with very high water solubility (650 g/L at 25^{o}C). The vapour pressure (25^{o}C) of acephate is 0.2 mPa.

Pesticide deposition and dissipation

Many factors contribute to acephate deposition and residue dissipation, e.g. the morphology of the crop, cuticle characteristics, stage of growth at treatment, growth rate, pesticide application method (formulation, rate, nozzle type), and climate (sunshine, rainfall and temperature). Usually, pesticide dissipation rates are crop-specific, and hence its residues must be examined individually according to the prevalent climatic conditions of a country. Data on dissipation of pesticides in tropical vegetables are relatively few. Higher and frequent rainfall, high temperatures and higher solar radiation can increase the rate of pesticide dissipation in the tropics.

Maximum Residue Limit (MRL)

The World Health Organization/Food Agriculture Organization Codex Alimentarious Commission (Codex) provides the permitted level or Maximum Residue Limit (MRL) for pesticide residues in food. The Codex MRL for acephate in lettuce is 5 mg/kg. The Malaysian MRL for acephate in green mustard is 0.01 mg/kg.

Climate

The maximum and minimum air temperatures during the experimental periods were close to 32^{o}C and 23^{o}C respectively, while the average relative humidity was 84 %. The meteorological data for mean air surface temperature, sunshine and rainfall varied at the three experimental sites. In general, the mean air surface temperature ranged from 24.8 to 28.2^{o}C. The amount of sunshine was higher (23.3-55.4h) at the Balai Ringin site as compared to the other two sites (7.4-41.6h). The rainfall also varied from no rainfall to the highest of 170 mm per week at Tarat.

Field dissipation studies

Three locations differing with respect to soil type and climate were used for the experiments: Balai Ringin, Tarat and Semongok. Before planting, the soils were tilled and chicken manure was incorporated into the soils at 0.5 kg/m^{2}. Three fertilizer applications (12:12:17:2; N:P:K:Mg at 50g/m^{2}) were carried out during planting at 10 days interval. Young seedlings of

green mustard (20 days old) were transplanted from nursery into the field at a density of 16 per m^2. Five liters of diluted acephate (75% w/w) solutions were sprayed onto the three replicate plots of green mustard using a knapsack sprayer, immediately after young seedlings had been transplanted into the field. Pesticides were applied again on green mustard three more times, at weekly intervals, on day 7, 14 and 21 after transplanting.

Newly transplanted green mustard

Fully grown green mustard

Soil characteristics

The three soils used in this study were all acidic. The gravimetric water and carbon contents of the soils ranged from 22-33 % and 1.4-2.2 %, respectively. The Balai Ringin soil had the lowest clay and highest sand contents (5.9 %; 76.3 %) compared to Tarat soil (13.9 %; 68.9 %) and Semongok soil (23.1 %; 45.1 %). X-ray diffractometry on ground soils showed that the clay fraction is dominated by kaolinite and a vermicullitic phase; in addition the less weathered Tarat soil contains illite. Many root channels, macro pores and cracks were found in the three soil profiles.

Dye showed root channels, macro pores and cracks in the subsoil

Dissipation of acephate residues on green mustard

The concentrations of acephate in green mustard were monitored after the last acephate application on day 21. Dissipation of acephate was observed with 30-45 % decrease in concentrations from day 21 to 23. At day 25, acephate residues were between 3.50-4.47 mg/kg, which are below the MRL of 5 mg/kg for lettuce (Codex MRL). A period of 13 days

elapsed before acephate dissipated completely to comply with the national MRL. Differences in acephate concentrations among the three sites were observed after the last spraying, day 21 (8.8-14.0 mg/kg). The differences in initial acephate concentrations (8.8-14.0 mg/kg) among sites at day 0 were probably due to different plant sizes as bigger plants with larger leaf surface area trap higher amounts of pesticide compared to smaller plants. The green mustard at the Balai Ringin site had the largest leaf area and hence had the highest content of pesticide residues.

Equipment used to detect acephate

Acephate extracted from green mustard

Metabolite methamidophos

The highest concentration of methamidophos was detected between day 21 and 23. Concentrations of the methamidophos (5.13 mg/kg), only exceeded the Codex MRL of 5 mg/kg (for lettuce) at the Balai Ringin site, in association with the high acephate concentration at this site. Methamidophos dissipated gradually to 0.01 mg/kg in compliance with the national MRL at day 13 after the last acephate application. Thus, acephate should not be recommended for use on green mustard unless a longer PHI of more than 13 days is specified.

