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Long Term Effect of three Carbamate Pesticides and Sewage Sludge on the Growth and Trace Metal Concentration in Vegetative Parts of Certain Vegetables

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ABSTRACT

The effect of different doses of three carbamate pesticides (I, II, III), anaerobically digested sewage-sludge, and their mixture on the growth of some vegetables viz., tomato, brinjal, and potato planted in illitic sandy loam soil of Aligarh district and on the concentration of Zn, Cu, Mn, Fe, Cr, Ni and Pb, in vegetable parts of these vegetables was studied for seven years (2007-2013) in earthenware pots. The results indicated that lower concentration of pesticides (0.2-0.3g kg^{-1} soil) and sewage sludge (3g kg^{-1} soil) enhanced the plant growth and yield of edible part as well. The effect of pesticides was in the order: II > I > III. The mixture of sewage sludge and pesticides (I, II, III)had almost same effect as sewage-sludge alone. The concentration of heavy metals in the root parts were maximum and followed the crop order: tomato > brinjal > potato. The results of this study also denote that continuous application of sewage sludge for a long period causes initial increase in the shoot height, shoot weight crop yield followed by decrease in the shoot height, shoot weight, and crop yield which may be due to phytoxicity and/or non-availability of nutrients. With continuous application of pesticides for a long period there was no appreciable change in the heavy metal concentration in stem, root and edible part of studied vegetables), while with continuous application of sewage sludge for a long period causes a progressive increase in the heavy metal concentration in stem, root and edible part of studied vegetables.

Key words: *Carbamate pesticides, sewage sludge, vegetables, tomato, brinjal, potato.*

INTRODUCTION

Mobility of applied agricultural chemicals, especially pesticides in soil profile, and their loss by volatilization, degradation by biotic and abiotic paths, plant uptake, influencing the crop growth are the major factors that are affected by the adsorption of agrochemicals by soil colloids[1]. Carbamate pesticides, a new horizon, agrochemicals are widely used as insecticides and herbicides in home, garden and agriculture, as they are less persistent, possess less mammalian toxicity and may be used against those pests which have acquired immunity against organochlorine and organophosphate pesticides. Heavy metal accumulation is one of the most serious environmental concerns of the present day, not only because many of these metals are toxic to the crops themselves, but also because of their potential harm to animals and humans. Metals are non-biodegradable and are considered major environmental pollutants resulting in cytotoxic, mutagenic and carcinogenic effects in animals[2,3].Sewage-sludge has been used as an amendment to agricultural soils mostly for the cultivation of vegetables. This leads to the accumulation of micronutrients in the soil resulting in their enhanced uptake by plants[4]. The accumulation of heavy metals in plants occurs mostly in roots and above ground tissue[5,6]. As the soil contaminates modify the nutritional value of the food crops and their safety of human consumption, it was considered worthwhile to study the long term effects of different amounts of three carbamate pesticides [oxamy l, l {methyl-2-(dimethylamine)- N- [(methylamino) carbonyl)) oxy]-2-oxoethanimidothioate (I) ; {S-ethyl-N-ethyl (carbamoyl) oxy] thioacetimidate (II) and {N- Phenyl (ethylcarbamoyl) propyl carbamate (III)], sewage-sludge, and combination of pesticide and sewage sludge on the growth of few vegetables viz., tomato, brinjal, and potato on the concentration of Zn, Cu, Mn, Fe, Cr, Ni and Pb, in vegetable parts of these vegetables.

MATERIALS AND METHODS

The soil used in this study was illitic sandy loam from Aligarh district. The surface soil (0-25 cm depth) was air dried, crushed and grounded to pass through <70 mesh sieve before use. The physico-chemical properties along with sewage sludge were determined by usual methods[7] and values are given in Table 1.
Greenhouse experiments were conducted in the several glazed earthenware pots in triplicate. Each pot was filled with 10 kg of the soil in three sets of experiments. (i) In the first set, three carbamate pesticides (I,II,III) were applied at seven levels 0.0, 0.1, 0.2, 0.25, 0.3, 0.4 and 0.5g kg^{-1} (t_1-t_7) (equal to 0-5 kg ha^{-1}). In the second set, the soil samples were amended with 0,1,2,3,5,7.5 and 10 g kg^{-1} soil of dried and powdered sewage-sludge (t_1-t_7), in the third set soil samples amended with 0,1,2,3,5,7.5 and 10 g kg^{-1} soil of dried and powdered sewage-sludge in presence of 0.3 g of carbamate pesticides (t_1-t_7) pesticides I,II,III separately. Four pregerminated seedlings of tomato (*Lycopersicon esculentum*var.CO1), brinjal (*Solanum melongena*), and potato (*Solanum tuberosum* Kufri chander Mukhi) were planted in all the pots. The plants were watered daily to maintain requisite soil moisture. These pots including blanks were also amended with NH_4NO_3, superphosphate and KCl. At maturity of plants shoot height, weight of shoot, root lengths were measured. The concentration of Zn, Cu, Mn, Fe, Cr, Ni and Pb in root, stem and edible parts of these six experiments, conducted in triplicate, were estimated by atomic absorption spectrophotometer after digesting with $HClO_3$: $HClO_4$ (1:4 mixture). The studies were repeated for seven consecutive years (2007-2013).

