Journal of Postharvest Technology
2018, **06**(3): 87-96
http://www.jpht.info

RESEARCH ARTICLE

Studies on the dissipation pattern of Thiacloprid and Hexythiazox on apple in Kashmir

Abid S. Khan[1], Bilal Sheikh[1], Zakir S. Khan[2]* and Mohmad Sayeed Bhat[3]

[1]Sheri- Kashmir University of Agricultural Sciences and Technology, Division of Entomology, Shalimar, Srinagar, Kashmir- 191121
[2]Islamic University of Science and Technology, Awantipora, Kashmir-192123
[3]Institute of Chemical Technology. Matunga, Mumbai-400019

Received: 02.06.2018 Accepted: 15.07.2018

ABSTRACT

Indiscriminate use of pesticides against insect pests and diseases pose a potential threat to our living environment. . Exposure to the pesticide residues causes number of ailments in human beings. Food commodities like fruits, vegetables, cereals etc. having excessive residues, are unacceptable both in the national and international markets. It was, therefore thought pertinent to undertake the investigation on the determination of pesticides residues in apple and to study the dissipation behaviour of the two newly inducted pesticides thiacloprid (21.7SC) and hexythiazox (5.45EC). An apple orchard at Lousdanew (Shopian Kashmir India) having 15 years old Red Delicious cultivar was selected for the experiment. Each pesticide was sprayed at two concentrations, thiacloprid (21.7SC) at the concentration of 0.0096 and 0.0192 percent and hexythiazox (5.45EC) at the concentration of 0.002 and 0.004 percent, were applied by 30th August before one month of harvesting apple fruit. . Representative samples weighing about 1kg were taken and reduced to 15g by standard quartering technique for residue analysis, by using Buffered QuEChERS technique and quantified on HPLC Dionex 3000 ultimate with PDA detector. The residues of thiacloprid (21.7SC) on Red Delicious apples recorded initial deposits of 0.784 ppm and 0.901 ppm from 0.0096 and 0.0192 percent concentrations with a dissipation of 91.07 and 89.78 percent in 15 days, respectively. The dissipation was dose dependent as residues from higher concentration of 0.0192 percent persisted for 30 days while residues from lower concentration of 0.0096 percent persisted only up to 15 days. Similar behaviour was observed in case of hexythiazox (5.45EC) as the higher concentration of 0.004 percent left an average initial deposit of 0.790 ppm which recorded dissipation of 99.74 percent in Red Delicious apples and residue persisted up to 30 days (harvest time) while the lower concentration of 0.004 percent left an average initial deposit of 0.670 ppm in Red Delicious cultivar which recorded dissipation of 99.73 percent, and residues persisted up to 15 days only. Both concentrations of hexythiazox degraded faster than thiacloprid which degraded fairly slowly. The higher concentration of thiacloprid (0.0192 percent) degraded with half-life value of 6.57 days while the lower concentration of 0.0096 percent dissipated with half-live value of 4.70 days in Red Delicious varieties. Similarly, the higher concentration of hexythiazox 0.004 percent degraded with half-life value of and 6.68 days while the lower concentration of 0.002 percent dissipated with half-live values of 1.88 days in Red Delicious varieties. The residues of both pesticides at recommended concentrations could not be detected in harvest time fruits indicating 100 percent dissipation of pesticides at the harvest time. Based on the MRL value of 0.3 mg/kg for thiacloprid on Red Delicious, the waiting periods of 5.82 and 7.17 days at 0.0096 and 0.0192 percent concentrations, respectively, were worked out for the safe consumption of the fruit. Again, on the basis of 0.2 mg/kg MRL value of hexythiazox on Red Delicious, the waiting periods of 4.37 and 9.31 days at 0.002 and 0.004 percent concentrations, respectively were worked out for the safe consumption of the fruit.

***Key words*:** Apple; thiacloropid; hexythiazox; MRL, pesticidal use

Citation: Khan, A.S., Sheikh, B., Khan, Z.S. and Bhat, M.S. 2018. Studies on the dissipation pattern of thiacloropid and hexythiazox on apple in Kashmir. *Journal of Postharvest Technology*, **6**(3): 87-96.

