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Presence of pesticide residue in vegetable crops: A review

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ABSTRACT

The economic implications of crop loss due to pest incidences have resulted in superfluous pesticide usage by the farming community, which in turns resulted in several ecological and environmental consequences. Considering this, present review is presented with the objective to determine which pesticides are being used by the farmers and also the presence of different pesticide residues in different vegetable crops. This review paper analysed a total of 21 research articles published in reputed journals. It was observed that application of insecticides was the major protective measure against the attacks by devastating pests. Vegetables mostly found to be contaminated were okra, brinjal, lettuce, cucumber and tomato. Pesticides found in most of the vegetable samples in the preliminary observations were Chlorpyrifos, Monocrotophos, Endosulfan, DDT and Lindane *etc*. Provisions to adherence of the policies of the government in the domain of pesticide application measures should be made and appropriate watch should also be kept against any violation of these policies and recommendations.

Key words: Contamination, Maximum residual limit, Pesticide residue, Use of pesticides, Vegetables.

The economy of India is agriculture based, known for possessing its own rich and diverse knowledge about cultivation practices. Agriculture supports 14% to the national GDP, though the contribution of this sector has decreased as compared to previous year which was 30% in 2000 because of the growth of other sectors, particularly the service sector (Ministry of Agriculture, 2015) Despite the reduction in the share of agriculture in GDP, its share in employment has not declined drastically, as it was 57 % in 2000 while it was 50 % in 2012 (OECD/FAO 2014). Agriculture is still the main dependent sector for rural self-employed population, whose average farm size continues to decline with population growth and they contribute to approximately 68% of population of the country (Ministry of Agriculture, 2015).

India ranks second in vegetable production in the world (APEDA, 2015) and the productivity of horticultural products in India can be by and large ascribed to the diverse climate that provides the required conditions for the production of variety of fresh fruits and vegetables. As per the National Horticulture Database, India produced 1,62,897 thousand MT of vegetables during the year 2013-14 which is 74,275 thousand MT higher than the production of the year 2001-02 that was only 88,622 thousand MT. Consequently, there is an increase in the area under cultivation of vegetables of 3,240 thousand hectares from 6,156 thousand hectares in the year 2001-02 to 9,396 thousand hectares in the year 2013-14 (NHB, 2015).

As per Agricultural and Processed Food Products Export Development Authority (APEDA), total vegetable export for the year 2014-15 was Rs. 4702.78 crores in India. India is reported to be the largest producer of ginger and okra and second largest producer of potato, onion, cauliflower, brinjal and cabbage across the world. The availability of vast production base offers tremendous opportunities for export to India and there has been an expansion in the acceptance level of horticultural imports from India worldwide especially by UAE, Bangladesh, Malaysia, UK, Netherland, Pakistan, Saudi Arabia, Sri Lanka and Nepal (APEDA, 2015). Institute for Financial Management and Research (IFMR) data, 2013, shows a rise in the demand for fruits and vegetables by 2-3 percent per annum over recent years (Govil, 2013).

In recent times, resorting to vegetable cultivation is considered to be a highly profitable business amongst the farming community in India. There are many reasons for preference of vegetable cropping among the Indian farming community such as; requirement of very less quantity of water for irrigation, seed rate of vegetables is nominal compared to field crops, available for harvesting between 45-60 days as compared to cereal crops, farming even on the small patches of land is remunerative compared to cereal cropping and average yield of vegetable crops is about 5-10 times more than of cereals which can be further increased by 10-12 times if farmers opt for an off-season cultivation, depending on the type of greenhouse, type of crop, environmental conditions etc. All these factors make

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vegetable cultivation a flourishing business in India as well as in the world (Joshi, 2013)

The economic implications of the crop damage and crop loss due to pest incidences have compelled many Indian farmers to resort to frequent pesticide applications. Pesticides are considered responsible for the agrarian growth because of the benefits associated with them like improved crop yields. That is why extensive use of pesticides has taken place in the last few years (Government of Puducherry, 2015).

The superfluous pesticide usage for fulfilling escalating quest for higher profit has resulted in several ecological and environmental consequences as well as unsafe practices in farming sector. The percentage of pesticide use on vegetable crops of total pesticide use in the country is constantly increasing for the years as it was only 13-14% of the total pesticide use in the 1990s (Sardana, 2001) while the share has increased to 21% in 2010-11(Peshin *et al.*, 2014). It is mentioned by Peshin and coworkers that during the year 2010-2011, the estimated pesticide use in vegetable crops was 10,596 metric tonnes despite the introduction of low-dose pesticides in the 1990s and 2000s and prohibition of the use of Benzene hexachloride (BHC), in 1997.