RESULTS AND DISCUSSION

The effects of different doses of pesticides (I, II, III), sewage sludge alone and pesticide and sewage sludge together on the growth of tomato, brinjal and potato plants are given in in Tables 2. The shoot height, shoot weight, root length and total edible part of tomato plants in presence of carbamate pesticides increased significantly (Table2) The effect of different doses of carbamate pesticide I (oxamyl) was in the order $t_4 > t_5 > t_3 > t_6 > t_7 > t_2 > t_1$; for carbamate pesticide (II) the order was $t_3 > t_4 > t_5 > t_6 > t_7 > t_2 > t_1$ and in case of different doses of carbamate pesticide III the order was : $t_5 > t_4 > t_6 > t_3 > t_7 > t_2 > t_{1.}$ The increase in the yield of edible parts may be due to enhanced activity of ascomycetes, actinomycetes and aspergillus niger, Rhizobium, Thiobacillus thiooxidants etc in presence of moistened pesticides[8]. Due to toxic effects of higher doses of carbamate pesticides on these microorganisms the growth of plants and yield of edible part decreased. In presence of sewage sludge the growth of tomato plants increase initially upto 2.0 g of sewage sludge kg^{-1} soil and then declined. The increase in shoot height, shoot weight, root length and total edible part of tomato plants may be due to availability of more micro and macro nutrients to plants, whereas at higher concentrations there may be phytotoxicity causing retardation of plant growth and yield of edible part[9]. The maximum yield of edible part in presence of 0.3 g of carbamate pesticides kg^{-1} soil and different doses of sewage sludge was with 3.0 g of sewage sludge kg^{-1} soil. The yield of edible part in presence of mixture of pesticide and sewage sludge was found lesser than when sewage sludge was present alone.
The yield of edible part of brinjal in presence of different doses of carbamate pesticide I (oxamyl) was in the order: $t_4 > t_3 > t_2 > t_5 > t_6 > t_1 > t_7$; that for carbamate pesticide (II) was the order: $t_4 > t_5 > t_3 > t_6 > t_2 > t_7 > t_1$ and the order of carbamate pesticide III was: $t_4 > t_5 > t_6 > t_3 > t_7 > t_1 > t_2$ (Table 2). The increase in the yield of edible part at lower concentration of pesticides may be due to enhanced microbial activity and at higher concentration the retardation of yield may be due to reduction in enzymatic activities[10]. The effect of carbamate pesticides on yield was in the order pesticide II > I > III. In presence of sewage sludge the yield of edible part was in the order: $t_3 > t_4 > t_5 > t_2 > t_6 > t_7 > t_1$. The decrease in the yield of edible part at higher concentrations of sewage sludge may be due to decreasing availability of nutrients[11]. The maximum yield of edible part in presence of 0.3 g of carbamate pesticides (I, II, III) kg^{-1} soil and different doses of sewage sludge was with 3.0 g of sewage sludge kg^{-1} soil.

The decrease in the yield of edible part at higher concentration may be due to unavailability of nutrients to plants due to formation of complex in the soils[12].

The growth of potato in presence of different concentrations of carbamate pesticide I, II, III (Table 2) showed that shoot height, shoot weight, and crop yield increased up to t_4 for the pesticide I (oxamyl); t_3 for pesticide II and t_5 for pesticide III and then decreased. The increase in potato yield may be due to prevention of soil from nematode infection by pesticides[13]. The pesticidal activity was in the order: II > I > III. The shoot height and shoot length in presence of different concentration of sewage sludge was in the dose order: $t_1 > t_5 > t_2 > t_6 > t_4 > t_7 > t_3$. The yield of edible part increased initially and then found to decrease, which may be due to toxic effects of heavy metals at higher concentrations of sewage sludge. The shoot height, shoot weight, and yield of edible part of potato in presence of 0.3 g of carbamate pesticides (I, II, III) kg^{-1} soil and different doses of sewage sludge initially increased and then decreased.