INTRODUCTION

Apple (*Malus domestica* Borkh.) is a typical temperate fruit, primarily growing in USA, China, France, Italy, Turkey, Spain and Japan (Thompson, 1989). The world's production of apple is about 59.51 million tonnes (Anonymous, 2013a). The commercial cultivation of apple fruit in India is confined to the states of Jammu and Kashmir, Himachal Pradesh and Uttaranchal and to a

* *For correspondence:* Z.S. Khan (Email: khanzakir204@gmail.com)

ISSN: 2348-4330

limited extent to the states of Arunachal Pradesh, Sikkim, Nagaland, Meghalaya and Manipur covering a total area of 283.3 thousand hectares with an annual production of 2891 thousand metric tonnes (Anonymous, 2013b). The area under apple cultivation in Kashmir valley is 131.822 thousand hectare which accounts for 1337 thousand metric tonnes production and productivity about of 12-15 tonnes per hectare (Anonymous, 2013).

In spite of the unique agro climatic conditions of the Kashmir valley being quite conducive for temperate fruit production, apple productivity per unit area is still low owing to many biotic and abiotic factors. The major biotic factors inflicting huge economic losses are the insect pests, the prominent among them being San jose scale (*Quadraspidiotus perniciosus* Comstock), Woolly Aphid (*Eriosoma lanigerum* Hausmann), stem borer (*Apriona cinerea* Solsky) and European red mite (*Panonychus ulmi* Comstock), (Sharma and Bhardwaj, 1999).

Keeping in view the loss caused by these pests, a large number of insecticides and acaricides comprising of systemic and non-systemic are being sprayed on apple trees to manage the pest populations. Insecticides and miticides are very important and have found permanent place in the integrated spray schedule of SKUAST-Kashmir. However, it is important to remember that any pesticide should be considered an active poison (Kaufman and Weeks, 2006). These pesticides are being sprayed throughout the growing season at different phenological stages and some of the sprays coincide with maturity and harvesting of most apple cultivars. Because of the use of pesticides there is every apprehension of their occurrence in apple fruits affecting the environment as well as human health to a greater extent. The increasing public concern in recent years about the possible health risk due to the pesticide residues in the diet has deeply modified the strategy for crop protection, with emphasis on food quality and safety and the wide spread concern for the health of society lead to the strict regulation of maximum residue limits (MRLs) of the pesticide residues in food commodities (Safi *et al.*, 2002). It has been found that human poisoning by pesticides through the world has increased from 5 lakh cases per year in 1972 to 250 lakh cases per year in a 1990 estimate (Levine and Doull, 1992). This warrants a thorough study of pesticides on different food commodities for the safety of consumers.

Despite the fact that the consumption of pesticides in India is still very low, about 0.5 kg a.i/ha of pesticides against 6.60 and 12.00 kg a.i/ha in Korea and Japan, respectively. There has been a widespread contamination of food commodities with pesticide residues, basically due to non-judicious use of pesticides. In a survey carried out by the Indian Agriculture Research Institute (IARI), New Delhi, it was found that 51 percent of our food commodities were contaminated with pesticide residues and out of these 20 percent had pesticide residues above the MRL values (Agnihotri, 1999).

Non judicious use of pesticides for pest and disease management has given rise to the problem of pesticide residues not only in different environmental matrices but also in food commodities. Pesticides gain entry into the human system through the consumer items like fruits, vegetables, cereals etc. and their build-up may result in bio magnification of toxic residues over a period of time which may lead to acute and chronic toxicities to human beings. Such a state of affairs warrants periodic screening of the food items for pesticide residues in them. The present investigations were, therefore, carried out to study the dissipation of thiacloprid (21.7SC) at 0.0096, 0.0192 percent and hexythiazox (5.45 EC) at 0.002, 0.004 percent on apple with a view to assay their dissipation and accordingly work out their waiting periods for safe consumption of the apple.

MATERIALS AND METHODS

Studies on the determination of pesticides residues in apple (*Malus domestica* Borkh.) cultivar viz; Red Delicious were carried out in the Research Centre of Residue and Quality Analysis of Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir (SKUAST-Kashmir), Shalimar, Srinagar during the year 2013-2014.