As per the recommendation of WHO, there should be at least 30% fruits and vegetables in our daily diet, depending on the body weight of the person. Vegetables are the major source of vital nutrients. But it is not heartening to know that instead of fulfilling the nutritional requirements, these fruits and vegetables carry pesticide residue, and harm the health of the consumers. Main reasons of finding the pesticide residues in these foodstuffs may be because of providing shiny and fresh appearance and good colour to the crop. This leads to usage of synthetic chemicals beyond the safe limits. Due to the persistent nature of some of the highly toxic pesticides, or may be due to illegal use of prohibited /banned pesticides, these compounds have been detected in the environment worldwide (Rajendran and Subramanian, 1999). So, usage of restricted pesticides is a matter of concern especially in case of vegetables. There is a general belief that these food items are much harmful if impregnated with pesticides in comparison to other food stuffs, because they are generally consumed raw or semi-cooked. Many studies support the presence of pesticide residues in vegetables, on an average, this percentage is 50-70% in India as mentioned by Karanth, 2002; Charan *et al.*, 2010; and Ranga, *et al.* 2009. In India, 51% of the food commodities have been detected with pesticide residues (Gupta, 2004). A study conducted by Charan *et al.* in 2010, revealed that 35.62% of total contaminated samples exceeded the maximum residue limit (MRL) values recommended by the Food and Agriculture Organization (FAO)/ World Health Organization (WHO). Another study conducted by Ranga *et al.* (2009) revealed the presence of Monocrotophos, Chlorpyrifos, Cypermethrin and Endosulfan etc. in the vegetables. According to a report, over 98% of sprayed insecticides and 95% of herbicides reached non-target destinations such as other species, air, water and soil. It is also reported that pesticide drift occurs when pesticides are delivered from the air as particles are carried by the wind to other areas, potentially spreading the area contaminated (Henkel, no date). Considering the gravity of the vital situation discussed, the present review was done. The objectives of this review are to determine which pesticides are being used by the farmers in vegetable cropping to protect their crops against various pests and to evaluate the presence of different pesticide residue in various vegetables along with the degree of contamination found in terms of percentages.

Search strategy: In order to collect the secondary information on the study area, relevant cases from peer-reviewed esteemed journals, online technical and government reports were retrieved using a systematic approach. The search was restricted to the studies published in English only. The data mining enquiry was performed with a combination of the following search words/ terms: “pesticide residue”, “use of pesticides”, “vegetable production” etc.

Study population: The studies evaluated in this paper, include researches giving information on the statistics of pesticides used in vegetable crops and statistics of pesticide residue in vegetable crops. As the review is divided into two parts, for the first part of the study, farmers, cultivating vegetables and applying pesticides on their crops were considered, whereas, for the second part, studies on the occurrence of pesticide residues contaminating samples of selected vegetables were taken. Studies done around the world were taken, which include regions such as Ghana, Polland, India, Thailand, Egypt, China, Cameroon, Kenya, Nigeria, Tanzania and Nepal.

Inclusion criteria: This review includes researches conducted around the world providing information either on the application of pesticides used or presence of pesticide residues in vegetable crops. Studies published in the English language in various esteemed journals were considered for this review. All the studies reviewed had targeted at the agricultural working population. The inclusion criteria considered for the present review were the application of major pesticides in vegetable cropping and the statistics on the contamination of selected vegetables with pesticide residue.

Types of outcomes: The primary researches evaluated in this review represent outcomes in two domains as follows:

I. Statistics of pesticides used in vegetable crops
II. Statistics of pesticide residues in vegetable crops

The current analysis considered nearly 200 abstracts and citations, 100 full articles were also perused dealing with pesticide usages and contamination of vegetable samples with residue of some common pesticides, being used by the

farmers around the world. In order to focus the analysis, total 21 articles out of which 15 articles on the contamination of vegetable samples and 6 articles on the pesticide usage were abstracted and included in the present review, based on the criteria considered for the selection of the paper. The current analysis documents the results of the primary researches conducted in this domain and evaluates the pesticide residual data obtained for various vegetables collected from different parts of the world. The Table 1 includes parameters such as the name of the pesticides applied, the name of the vegetable, area of the study, percentage of total farmers using pesticides. The Table 2 includes parameters such as name of the vegetable, name of the pesticide found in the samples, area of the study, percentage of total contaminated samples, average/mean value of pesticide residue in the sample, percentage of samples exceeding the Maximum Residual Limit (MRL), percentage of range of exceedance MRL and standard/ recommended MRL of the mentioned pesticides for specific vegetables. For the first part of the study farmers, cultivating vegetables and applying pesticides on their crops were considered, whereas, for the second part, studies on the occurrence of pesticide residues contaminating samples of selected vegetables were taken.

Statistics of pesticides used in vegetable crops: This section discusses about the usage of pesticides in vegetable crops by the farmers. Data collected through primary researches in the current review shows that there are lots of pesticides being used by the farmers. It shows that most of the pesticides are known to the farmers only through their trade names, that is why trade names are mentioned in the researches, considered here. In a research conducted by Abang *et. al*, (2013) in Cameroon, pesticides such as Actellic, Agrizeb, Callomil, Bastion, Beauchamp, Beauchamp, Bravo, Callidim, Callisulfan, Calthio DS, Camindacal, Carbofuran, Cigogne, Cypercal, Cyperdim, Cyperplant, Cyplandim, Cyplandim, Decis, Dimex, Dursban, Furaplant, Gamaline, Gramoxone, Ivory, Karate, Kunter, Lambdacal, Malathane, Nordox, Orthene, Pacha, Parastar, Penncozeb, Penncozeb, Planthoate, Plantineb, Plantizeb, Pylory, Pyriforce, Ridomil, Thiodan, Thioplant, Trimangol were found in the vegetable crops such as tomato, hot pepper, sweet pepper, onion, cabbage, amaranth, okra and eggplant. They observed that weekly sprays of pesticides were the most common practice among the participant farmers. They also mentioned that insecticides were sprayed by 40% farmers while fungicides were sprayed by 28% farmers. Another study by Nyakundi *et.al*., (2010) in Kenya found the use of Ace 750wp, Actra