The data of this study also denote that yield of edible part with continuous application of pesticides decreased with period of application (2007-2013) (Table 3) which may be due to formation of pesticide resistant microbes. Continuous application of sewage sludge for a long period causes initial increase in the shoot height, shoot weight crop yield followed by decrease in the shoot height, shoot weight, and crop yield which may be due to phytoxicity and/or non-availability of nutrients.

The results of this study indicated (Table 4-6) that in presence of carbamate pesticides the concentration of Zn, Cu, Mn, Fe, Cr, Ni and Pb increased significantly in root, stem and edible parts of all the studied vegetables. The concentration of metals was maximum in the root followed by stem and then in edible part. The percent increase was found in the range Zn 12-34; 12-25; 12-28; Cu 13-25; 19-50; 18-25; Mn 22-32; 25-37; 14-40; Fe 23-28; 24-26; 12-25; Cr 12-20; 2-10; 10-35; Ni 2-18; 2-14; 2-15 and Pb 6-13; 18-25; 5-25 in root, stem and edible part respectively for all the carbamate pesticides on metal concentration was in the order II > I > III. The metals concentration in all the studied vegetables in presence of the carbamate pesticides were found in the range (Table 4-6): Zn 70-128; 43-119; 8-21; Cu 25-31.6; 13.1-25.6; 1.3-2.0; Mn 58-78; 40-55; 15-29; Fe 242-392; 193-300; 166-206; Cr 1.5-3.1; 1.1-2.1; ND-0.5: Ni 0.9-1.7; 0.5-1.0; 0.1-0.6 and 1-2.3; 0.5-1.5; ND-0.6 (ug g^{-1} on dry basis) in root, stem and edible part respectively. The concentration of metals in the crops (ug g^{-1} on dry basis) was in the order tomato> brinjal> potato. The change in the micronutrient concentration in root, stem and edible part with different doses of carbamate pesticides may be due to active role played by the pesticides on soil-microbial status[14-16]. Previous studies by the author himself indicated that microbial population[17] in presence of studied carbamate pesticides increased with their doses. The optimum effect was with 0.25 g kg^{-1} of pesticide I; 0.2 g kg^{-1} pesticide II and 0.3 g kg^{-1} of pesticide III. Thereafter there was a decrease in the microbial population. The increase and thereafter decrease in micronutrient concentration in presence of different doses of pesticides may be due to solubilising effects by *Aspergillus niger*, *Thiobacillus, Rhizobium* etc. (which converts unavailable nutrients into available nutrients), accompanied with decrease in soil pH (8.6 to 8.05) and increase in EC (0.56to 0.72dS^{-1}) by lower doses with the release of soil humic acid[18]. Higher doses of pesticides caused negative influence which may be due to reduction of biological activity and adsorption by soil minerals.

In presence of different doses of sewage-sludge the concentration of metals in different parts of crops increased with sewage-sludge up to 3.0 g of sewage sludge kg^{-1} soil (Tables 4-6) in tomato and potato while the concentration increased up to 5g kg^{-1} soil for brinjal. The increase in percentage of micronutrient concentration was found: Zn 40-64; 45-60;40-50; Cu 20-50; 20-56; 20-36; Mn 38-70; 32-75; 18-48; Fe 40-55; 32-55; 40-78; Cr, Ni, and Pb 18-26; 22-40; 30-80 in root, stem and edible part respectively for all the three studied crops. The metals concentration in all the studied vegetables in presence of the carbamate pesticides were found in the range (Table 4-6): Zn 76-164; 48-140; 13-35; Cu 25-356; 13-23; 1.3-2.1; Mn 56-78; 40-56; 17-32; Fe 260-463; 160-412; 120-276; Cr 1.6-2.0; 1-1.7; 0.1-0.6: Ni 1.1-1.4; 0.5-0.9; ND -0.4 and Pb 1-2.3; 0.5-1.7; ND-0.3 (ug g^{-1} on dry basis) in root, stem and edible part respectively. The concentration of metals in root, stem and edible parts of all the studied crops was more than in the presence of pesticide. At higher concentration of sewage-sludge the concentration of metals in crops decreased which may be due to the formation of metal complexes with soil[19,20]. The concentration of metals in different parts of crops in presence of 0.3 g of pesticide and different doses of sewage sludge was almost same as in the presence of sewage sludge only, indicating that studied carbamate pesticides had no appreciable effect on availability of nutrients from sewage sludge.

The data of this study also denote that there was no appreciable change in the heavy metal concentration in stem, root and edible part of studied vegetables with continuous application of pesticides for a long period (2007-2013), while with continuous application of sewage sludge for a long period the heavy metal concentration in stem, root and edible part of studied vegetables increased progressively (preliminary studies by author found that total heavy metal concentration in soil after harvesting the crop remain almost same).