Field trial

To determine the dissipation behavior of two pesticides in Red Delicious apples, a 17-year old commercial orchard at Lousdenew (Shiopian) was selected. Two pesticides viz; hexythiazox (5.45 EC) at 0.002 percent (recommended concentration of SKUAST-Kashmir), 0.004 percent (double the recommended) and thiacloprid at 0.0096 percent (recommended concentration of SKUAST-K), 0.0192 percent (double the recommended) on active ingredient basis, on Red Delicious apple trees were sprayed separately. Red Delicious being a mid-maturing variety was sprayed on 30 August, 2013, approximately one month before harvesting the fruit. The meteorological data during the experimental periods were collected.

Sampling

Samples of the fruit weighing 1kg each from the treated trees were collected from four directions of the tree at different elevations in transparent polyethene bags and taken to the laboratory for analysis. Samples were collected at the intervals of 0, 1, 3, 7, 10, 15 and 30 days after spray. Zero day samples were collected within 1 hour of spraying after the spray solution had properly dried up.

Extraction and clean up using QuEChERS technique

Thiacloprid: Thiacloprid residues were extracted and cleaned up by using QuEChERS technique developed by Michelangelo et al., (2003). The samples were analysed on HPLC Dionex 3000 ultimate with PDA detector.

Hexythiazox: The methodology used for the extraction and clean up of thiacloprid was also used in case of hexythiazox.

Preparation of Standard Curves

Standard calibration plots for thiacloprid and hexythiazox were prepared by adopting the procedure for residue analysis for each pesticide already described. Analytical grade thiacloprid and hexythiazox supplied by Dr. Ehrenstorfer GmbH, Germany were used for the preparation of standard curves. Different concentrations of thiacloprid and hexythiazox in the range of 0.010 to 1.00 ppm for both thiacloprid and hexythiazox were used for the preparation of standard curves.

Recovery

Authenticity of the procedure was tested by the recovery of pesticides. Thiacloprid and hexythiazox were determined by fortifying 15 g of apple samples individually with 0.20, 0.30 and 0.40 ppm of thiacloprid and 0.10, 0.20 and 0.30 ppm of hexythiazox. After 4 hours, the samples were extracted, cleaned and assayed for each pesticide by the procedure described.

Analysis of data

The residues of thiacloprid and hexythiazox in ppm were determined by using following formula:

$$\text{Residues in ppm} = \frac{\text{Peak area of sample in mAU} \times \text{Conc. of standard in mg} \times \text{Sample volume in ml}}{\text{Peak area of standard} \times \text{Vol. of sample injected (µl)} \times \text{Wt. of sample in grams}}$$

$T_{1/2}$ values corresponding to the rate of dissipation is the time period required for half of the applied pesticide to disappear from the fruit and waiting period T_{total} is the time taken for a pesticide residue to get dissipated to the level of Maximum Residue Limit (MRL) and both were calculated by the method of Hoskins (1961).

$$T(1/2) = \frac{\text{Log } 2}{B}$$

$$T(\text{total}) = \frac{\{a - \log(103 \times \text{MRL})\}}{B}$$

Where 'a' is the intercept of y axis (x = 0) and b is the slope of the line

RESULTS

Residues of thiacloprid in/on apple cv. Red Delicious at recommended concentration of 0.0096 percent

The data on the dissipation of thiacloprid (21.7SC) applied at 0.0096 percent concentration is presented in Table 1 and Fig 1. A Perusal of the data in Table 1 showed that thiacloprid (21.7SC) at a concentration of 0.0096 left an initial deposit of 0.784 ppm on the apple fruits at Zero day after application. The residues decreased slowly with the passage of time and reduced to 0.540, 0.444, 0.280, 0.190 and 0.070 ppm in 1, 3, 7, 10 and 15 days after application respectively. The residues dissipated gradually recording 31.122, 43.367, 64.285, 75.765 and 91.071 percent dissipation after 1, 3, 7, 10 and 15 days, respectively. The residues could not be detected on 30th day after the application which indicated that either the pesticide fell below the detection limit or had dissipated to 100% in 30 days (i.e. at harvest time of the apple). The residues dissipated with a $T_{1/2}$ value of 4.70 days. On the basis of MRL of 0.3 ppm for thiacloprid on apple, a T_{total} value of 5.82 days was worked out.