Table 1: Statistics of pesticides used in vegetable crops

Author	Area	Trade name of Pesticide	Name of vegetable	Percentage of farmers using
Abang, *et. al*,(2013)	Cameroon	Actellic, Agrizeb, Callomil, Bastion, Beauchamp, Beauchamp, Bravo, Callidim, Callisulfan, Calthio DS, Camindacal, Carbofuran, Cigogne, Cypercal, Cyperdim, Cyperplant, Cyplandim, Cyplandim, Decis, Dimex, Dursban, Furaplant, Gamaline, Gramoxone, Ivory, Karate, Kunter, Lambdacal, Malathane, Nordox, Orthene, Pacha, Parastar, Penncozeb, Penncozeb, Planthoate, Plantineb, Plantizeb, Pylory, Pyriforce, Ridomil, Thiodan, Thioplant, Trimangol	Tomato, Hot Pepper, Sweet, Pepper, Onion, Cabbage, Amaranth, Okra, Eggplant	
Nyakundi, *et. al*,(2010)	Kenya	Ace 750wp, Actra 25 WG, Diazol 60EC, Dimekil 40 EC, Dithane m45, Folicur EW, Fungarun- OH, Glyphogan 48 SL, Karate zeon, Lambdex 5EC, Linurex, Methomex 90sp, Milpan 10wp, Nimrod 25EC, Previcur N, Score EC, Touchdown	Kales, French beans, Cabbage	
Oluwole and Cheke, (2009)	Nigeria	2,4-D amine, Apron star, Atra Force, Copper sulphate, Gammalin 20, Gramoxone, Nuvacron, Primextra, Ridomil plus, Roundup		26.7, 47.3, 64.7, 90.7, 22.7, 98.7, 78.0, 86.7, 87.3, 28.0
Ngowi, *et. al*,(2007)	Tanzania	2-4D, Actellic 50EC, Actellic Super, Alto, Ashes, Bayleton, Blue Copper, Cobox, Cypercal, Decis, Diazinon, Dimethoate, Dithane M45, Dursban, Dust, Dynamec, Fenesta, Fenom, Funguran, Furadan, Helarat, Impact, Ivory 80WP, Karate, Keshet, Lannate, Majester, Mamba, Phostoxin, Polytrin, Red cat, Ridomil, Rogor, Ronstar, Roundup, Selecron, Shumba dust, Sumithion, Thiodan, Thionex , Thiovit, Tilt	Onions, Tomatoes, Cabbages	
Shrestha, *et. al*,(2010)	Nepal	Aerosol, Antirot , Bicep, Bloom, Current, Cypermethrin, Desist, Durban, Farsa, Furan, Kriiaxyl Mz 72%WP, Manex, Nuwan, Propel, Rogor, Rogorin, Rogoris, R-Sulfa, Super-D, Surya M-45, Surya Methrin-10, Targmil, Thiodan, Uthane M-45		
Banjo, *et. al*,(2010)	Nigeria	Trichlorfon (Nequvon), Cyhalothrin – Lambda (Warrior), Cyhalothrin – Lambda (Attacke)		11.5, 96.23, 19.23

Table 2: Statistics of Pesticide residues in vegetable crops

Author	Name of pesticide	Area of study	Name of vegetable	Percentage of samples contaminated	Average value of pesticide residue in vegetable (mg/kg)	Percentage of samples with >Maximum Residual Limit (MRL)	Range of exceedance MRL (%)	Recommended MRL
Amoah, *et. al*, (2006)	Lindane	Ghana	lettuce	31	0.3			0.01
	Endosulfan			36	0.4			0.05
	Lambda-cyhalothrin			11	0.5			1.0
	Chlopyrifos			78	1.6			0.05
	DDT			33	0.4			0.05
Arora, (2009)	Monocrotophos	Uttar pradesh	Brinjal		**1.25**			0.2
	Chlorpyrifos		Okra		**5.75**			0.2
	Cypermethrin				**0.63**			0.2
Bempah, *et. al*, (2012)	Lindane	Ghana	Cabbage	∑68.0	**0.100**			0.01
	Methoxychlor				**0.023**			0.01
	Aldrin				-			0.01
	Dieldrin				**0.035**			0.01
	Endrin				0.007			0.01
	DDE				0.008			0.05
	DDT				0.032			0.05
	Diazinon				0.016			0.02
	Dimethoate				-			0.02
	Pirimiphos-methyl				0.003			0.50
	Chlorpyrifos				0.007			0.50
	Profenofos				0.008			0.05
	Malathion				0.004			-
	Lindane		Cucumber	∑43.3	-			0.01
	Methoxychlor				**0.020**			0.01
	Aldrin				-			0.02
	Dieldrin				0.010			0.02
	Endrin				-			0.01
	DDE				-			0.05
	DDT				0.009			0.05
	Diazinon				0.009			0.02
	Dimethoate				-			0.02
	Pirimiphos-methyl				0.010			0.10
	Chlorpyrifos				-			0.05
	Profenofos				0.003			0.05
	Malathion				0.010			3.00
	Lindane		Lettuce	∑46.7	0.006			0.01
	Methoxychlor				**0.023**			0.01
	Aldrin				0.008			0.01
	Dieldrin				-			0.01
	Endrin				**0.040**			0.01
	DDE				0.041			0.05
	DDT				0.020			0.05
	Diazinon				0.004			0.02
	Dimethoate				0.021			0.50
	Pirimiphos-methyl				-			0.50
	Chlorpyrifos				0.011			0.05
	Profenofos				-			0.05
	Malathion				0.003			3.00

Contd.....