From these results it may be inferred that the different doses of carbamate pesticides, sewage-sludge, and their mixture influenced the growth, yield of edible part and concentration of metals viz. Zn, Cu, Mn, Fe, Cr, Ni and Pb in different parts of tomato, brinjal and potato plants. Continuous application of sewage sludge causes more deposition of heavy metals in the stem, root and edible part of studied vegetables.

Table: 1. Physico-chemical properties of illitic sandy loam of Aligarh and anaerobically digested sewage sludge

Illitic sandy loam		Sewage sludge	
Silt%	50.9	pH (1:2.5)	7.0
Clay %	17.0	EC (1:2.5) (dSm^{-1})	2.0
EC (1:2.5) (dSm^{-1})	0.56	Organic Carbon %	16.8
Cation exchange capacity (CEC) (C mol(P^+) kg^{-1})	18.0	Total nitrogen %	2.56
pH (1:2.5)	8.6	Na (mg kg^{-1})	18.0
Organic Carbon %	1.14	K (mg kg^{-1})	10.6
Surface area (m^2)	32.2	Total metals (mg kg^{-1})	
Exchangeable (mg kg^{-1})		Fe	1920
Ammonium N	100	Mn	712
Nitrite N	46	Ni	32
Nitrate N	80	Zn	620
Available (mg kg^{-1})		Cd	3.8
P	3.2	Pb	62
K	143	Cu	270
DTPA extractable (mg kg^{-1})		Cr	54
Cu	0.58	Co	28
Cd	Traces		
Ni	0.06		
Zn	0.76		
Mn	3.8		
Fe	16.2		
Pb	0.1		
Cr	0.1		

Table 2. Effect of different doses of three carbamate pesticides, sewage sludge and sewage Sludge & carbamate pesticides on the growth of tomato, brinjal and potato plant