Table 1: Dissipation (mean ± SD) of thiacloprid in apple fruit cv. Red Delicious at recommended concentration of 0.0096 percent

Days after treatment	Average residues (mg/kg)	Dissipation (mg/kg)	% Dissipation
0	0.784±0.020	-	-
1	0.540±0.025	0.244	31.122
3	0.444±0.010	0.340	43.367
7	0.280±0.008	0.504	64.285
10	0.190±0.002	0.594	75.765
15	0.070±0.001	0.714	91.071
30 (At harvest)	BDL		100
Mean	0.385		

$T_{1/2}$ =4.70 days, T_{total}= 5.82 days, BDL = Below Detectable Level, p-value = 0.001, Correlation coefficient 'r' = -0.99, MRL = 0.3 mg/kg

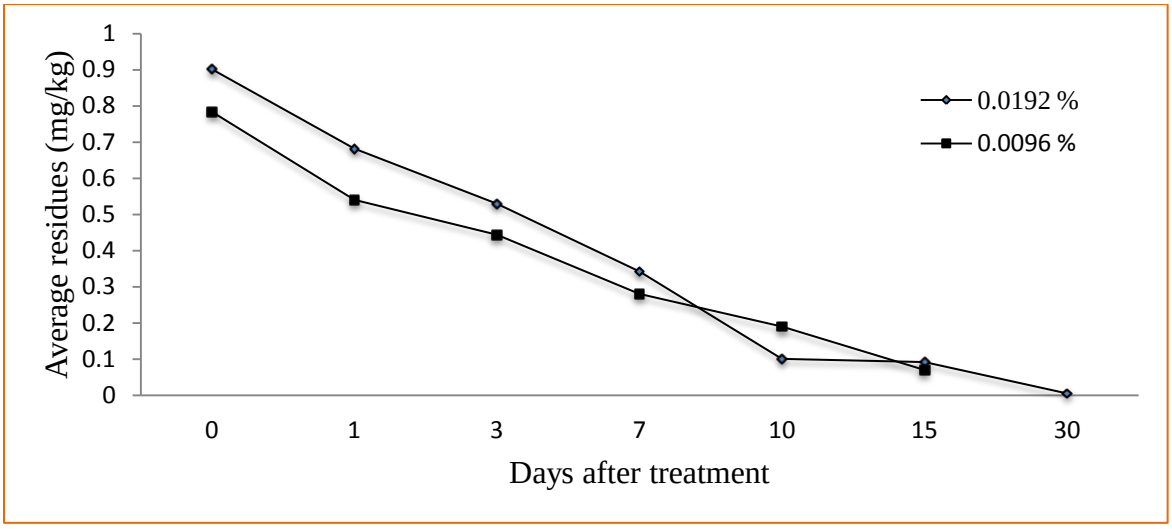

Fig. 1: Average residues of thiacloprid with days after treatment at concentrations of 0.0096 and 0.0192 percent in Red Delicious**.**

Residues of thiacloprid in/on apple cv. Red Delicious at double the recommended concentration of 0.0192 percent

The data on the dissipation of thiacloprid applied at 0.0192 percent concentration is presented in Table 2 and Fig 1. A Perusal of the data in Table 2 and Fig 1 showed that at higher concentration of 0.0192 percent thiacloprid (21.7SC) left an initial deposit of 0.901 ppm on the apple fruits at zero day after application. The residues decreased slowly with the passage of time and reduced to 0.683, 0.530, 0.342, 0.101, 0.092 and 0.005 ppm in 1, 3, 7, 10, 15 and 30 (at harvest time of apple) days after the application of respectively. The residues dissipated gradually recording 24.30, 41.17, 62.04, 88.79, 89.78 **and 99.44** percent dissipation after 1, 3, 7, 10 and 15 and 30 days, respectively. The residues dissipated with a $T_{1/2}$ value of 6.57days. On the basis of MRL of 0.3 ppm for thiacloprid on apple, a T_{total} value of 7.17 days was worked out.