Continue Table 2

Author	Name of pesticide	Area of study	Name of vegetable	Percentage of samples contaminated	Average value of pesticide residue in vegetable (mg/kg)	Percentage of samples with >Maximum Residual Limit (MRL)	Range of exceedance MRL (%)	Reco-mmended MRL
	Lindane		Tomato	∑ 50.0	0.008			0.01
	Methoxychlor				0.004			0.01
	Aldrin				-			0.01
	Dieldrin				0.004			0.01
	Endrin				-			0.01
	DDE				0.013			0.05
	DDT				0.012			0.05
	Diazinon				0.009			0.50
	Dimethoate				0.013			0.02
	Pirimiphos-methyl				0.017			0.20
	Chlorpyrifos				0.026			0.50
	Profenofos				0.010			0.05
	Malathion				0.038			3.00
	Lindane		Onion	∑43.3	**0.019**			0.01
	Methoxychlor				**0.041**			0.01
	Aldrin				**0.006**			0.01
	Dieldrin				-			0.01
	Endrin				-			0.01
	DDE				0.023			0.05
	DDT				0.035			0.05
	Diazinon				0.008			0.50
	Dimethoate				0.006			0.02
	Pirimiphos-methyl				-			0.10
	Chlorpyrifos				0.055			0.20
	Profenofos				0.040			0.05
	Malathion				-			3.00
	Lindane		Carrot	∑52.0	-			0.01
	Methoxychlor				0.008			0.01
	Aldrin				0.010			0.01
	Dieldrin				-			0.01
	Endrin				**0.016**			0.01
	DDE				-			0.05
	DDT				0.004			0.05
	Diazinon				0.005			0.20
	Dimethoate				0.020			0.02
	Pirimiphos-methyl				-			0.05
	Chlorpyrifos				0.040			0.10
	Profenofos				0.012			0.05
	Malathion				0.007			0.50
Charan, *et. al*, (2010)	Monocrotophos	Central Aravalli region, Rajasthan	Brinjal	∑50%		8.69		
	Methyl -parathion					15.21		
	Cypermethrin					4.34		
	Endosulfan					0		
	Fenvalerate					0		
	Quinolphos					0		
	Methyl- parathion		Cabbage	∑ 28.20%		0		
	Monocrotophos					5.12		
	Chlorpyriphos					2.56		
	Endosulfan					0		
	Methyl parathion		Cauliflower	∑ 51.85%		14.81		
	Quinolphos					7.40		
	Chlorpyriphos					0		
	Endosulfan					3.70		
	Cypermethrin					0		

Contd.....

Continue Table 2

Author	Name of pesticide	Area of study	Name of vegetable	Percentage of samples contaminated	Average value of pesticide residue in vegetable (mg/kg)	Percentage of samples with >Maximum Residual Limit (MRL)	Range of exceedance MRL (%)	Recommended MRL
	Methyl- parathion		Okra	∑ 32%		4		
	Quinolphos					0		
	Fenvalerate					0		
	Endosulfan		Tomato	∑ 46.43%		0		
	Cypermethrin					0		
	Methyl-Parathion					0		
	Fenvalerate					0		
	Monocrotophos					0		
	Dichlorvos		Potato	∑23.53%		11.76		
Dogheim, *et. al*, (2004)	Profenofos	Egypt	Cabbage			0		
	Chlorpyrifos Profenofos		Lettuce			∑ 3.63		
	Dimethoate Profenofos		Spinach			∑ 01.92		
	Malathion Profenofos		Celery			∑ 20		
	Acephate Chlorpyrifos Malathion Profenofos		Green coriander			∑ 7.14		
	Bendiocarb Carbaryl Chlorpyrifos Dimethoate Malathion Metalaxyl Omethoate Profenofos		Green mint			∑ 35.71		
Essumang, *et. al*, (2013)	Methamedophos	Ghana	Okra		**6.05**			4.0
	Enthoprophos				**5.10**			0.4
	Phorate				**19.40**			0.7
	Diazinon				**6.10**			2.0
	Dimethoate				**50.60**			2.0
	Pirimipphos				**9.80**			30.0
	Chlorpyrifos				**1321.10**			10.0
	Fenitrothion				**36.50**			10.0
	Parathion				**5.30**			3.0
	Fonofos				**3.90**			10.0
	Profenofos				**13.80**			10.0
	Malathion				**23.30**			3.0
	Chlorfenvinp				**7.40**			10.0
	Lindane				**10.50**			10.0
	Heptachlor				**4.00**			0.10
	Aldrin				**4.90**			0.10
	Endosulfan				**10.36**			10.0
	DDE				**3.90**			10.0
	Dieldrin				**4.20**			0.10
	DDD				**3.10**			10.0
	DDT				**6.20**			6.0
	Methoxy				**5.20**			50.0
	Endrin				**4.10**			0.2

Contd.....