Half-lives

The half-lives of acephate (time needed to reduce the amount of acephate to 50% from its initial concentration) were 2.5 days, 1.6 days, and 2.1 days for Semongok, Tarat and Balai Ringin sites, respectively. As expected for a tropical climate with high solar intensity and high rainfall, the half-lives of acephate reported in our study (1.6-2.5 days) were shorter compared to those reported earlier for tomato (5.8 days), cucumber (3.7 days), and pepper (6 days), grown under a temperate climate.

Effect of rainfall and sunlight

Rainfall, and hence pesticide wash-off from leaves can cause rapid dissipation of pesticides. The acephate dissipation from day 0 to 4 after the last application followed the order Tarat > Balai Ringin > Semongok. This is in reasonable agreement with rainfall data: Tarat (27 mm, day 0), Balai Ringin (10.5 mm, day 0; 33.5 mm, day 1) and Semongok (12 mm, day 2). Losses of pesticides by solar radiation are directly related to the input of solar radiation and heat. High volatility of pesticides has been commonly observed, and photodegradation influences organophosporus insecticides such as acephate. The vapour pressure for acephate is 0.2 mPa. Thus, solar radiation and hence volatilization and photodegradation may also contribute to dissipation in green mustard.

Degradation of acephate on topsoils

The dissipation of acephate in topsoils occurred immediately after the first pesticide application. Initial acephate concentrations after the first spraying were between 0.56-1.51 mg/kg while the highest acephate concentrations of 3.57-5.25 mg/kg were detected at day 14 after the 3rd spraying. Acephate dissipated completely at day 28 (Tarat and Balai Ringin) and day 35 (Semongok), i.e. 7-14 days after the last spraying. Low amounts of acephate in the range of 0.06-0.26 mg/kg were detected in soils at day 7 immediately before the second acephate application on green mustard but none were found at day 14 and 21 before the new pesticide applications.

Dissipation of acephate in topsoil was rapid. This is evidenced from the low amounts of acephate (0.06-0.26 mg/kg) detected in soils at day 7 before the second acephate application on green mustard and none were found at day 14 and 21 before the new pesticide applications. This indicates that either the acephate might have degraded completely or leached into the subsoil during the 7-day period between pesticide applications. Although additional acephate was added at the last spraying at day 21, the soil concentrations were lower than after the 3rd spraying at day 14 likely because the green mustard retained higher amounts of the pesticide spray at day 21. Similarly, at day 21, the Tarat soil contained double the amounts of acephate compared with Semongok and Balai Ringin, most likely due to the smaller size and less leaf coverage of the green mustard plants at the Tarat site.

Half-lives

The half-lives for acephate after the last (4th) acephate application on day 21 were 2.6 days, 1.4 days, and 1.8 days for Semongok, Tarat and Balai Ringin soils, respectively.

Metabolite methamidophos

The metabolite of acephate, methamidophos, was found in all the three soils with concentrations in the range of 0.03-0.16 mg/kg after the first spraying. However, the residue levels were very low throughout the 35 days period (0.03-0.20 mg/kg). Methamidophos dissipated rapidly in all soils and could not be detected at day 7 (Tarat and Balai Ringin soil) and day 14 (Semongok) after the last (4th) pesticide treatment in agreement with its fast degradation.

Flowering green mustard at the end of experiment

CONCLUSION

The persistence and dissipation of the acephate in green mustard and soil varied among sites and may have been affected by plant size, soil type, rain and solar radiation. The half-lives of acephate in green mustard and topsoil were almost similar (about 2 days). Rainfall was associated with acephate dissipation in green mustard. High solar radiation and hence volatilization and photo-degradation appeared to increase acephate dissipation in the vegetables. A PHI of 13 days was required for acephate (including its metabolite), to degrade below the national tolerance levels in green mustard. Vegetable shading appeared to retard pesticide degradation in soil. The metabolite methamidophos was observed at low levels of below 3.22 mg/kg in topsoil and dissipated completely between 28 and 63 days, depending on the soils. The results from this study show that the metabolites need to be taken into account when establishing the national permitted levels and also when making recommendations for their use.