Table 2: Dissipation (mean ± SD) of thiacloprid in apple fruit cv. Red Delicious at double the recommended concentration of 0.0192 percent

Days after treatment	Average residues (mg/kg)	Dissipation (mg/kg)	% Dissipation
0	0.901±0.032	-	–
1	0.682±0.027	0.219	24.30
3	0.530±0.019	0.371	41.17
7	0.342±0.014	0.559	62.04
10	0.101±0.010	0.800	88.79
15	0.092±0.009	0.809	89.78
30 (At harvest)	0.005±0.002	0.896	99.44
Mean	0.379		

$T_{1/2}$= 6.57 days, T_{total} = 7.17 days, p- value = 0.001 , Correlation coefficient 'r' = -0.92, MRL = 0.3 mg/kg

Residues of hexythiazox in/on apple cv. Red Delicious at recommended concentration of 0.002 percent

The data on the dissipation of hexythiazox (5.45) applied at 0.002 percent concentration is presented in Table 3 and Fig 2.

Perusal of the data in Table 3 shows that 0.002 percent of hexthiazox (5.45 EC) left an initial deposit of 0.670 ppm on the apple fruits at zero day after application. The residue decreased slowly with the passage of time and reduced to 0.540, 0.320,

0.190, 0.047 and 0.0018 ppm in 1, 3, 7, 10 and 15 days after treatment respectively. The residues dissipated gradually recording 19.402, 52.238, 71.641, 92.985 and 99.731 percent after 1, 3, 7, 10 and 15 days respectively. The residues could not be detected at 30th day after the pesticide application which indicated that either the pesticide fell below the detection limit or had dissipated to 100% in 30 days (i.e. at harvest time of the apple). The residues dissipated with a $T_{1/2}$ value of 1.88days. On the basis of MRL of 0.2 ppm for hexythiazox on apple, a T_{total} value of 4.37 days was worked out.

Fig. 2: Average residues of hexythiazox with days after treatment at concentrations of 0.002 and 0.004 percent in Red Delicious.

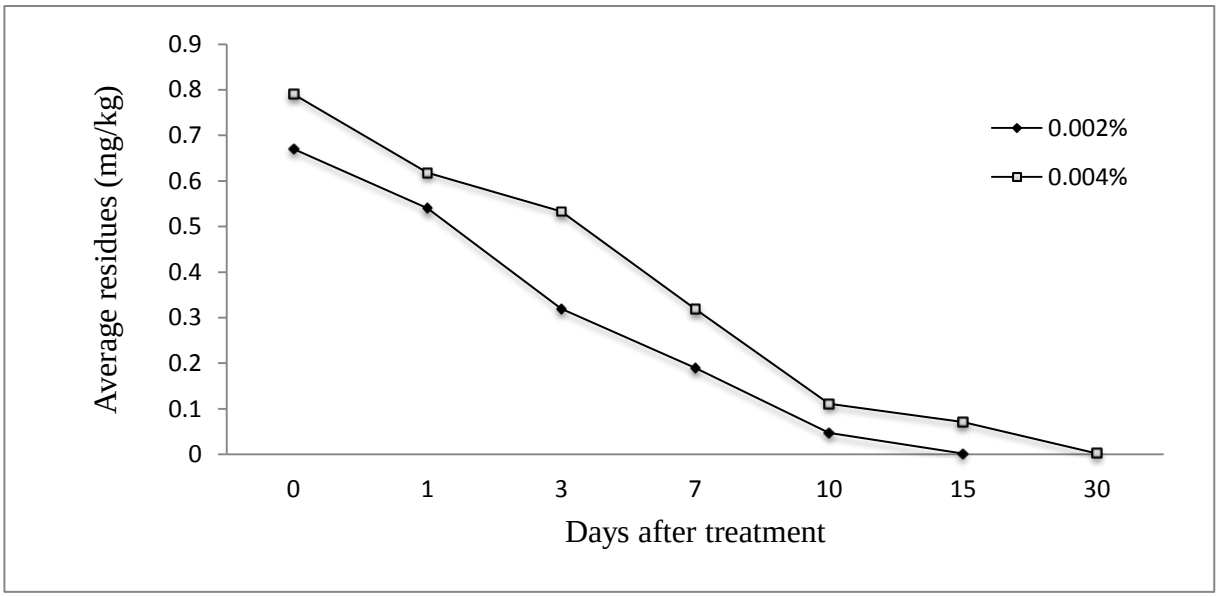

Table 3: Dissipation (mean ± SD) of hexythiazox in apple fruit cv. Red Delicious at recommended concentration of 0.002 percent