Continue Table 2

Author	Name of pesticide	Area of study	Name of vegetable	Percentage of samples contaminated	Average value of pesticide residue in vegetable (mg/kg)	Percentage of samples with >Maximum Residual Limit (MRL)	Range of exceedance MRL (%)	Recommended MRL
	Bifenthrin				3.90			20.0
	Lambda-C				4.00			20.0
	Permethrin				4.80			50.0
	Cyfluthrin				5.80			20.0
	Cypermethrin				7.10			50.0
	Fenvalerate				3.90			20.0
	Deltamethrin				5.80			10.0
Sapbamrer and Hongsibsong, (2014)	Chlorpyrifos	Ghana	Chinese cabbage	12.5	**2.864**			0.5
	Monocrotophos		Cucumber	75	**0.102**			0.01
	Chlorpyrifos		Lettuce	100	0.008			0.05
	Diazinon		Spring onion	100	0.245			0.02
	Dicrotophos			66.7	**0.012**			-
	Malathion			100	0.011			0.02
	Omethoate			100	0.323			-
	Monocrotophos		Morning glory	50	0.053			0.01
	Chlorpyriphos		Cowpea	50	0.027			0.05
	Monocrotophos			25	**0.076**			0.01
	Chlorpyrifos		Lemon Balm	100	**2.42**			0.05
	Malathion			75	0.007			0.02
	Monocrotophos			25	**0.033**			0.02
Farag, *et. al*, (2011)	Carbendazim	Egypt	Green beans	14.28	**0.613**			0.2
Mukherjee, (2003)	Cypermethrin	Delhi	Cauliflower			14.28		
	Chlorpyrifos					14.28		
	Quinalphos					14.28		
	Chlorpyrifos		Green Chilli			20.00		
	Chlorpyrifos		Okra			28.57		
	Endosulfan		Tomato			0		
	Methyl parathion					0		
	Malathion					28.57		
	Chlorpyrifos					28.57		
	Cyhalothrin					0		
	Quinalphos					14.28		
	Fenvalerate					0		
	Chlorpyrifos		Mustard			20.00		
	Quinalphos					20.00		
Osei-Fosu, *et. al*, (2014)	Dimethoate	Ghana	Cabbage				550- 700	
	Dimethoate		Cucumber				25- 550	
	Chlorpyrifos						10- 40	
	Malathion						40- 100	
	Fenitrothion						1200- 1400	
	Lambda- cyhalothrin		Lettuce				1500- 4400	
	Dimethoate						2800-	
	Diazinon						15450	
	Chlorpyrifos						400- 700	
							1140- 1170	

Contd.....

Continue Table 2

Author	Name of pesticide	Area of study	Name of vegetable	Percentage of samples contaminated	Average value of pesticide residue in vegetable (mg/kg)	Percentage of samples with >Maximum Residual Limit (MRL)	Range of exceedance MRL (%)	Recommended MRL
Ranga Rao, *et. al*, (2009)	Monocrotophos	Andhra Pradesh	Brinjal		0.003			
	Chlorpyrifos				0.008			
	Endosulfan				0.019			
	Cypermethrin				0.052			
	Monocrotophos		Cucumber		0.004			
	Chlorpyrifos				0.066			
	Endosulfan				0.019			
	Cypermethrin				0.010			
	Monocrotophos		Okra		0.013			
	Chlorpyrifos				0.605			
	Endosulfan				0.130			
	Cypermethrin				0.025			
	Monocrotophos		Tomato		0.005			
	Chlorpyrifos				0.035			
	Endosulfan				0.032			
	Cypermethrin				0.024			
	Monocrotophos		Ridge gourd		0.015			
	Chlorpyrifos				0.050			
	Endosulfan				0.021			
	Cypermethrin				0.086			
Swarnam and Velmurugan, (2013)	Cypermethrin	Andaman Islands	Brinjal		0.028			
	Endosulfan		Green chilli		0.092			
	Cypermethrin				0.091			
	Endosulfan		Okra		0.169			
	Cypermethrin				0.023			
	Endosulfan		Crucifers		0.185			
	Endosulfan		Cucurbits		0.128			
	Cypermethrin				0.031			
Szpyrka, *et. al*, (2015)	Azoxystrobin	Poland	Tomato	∑ 50.0	0.04			3
	Boscalid				0.10			3
	Cyprodinil				0.08			1
	Dithiocarbamates				0.13			3
	Fludioxonil				0.03			0.9
	Famoxadone				0.04			1
Tomar, (2013)	DDT	NCR	Okra	53.12				0
	DDT		Pumpkin	42.22				0
Yu, *et. al*, (2016)	Methamidophos	China	Chinese cabbage			3.6		
	Dichlorvos					3.6		
	Omethoate					7.1		
	Phorate					10.7		
	Dimethoate					0		
	Diazinon					3.6		
	Parathion-methyl					0		
	Fenitrothion					0		
	Malathion					0		
	Fenthion					0		
	Parathion					7.1		

Contd.....