Days after treatment	Average residues (mg/kg)	Dissipation (mg/kg)	% Dissipation
0	0.670±0.019	-	–
1	0.540±0.015	0.130	19.402
3	0.320±0.011	0.350	52.238
7	0.190±0.007	0.480	71.641
10	0.047±0.005	0.623	92.985
15	0.0018±0.002	0.668	99.731
30 (At harvest)	BDL		100
Mean	0.294		

$T_{1/2}$= 1.88 days, T_{total}= 4.37 days, BDL = Below Detectable Level , p-value = 0.001, Correlation coefficient 'r' = -0.96 , MRL = 0.2 mg/kg

Residues of hexythiazox in/on apple cv. Red Delicious at double the recommended concentration of 0.004 percent

The data on the dissipation of hexythiazox (5.45 EC) applied at 0.004 percent concentration is presented in Table 4 and Fig 2.

A Perusal of the data in Table 4 shows that 0.004 percent of hexythiazox (5.45 EC) left an initial deposit of 0.790 ppm on the apple fruits at zero day after application. The residues decreased slowly with the passage of time and reduced to 0.618, 0.533, 0.319, 0.111, 0.071 and 0.002 ppm in 1, 3, 7, 10, 15 and 30 (at harvest time of apple) days after treatment respectively. The residues dissipated gradually recording 21.77, 32.53, 59.62, 85.94, 91.01 and 99.74 after 1, 3, 7, 10, 15 and 30 days respectively. The residues dissipated with a $T_{1/2}$ value of 6.68 days. On the basis of MRL of 0.2 ppm for hexythiazox on apple, a T_{total} value of 9.31 days was worked out.

Table 4: Dissipation (mean ± SD) of hexythiazox in apple fruit cv. Red Delicious at double the recommended concentration of 0.004 percent

Days after treatment	Average residues (mg/kg)	Dissipation (mg/kg)	% Dissipation
0	0.790±0.03	-	-
1	0.618±0.025	0.172	21.77
3	0.533±0.021	0.257	32.53
7	0.319±0.017	00471	59.62
10	0.111±0.012	0.679	85.94
15	0.071±0.008	0.719	91.01
30 (At harvest)	0.002±0.001	0.788	99.74
Mean	0.349		

$T_{1/2}$ = 6.68 days, T_{total}= 9.31 days, BDL = Below Detectable Level, p-value = 0.001, Correlation coefficient 'r' = -0.93, MRL = 0.2 mg/kg

DISCUSSION

The persistence and rate of degradation of pesticides varies with the crop and also with the agroclimatic conditions of the place (Teotia and Dham, 1950; Gupta, 1980). The pesticides generally dissipate rapidly in situations where high temperatures are experienced but degrade very slowly in situations where low temperatures exist (Verma and Lal, 1967). In Kashmir valley which has different climatic conditions, a limited number of studies have been directed to this arena of pesticide residue build up. It was therefore thought pertinent to undertake the present investigation on "Studies on the Dissipation pattern of Thiacloprid and Hexythiazox on Apple in Kashmir" so as to gain knowledge on the dissipation of thiacloprid and hexythiazox on apple.

Residues of thiacloprid on apple

The data on the dissipation of thiacloprid in Red Delicious cultivar of apple showed that thiacloprid @ 0.0096 and 0.0192 percent left an average deposit of 0.784 and 0.901 ppm. Similar observations was observed by Sahoo *et al.* (2013) who reported that thiacloprid left an average initial deposit of 0.48 and 1.05 mg/kg when sprayed at recommended and double the recommended doses respectively on brinjal. Our findings also draw support from the work of Omirou *et al.* (2009) who reported that thiacloprid left an average initial deposit of 0.740 when applied at normal dose on tomato fruits. A perusal of the data indicates that the higher concentration of 0.0192 percent thiacloprid dissipated slightly slowly as compared to lower concentration of 0.0096 percent. Higher concentration of 0.0192 percent persisted up to 30th day after spraying recording 99.44 percent dissipation on 30th day while lower concentration of 0.0096 percent persisted up to 15 days after spraying recording 91.071 percent dissipation. The dissipation pattern of residues appears to be dose dependent. These findings draw their support from the findings of Mohapatra *et al.* (2011) who reported that imidacloprid Confidor 200 SL sprayed @ 80 and

60 g a.i/ ha on grape berries left an average initial deposit of 0.74 and 1.26 mg kg^{-1} for lower and higher concentrations respectively.

Table 5: Comparative studies of two pesticides viz., Thiacloprid and Hexythiazox on Red delicious variety of apple in Kashmir

Pesticide	Concentration (ppm)	Initial deposit	$T_{1/2}$ (days)	MRL (mg/kg)	T_{total} (days)
Thiacloprid	0.0096	0.784	4.70	0.3	5.82
	0.0192	0.901	6.57	0.3	7.17
Hexythiazox	0.002	0.670	1.88	0.2	4.37
	0.004	0.790	6.68	0.2	9.31

A perusal of data in Table 5 indicates that the residues of thiacloprid at lower concentration of 0.0096 percent degraded with a half-life value of 4.70 days while the higher concentration of 0.0192 percent degraded with half life value of 6.57 days. These findings draw their support from the findings of Dubey *et al.* (2008) who reported half-life values of 4.60 and 6.50 for thiacloprid when sprayed @ 120 and 240 g a.i/ha on apples respectively. The T_{total} values of 5.82 and 7.17 days for lower and higher concentration of thiacloprid respectively are again an indication of slow rate of degradation of a pesticide for higher dose as compared to lower dose. The lower waiting periods of 5.82 days seem to be justified as is evident from the lower persistence of pesticides on apple. Since residues dissipated to the level of 91.07 percent in 15 days, it was inferred that the fruit did not contain any pesticide residue at harvest time. These findings draw their support from the work of Malhat *et al.* (2013) who reported 4.3-6.0 and 7.0-9.3 days of waiting periods for the safe consumption of apple when kresoxim methyl was sprayed @ 0.125 and 0.25 kg a.i./ha respectively.

Residues of hexythiazox on apple

The data on the dissipation of hexythiazox in Red Delicious cultivar of apple showed that hexythiazox @ 0.002 percent left an average initial deposit of 0.670 ppm while higher concentration of 0.004 percent had left an average deposit of 0.790 ppm. These findings draw their support from the findings of Abd-Alrahman (2012) who reported that hexythiazox (Maidan 5.45 EC) left an average initial deposit of 0.65 and 0.750 mg/kg on bean pods at normal and double doses respectively. These findings also draw their support from the work of Abd-Alrahman *et al.* (2012) who reported that fenpyroximate left an average initial deposit of 0.68 and 0.80 mg/kg when applied at recommended and double the recommended rates on apple fruits. A perusal of the data indicated that the higher concentration of 0.004 percent hexythiazox dissipated slightly slowly as compared to lower concentration of 0.002 percent. Higher concentration of 0.004 percent persisted up to 30th day after spraying recording 99.74 percent dissipation on 30th day after spraying while lower concentration of 0.002 percent persists up to 15 days after spraying recording 99.73 percent dissipation on 15th day after spraying. The dissipation pattern of residues appears to be dose dependent. These findings draw their support from the findings of Kumar *et al.* (2004) who reported that propargite sprayed on apple fruits at 0.125 and 0.250 kg a.i/ha left an initial deposit of 0.70 ppm and 0.85 ppm for lower and higher concentrations respectively.

A perusal of data in Table 5 indicates that the residues of hexythiazox @ 0.002 percent degraded with a half-life value of 1.88 days while at higher concentration of 0.004 percent the value were 6.68 days. These findings draw their support from the works of Kumar *et al.* (2005) who reported half-life values of 1-3 and 6.5-8 days for propargite when sprayed @ 0.6 and 1.2 kg a.i/ha on apple. The T_{total} values of 4.37 and 9.31 days observed in present investigations for lower and higher concentration of hexythiazox again is an indication of slow rate of degradation for higher dose (0.004%) as compared to lower dose (0.002%).

CONCLUSION

The residues of both pesticides at recommended concentrations could not be detected in harvest time fruits indicating 100 % dissipation of pesticides at the harvest time. Based on the MRL value of 0.3mg/kg for thiacloprid, the waiting periods of 5.82 and 7.17 days for 0.0096 and 0.0192 percent concentrations respectively were worked out for the safe consumption of the fruit. Likewise, on the basis of MRL value of 0.2 mg/kg for hexythiazox, the waiting periods of 4.73 and 9.31 days at 0.002 and 0.004 percent concentrations, respectively were worked out for the safe consumption of the fruit.