Continue Table 2

Author	Name of pesticide	Area of study	Name of vegetable	Percentage of samples contaminated	Average value of pesticide residue in vegetable (mg/kg)	Percentage of samples with >Maximum Residual Limit (MRL)	Range of exceedance MRL (%)	Reco-mmended MRL
	Methamidophos		Cucumber			3.2		
	Dichlorvos					3.2		
	Omethoate					3.2		
	Phorate					3.2		
	Dimethoate					-		
	Diazinon					0		
	Parathion-methyl					3.2		
	Fenitrothion					0		
	Malathion					0		
	Fenthion					0		
	Parathion					3.2		
	Methamidophos		Tomato			0		
	Dichlorvos					0		
	Omethoate					0		
	Phorate					0		
	Dimethoate					0		
	Diazinon					0		
	Parathion-methyl					0		
	Fenitrothion					0		
	Malathion					0		
	Fenthion					0		
	Parathion					0		
	Methamidophos		Welse onion			50.0		
	Dichlorvos					52.0		
	Omethoate					45.0		
	Phorate					65.0		
	Dimethoate					0		
	Diazinon					5.0		
	Parathion-methyl					40.0		
	Fenitrothion					0		
	Malathion					0		
	Fenthion					5.0		
	Parathion					57.5		
	Methamidophos		Raddish			12.5		
	Dichlorvos					0		
	Omethoate					12.5		
	Phorate					18.8		
	Dimethoate					0		
	Diazinon					12.5		
	Parathion-methyl					18.8		
	Fenitrothion					0		
	Malathion					0		
	Fenthion					12.5		
	Parathion					6.3		
	Methamidophos		Brinjal			0		
	Dichlorvos					0		
	Omethoate					0		
	Phorate					0		
	Dimethoate					0		
	Diazinon					-		
	Parathion-methyl					0		
	Fenitrothion					0		
	Malathion					0		
	Fenthion					0		
	Parathion					2.9		

25 WG, Diazol 60EC, Dimekil 40 EC, Dithane m45, Folicur EW, Fungarun- OH, Glyphogan 48 SL, Karate zeon, Lambdex 5EC, Linurex , Methomex 90sp, Milpan 10wp, Nimrod 25EC, Previcur N, Score EC, Touchdown on the vegetable crops like kales, french beans and cabbage. It was also reported in this research that 25% of farmers decreased the dosage of pesticides, 12% of them increased the dosage while majority of them i.e., 63% continued to use the same dosage of pesticides in crop production over the time of the study. Diazol 60EC from organophosphate family was the most frequently used pesticide followed by Methomex 90sp from carbamate family. Oluwole and Cheke, (2009) in Nigeria found application of 2,4-D amine, Apron star, Atra force, Copper, Sulphate, Gammalin 20, Gramoxone, Nuvacron, Primextra, Ridomil plus, Roundup pesticides by the farmers in the percentage of 26.7, 47.3, 64.7, 90.7, 22.7, 98.7, 78.0, 86.7, 87.3, 28.0 percent respectively. This study showed that majority of farmers (48.3%) used herbicides, 28.2% used fungicides while 23.5% used insecticides. Total 86.7% of pesticides used by the farmers in this research were classified as highly hazardous by WHO. Ngowi *et. al,* (2007) in Tanzania, found a number of pesticides to be used on onion, tomato, and cabbages crops. They observed that farmers used insecticides, fungicides, herbicides and rodenticides in the ratio of 59%, 29%, 10%, and 2% respectively. The frequency of application of pesticides by more than 50% of total farmers was 5 times or more increased per cropping season while 14% respondents reported to have decreased the trend of using pesticides. Shrestha *et. al,* (2010) in their study in Nepal observed usage of Aerosol, Antirot, Bicep, Bloom, Current, Cypermethrin, Desist, Durban, Farsa, Furan, Kriiaxyl Mz 72%WP, Manex, Nuwan, Propel, Rogor, Rogorin, Rogoris, R-Sulfa, Super-D , Surya M-45, Surya Methrin-10, Targmil, Thiodan, Uthane M-45 pesticides. In their study, they found that frequency of using the pesticides was 5-6 times per cropping season and majority of participants were using pesticides for six years. They also observed that more than 16% of the pesticides used was categorized as extremely hazardous and was banned for general agriculture use. Similarly, Banjo *et. al,* 2010 in Nigeria observed the use of Trichlorfon (Nequvon), Cyhalothrin – Lambda (Warrior), Cyhalothrin – Lambda (Attacke) pesticides by the farmers in the ratio of 11.5%, 96.23%, and 19.23% respectively. They observed that about 87% of the farmers applied prescribed dosage of the pesticides while 13% farmers used them indiscriminately. 54% of the farmers were reported to apply pesticides on monthly basis.

Statistics of pesticide residues in vegetable crops

Lettuce: Lettuce is a leafy vegetable and it is most often used for salads, soups, sandwiches and wraps etc. Though it is a rich source of vitamin K and vitamin C, it also serves as a moderate source of folate and iron, but contaminated samples proved to be unsafe and risky for human consumption (http://www.nutrition-and-you.com/lettuce.html). Contamination of lettuce was found in many researches considered in this review. Amoah *et. al,* (2006) in their study in Ghana observed that in most of the cases, pesticide residue levels exceeded the Maximum Residual Limits (MRL). The data observed that 78% of lettuce samples had chlorpyrifos residues and only 14% samples had no detectable pesticide residue. The average value of chlorpyrifos residues obtained was 1.6 mg/kg against the standard MRL i.e., 0.5 mg/kg. Dogheim *et. al,* (2004) in Egypt showed that 45 samples were contaminated with the residues of Chlorpyrifos and Profenofos with the average chlorpyrifos residues within the range of 2.8 mg/kg. Bempah *et. al,* (2012) observed contamination of samples with a number of pesticides but only Methoxychlor and Endrin found to exceed the limit of MRL. Average value of Methoxychlor residues found was 0.023 mg/kg while it was 0.040 mg/kg in case of Endrin residues against the recommended value of 0.01 mg/kg. Chlorpyrifos residues in this study were within the recommend range, similar findings were observed by Sapbamrer and Hongsibsong (2014) in their research. Osei-Fosu *et. al,* (2014) reported in their research that lettuce samples showed the highest range amongst all the vegetable samples. It was observed that pesticides such as Lambda- cyhalothrin and Dimethoate exceeded the recommended range. All these findings point towards bad agricultural practices and poor awareness amongst the farmers.

Brinjal: Brinjal is known as the king of vegetables as it is widely used in many forms such as *baingan bharta*, *sambhar*, chutney, curry, and *achaar*, owing to its versatile nature. In respect of nutrition value, it is a source of various minerals and vitamins and serves as a moderate source of manganese. Arora, (2009) reported in his research about the contamination of brinjal samples with Monocrotophos with an average value of 1.25 mg/kg against recommended value of 0.2 mg/kg in Uttar Pradesh region of India. Charan *et. al,* in (2010) found a total of 50% samples to be contaminated with a number of pesticides. They reported that 15.21% samples exceeded the Methyl –parathion residual limits while 08.69% and 04.34% samples exceeded the recommended limits for Monocrotophos residues and Cypermethrin residues respectively. Ranga Rao *et. al.*, (2009) in their research in Andhra Pradesh observed the contamination of brinjal samples with Monocrotophos, Chlorpyrifos, Endosulfan and Cypermethrin and found residues with most of the samples within the range of recommended MRLs. Hence, it is important to note that Endosulfan was not mentioned as a restricted chemical in their research at that time. Swarnam and Velmurugan, (2013) in the Andaman Islands found Cypermethrin residues with 0.028 mg/kg average value.

Okra: Okra is a very popular vegetable, prepared in many different ways. It is a rich source of fibre, vitamin C, Calcium, Potassium and Folate (Corleone, 2014). Arora, (2009) in Uttar Pradesh tested okra samples and found Chlorpyrifos and Cypermethrin residues above the recommended MRL value which were 5.75 mg/kg and 0.63 mg/kg respectively, against 0.2 mg/kg (MRL). Charan *et. al*, (2010) in Central Aravalli region, Rajasthan found 32% contaminated samples with 4% exceeding the recommended MRL with Methyl-parathion residues. A study by Essumang *et. al*, (2013) on the levels of pesticide residue in the non-target okra crop, which was not meant to receive pesticide application and was grown near the watermelon crop, found contamination of samples with a number of pesticides. The main crop sprayed with the pesticides was watermelon, but effects of pesticides were also observed in the non-target okra crop. Some of the main pesticides found above the recommended MRL were Methamedophos, Enthoprophos, Phorate, Diazinon, Dimethoate, Chlorpyrifos, Fenitrothion, Parathion, Profenofos, Malathion, Lindane, Heptachlor, Aldrin, Endosulfan, Dieldrin, DDT and Endrin. Major violation was found in case of Phorate, Dimethoate, Chlorpyrifos, and Malathion residues with 19.40 mg/kg, 50.60 mg/kg, 1321.10 mg/kg, and 23.30 mg/kg respectively against the recommend values 0.7 mg/kg, 2.0 mg/kg, 10.0 mg/kg and 3.0 mg/kg. Violations in case of Chlorpyrifos residues were also observed by Mukherjee, (2003) in her research in Delhi. She found that 28.57% samples exceeded the recommended MRL value. Ranga Rao *et. al*, (2009) and Swarnam and Velmurugan, (2013) in Andhra Pradesh and the Andaman Islands respectively found contamination in the samples of okra. Both of these researches show that samples were contaminated with Endosulfan and Cypermethrin. Ranga *et. al*, 2009 observed Monocrotophos and Chlorpyrifos residues in the samples found within the recommended range.