ACKNOWLEDGEMENT

Authors thank Mr. Malik Mukhtar and Mr. Bilal for their technical assistance during the course of study.

REFERENCES

Abd- Alrahman, S.H., Almaz, M.M. and Osama, I.A. 2011. Determination of degradation rate of acaricide fenpyroximate in apple, citrus and grape by HPLC-DAD. Food Analytical Methods, 5: 306-311.

Anonymous, 2013a. Food and Agriculture Organisation (FAO). Statistical Year Book 2013, Rome, Italy.

Anonymous, 2013b. Indian Horticulture Society. Ministry of Agriculture, Govt. of India Agriculture Research Database, pp. 144.

Dubey, J.K., Patyal, S.K., Sharma, I.D., Thakur, M. and Kumar, A. 2008. Residues of Thiacloprid in/on apple and tea. Pesticide Research Journal, 20(2): 269-272.

Gupta, D.S. 1980. Residue Analysis of Insecticides. [Ed. D.S. Gupta], p. 7.

Hoskins, WM. 1961. Mathematical treatment of the rate of loss of pesticide residues. FAO Plant Protection Bull 9: pp. 163-168

Kaufman, P.E and Weeks E. N. I., 2006. Pesticide safety around animals. http://edis.ifas.ufl.edu/IG128.

Kumar, V., Sood, C., Jaggi, S., Ravindranath S D., Bhardwaj S P., Shanker A., 2005. Dissipation behaviour of propargite- an acaricide residues in soil, apple (Malus pumila) and tea (Camellia sinensis). Chemosphere, 58: 837-843.

Levine, R.S. and Doull, J. 1992. Global estimates of acute pesticide morbidity and mortality. Reviews of Agnihotri, N.P. 1999. Pesticide Safety Evaluation and Monitoring. All India Coordinated Research Project on Pesticide Residues IARI, New Delhi pp 1-173.

Malhat F., Kamel E., Ayman Saber A., Hassan E., Youssef A., Almaz M., Hassan A., Fayz A E., 2013. Residues and dissipation of kresoxim methyl in apple under field condition. Food Chemistry, 140: 371-374.

Michelangelo A., Steven J. L., Darinka S., Frank J. S. 2003. Fast and easy multiresidue method employing acetonitrile extraction/partitioning and “dispersive solid-phase extraction” for the determination of pesticide residues in produce Journal of AOAC International, 86: pp.412-431

Mohapatra, S., Ahuja, A.K., Sharma, D., Deepa, M. and Kumar, S. 2011. Residue studyof imidacloprid in grapes (Vitis vinifera L.) and soil. Quality Assurance and Safety of Crops & Foods, 3: 24-27.

Omirou, M.; Vryzas, Z.; Papadopoulou-Mourkidou, E.; Economou, A., 2009. Dissipation rates of iprodione and thiacloprid during tomato production in greenhouse. Food Chemistry, 116, 499−504

Safi, J. M., Abou-Foul, N. S., el-Nahhal, Y. Z., & el-Sebae, A. H. (2002). Monitoring of pesticide residues on cucumber, tomatoes and strawberries in Gaza Governorates, Palestine. Nahrung, 46(1), 34–39.

Sahoo, S.K., Mandal, K., Kaur, R., Battu, R.S. and Singh, B. 2013. Persistence of thiacloprid residues on brinjal. Environmental Monitoring and Assessment, 185: 7935-7943.

Sharma, I.M. and Bhardwaj, S.S. 1999. Canker and foliar diseases of apple. IN : Diseases of Horticultural Crops-Fruits. (Eds. L.R. Verma and R.C. Sharma). Indus publishing company, New Delhi, pp. 724.

Teotia, T.P.S. and Dahm, P.A. 1950. The effect of temperature, humidity and weathering on residual toxicities to the house fly of five organic insecticides. Journal of Economic Entomology, 43: 864-876.

Thompson, A.K. 1989. A Colour Atlas of Post-harvest Diseases and Disorders of Fruits and Vegetables. Wolfe Publishing Ltd. London, England, pp. 170-196.

Verma, S. and Lal, R.: 1976, 'Residues and residual toxicity of endosulfan on cauliflower', Indian Journal of Agricultural Sciences, 46, 125–129.