Cabbage: Cabbage is a leafy vegetable and a good source of minerals and vitamins. It is reported to be a good source of Vitamin K and Vitamin C also. It also provides folate and some forms of Vitamin B in ample amounts (United States Department of Agriculture Research Service, 2015). Cabbage is used in pickles, salad and many other preparations. Contamination of the vegetable leads to various kinds of diseases. Some of these contaminations are discussed in the researches taken under this review. Bempah *et. al*, (2012) in their study found contamination of 68% samples with the different pesticides in Ghana and residue was also observed. He found that levels of Lindane, Methoxychlor, Dieldrin were above the recommended MRL i.e., 0.100 mg/kg, 0.023 mg/kg, 0.035 mg/kg respectively against the standard value 0.01 mg/kg. Charan *et. al*, (2010) in Rajasthan measured a total of 28% samples to be contaminated. He found that residue of Monocrotophos was 5.12% above the MRl value and value for Chlorpyriphos was 2.56% above the standard MRL. Osei-Fosu *et. al*, (2014) found contamination in vegetables with the Dimethoate pesticide as well as pesticide residue in the samples. They measured Dimethoate presence in the range of 550- 700% above the recommended MRL value. Sapbamrer and Hongsibsong, (2014) in Ghana observed 12.5% samples of Chinese cabbage to be contaminated with Chlorpyrifos. The average value of the pesticides found was 2.86 mg/kg against the recommended level of 0.5 mg/kg. Similarly Yu, *et. al*, (2016) also found samples of Chinese cabbage to be contaminated with a number of pesticides. In that study the measured amount of pesticide residue was 3.6% more than the MRL value for Methamidophos, 3.6% above the MRL for Dichlorvos, 7.1% above the MRL for Omethoate, 10.7% above the MRL for Phorate, 3.6% above the MRL for Diazinon and 7.1% above the MRL for Parathion.

Cucumber: Cucumber is a creeping vine that roots in the ground. It is enriched with essential nutrients and a good source of Vitamin K. It can be used in salads, pickles etc. There are a number of studies highlighting presence of pesticide residues in the vegetables. Bempah *et. al*, (2012) in Ghana region found the presence of Methoxychlor, Dieldrin, DDT, Diazinon, Pirimiphos-methyl, Chlorpyrifos, Profenofos and Malathion pesticide residues contaminating 43.3 % of the total samples. Sapbamrer and Hongsibsong in (2014) found residues of Monocrotophos in 75% of Cucumber samples with an average value 0.10 mg/kg against the standard 0.01 mg/kg. Osei-Fosu *et. al*, (2014) experimented cucumber samples and found the presence of Dimethoate, Chlorpyrifos, Malathion and Fenitrothion pesticides. The level was reported to be more than MRL for experimented pesticides: 25- 550% for Dimethoate, 10- 40% for Chlorpyrifos, 40- 100% for Malathion and 1200- 1400% for Fenitrothion. In a similar way, Yu, *et. al*. (2016) found Methamidophos, Dichlorvos, Omethoate, Phorate, Dimethoate, Diazinon, Parathion-methyl, Fenitrothion, Malathion, Fenthion and Parathion contaminations with 3.2 % level above the std. MRL for most of these pesticides.

Tomato: The tomato is a popular vegetable and eaten around the world in diverse forms. It is used in salads, ketchup, soups, juices and as an additive in most of the vegetable and curry preparations. Tomatoes are rich in vitamins especially Vitamin C. Bempah *et. al*, (2012) reported that 50% of total samples were contaminated with the residues of Lindane, Methoxychlor, Dieldrin, DDE, DDT, Diazinon, Dimethoate, Pirimiphos-methyl, Chlorpyrifos, Profenofos and Malathion pesticides. In the same way, Szpyrka *et. al*, (2015) in Poland found 50% samples to be contaminated with Azoxystrobin Boscalid, Cyprodinil, Dithiocarbamates, Fludioxonil and Famoxadone. Ranga Rao *et. al*, 2009 in Delhi also mentioned about the presence of Monocrotophos, Chlorpyrifos, Endosulfan and Cypermethrin pesticide residues in their samples of tomato.

CONCLUSIONS

The present review paper analysed a total of 21 primary researches published in a number of reputed journals in the domain. Fifteen articles reviewed were on the contamination of vegetable samples while six articles were on the pesticides usage. In regard to the application pattern of pesticides, it was observed that application of insecticides was the major protective measure against the attacks by devastating pests. It shows that the presence of insect- pests threaten the farmers involved in vegetable cropping in different parts of the world. Many of the participants found to be using pesticides categorized under highly hazardous class, which are also banned for the use. This may be because of the unawareness of these farmers or may be used intentionally in order to gain high profit. In regard to the statistics on the presence of pesticide residues, high amount of concentrations were seen in different vegetables experimented around the world. Vegetables majorly found to be contaminated were okra, brinjal, lettuce, cucumber and tomato, while others like chillis, radish, potato etc., were also showing little amount of pesticide residues. Major pesticide residues in most of the vegetable samples in the primary researches were found to be Chlorpyrifos, Monocrotophos, Endosulfan, DDT and Lindane etc. These chemicals are classified under hazardous category and some of them are even banned for the use in vegetable farming, still, their residues were found in the samples of different vegetables. This situation further points towards the illegal usage of the hazardous restricted/banned chemicals by the farming community. Pesticides affect ecology and health of humans so, sufficient provisions to adherence the policies of the government in the domain of pesticides application measures should be made and appropriate watch should also be kept against any violation of these policies and recommendations. It has also felt that there is a need for actions to be taken towards educating farmers against devastating effects of using the pesticides that may not only harm the health of the human beings but also destroy the environment.

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