Treatment	Addend a g kg^{-1} soil	Tomato				Brinjal				Potato		
		Shoot height (cm)	Shoot weight (g)	Root length (cm)	Total weight of edible part (g)	Shoot height (cm)	Shoot weight (g)	Root length (cm)	Total weight of edible part (g)	Shoot height (cm)	Shoot weight (g)	Total weight of edible part (g)
Carbamate pesticide I (Oxamyl)												
t_1	0.0	33.2	6.4	18.6	72	24.6	8.5	15.4	300	38.6	14.9	78
t_2	0.1	35.8	6.7	21.4	100	25.5	9.0	16.8	365	46.0	20.1	92
t_3	0.2	40.0	7.5	22.8	147	23.1	8.1	18.6	396	50.0	20.4	100
t_4	0.25	42.6	7.8	23.6	162	23.0	8.0	19.4	436	52.6	23.1	112
t_5	0.3	41.0	7.2	23.2	138	22.6	8.2	16.6	362	44.2	24.0	111
t_6	0.4	38.0	7.1	22.1	120	22.2	8.0	15.0	306	38.6	20.6	100
t_7	0.5	37.5	7.0	20.0	110	21.6	8.0	20.0	294	36.6	19.0	90
Carbamate pesticide II												
t_1	0.0	33.2	6.4	18.6	72	24.6	8.5	15.4	300	38.6	14.9	78
t_2	0.1	36.8	6.7	22.4	98	25.5	9.0	17.2	344	44.4	18.7	89
t_3	0.2	41.2	7.8	23.8	130	27.0	9.2	19.4	376	50.6	22.6	112
t_4	0.25	40.0	7.7	23.8	126	27.0	9.6	20.6	444	48.8	21.4	112
t_5	0.3	38.8	7.4	22.6	120	26.6	9.2	18.6	424	46.6	20.2	100
t_6	0.4	37.2	7.2	21.0	100	24.5	8.7	18.0	364	40.0	19.2	96
t_7	0.5	37.2	7.2	21.0	98	23.6	8.4	18.0	324	36.0	17.6	94
Carbamate pesticide III												
t_1	0.0	33.2	6.4	18.6	72	24.6	8.5	15.4	300	38.6	14.9	78
t_2	0.1	34.6	6.5	21.2	84	25.6	8.9	17.6	284	45.6	18.6	88
t_3	0.2	38.8	6.8	23.0	93	27.8	9.1	19.2	314	46.6	19.4	100
t_4	0.25	40.2	7.1	24.1	162	29.6	9.3	20.8	364	50.6	20.6	117
t_5	0.3	43.6	7.3	24.9	138	29.4	9.2	20.2	360	54.8	22.1	136
t_6	0.4	40.1	7.0	24.3	120	29.2	9.2	21.0	344	50.1	22.0	130
t_7	0.5	37.6	6.7	22.6	110	29.0	9.2	20.8	304	46.2	19.8	111
Sewage Sludge												
t_1	0.0	35.3	6.3	18.4	160	26.0	8.6	16.7	325	28.0	14.8	75
t_2	1.0	44.8	7.1	19.6	188	22.6	9.0	17.4	340	26.4	14.2	135
t_3	2.0	46.3	7.6	20.6	220	26.8	8.9	17.3	411	23.4	13.0	120
t_4	3.0	40.6	7.3	19.4	200	26.8	8.9	17.2	400	25.6	13.9	110
t_5	5.0	36.4	6.8	18.9	188	26.0	8.8	17.4	398	26.6	14.2	110
t_6	7.5	33.8	6.5	15.4	176	25.8	8.8	17.0	336	26.0	14.0	105
t_7	10.0	32.6	6.3	16.2	166	25.0	8.6	16.8	322	25.2	13.8	115
0.3 g Carbamate pesticide I +Sewage sludge												
t_1	0.0	38.8	6.6	19.6	97	33.3	9.6	9.8	317	28.2	18.0	90
t_2	1.0	48.0	8.0	25.0	120	36.4	9.8	20.6	362	29.3	16.6	120
t_3	2.0	47.5	8.0	23.8	210	32.3	9.5	19.2	387	29.5	17.2	124
t_4	3.0	50.6	8.2	25.6	172	25.5	9.3	18.2	414	24.6	15.2	118
t_5	5.0	45.2	7.4	23.1	112	25.0	9.3	18.26	356	22.2	15.6	112
t_6	7.5	40.1	6.7	21.6	99	24.8	9.2	18.6	327	21.6	15.0	105
t_7	10.0	35.8	6.4	19.0	110	22.0	8.7	18.0	346	17.8	14.6	102
0.3 g Carbamate pesticide II +Sewage sludge												
t_1	0.0	38.0	6.5	19.4	98	33.0	9.5	20.0	300	29.2	16.2	90
t_2	1.0	45.0	7.6	24.6	112	35.8	9.0	21.4	365	30.6	17.2	116
t_3	2.0	46.2	7.8	25.2	126	37.2	8.1	21.8	396	30.6	17.0	123
t_4	3.0	47.6	8.0	26.2	134	32.6	8.0	20.1	436	30.1	17.1	120
t_5	5.0	50.4	8.4	27.6	156	30.0	9.0	19.3	362	28.8	16.7	106
t_6	7.5	46.0	7.6	25.6	136	28.7	8.7	18.8	360	26.6	16.3	95
t_7	10.0	40.2	6.8	23.1	108	22.6	8.1	17.0	280	24.1	15.1	73
0.3 g Carbamate pesticide III +Sewage sludge												
t_1	0.0	40.2	6.6	20.1	90	32.6	9.6	19.4	200	30.0	16.6	84
t_2	1.0	42.6	6.9	24.5	100	34.6	9.5	21.3	244	31.0	16.5	94
t_3	2.0	46.2	7.4	26.0	110	35.2	10.1	22.4	312	32.6	17.3	103

t_4	3.0	48.2	7.8	26.6	133	34.4	10.0	22.4	333	29.6	17.1	73
t_5	5.0	45.2	7.7	26.2	130	30.2	8.9	20.0	300	33.2	17.5	114
t_6	7.5	44.4	7.1	25.2	126	28.4	8.7	18.6	242	28.6	16.2	84
t_7	10.0	36.8	6.1	19.1	94	24.2	7.6	17.4	192	25.1	15.9	76

Table 3. Long term effects of different doses of three carbamate pesticides, sewage sludge and sewage sludge& carbamate pesticides on the growth of tomato, brinjal and potato plants

Year	Tomato				Brinjal				Potato		
	Shoot height (cm)	Shoot weight (g)	Root length (cm)	Total weight of edible part (g)	Shoot height (cm)	Shoot weight (g)	Root length (cm)	Total weight of edible part (g)	Shoot height (cm)	Shoot weight (g)	Total weight of edible part (g)
Carbamate pesticide I (Oxamyl)											
2007	38.3	7.1	21.7	121	23.2	8.3	17.4	351	38.6	14.9	98
2008	36.4	7.0	21.4	115	24.5	8.7	16.8	335	46.0	20.1	112
2009	38.2	7.4	22.8	107	24.8	8.1	18.0	326	50.0	20.4	90
2010	31.2	7.2	23.6	112	23.6	8.3	17.4	336	52.6	23.1	82
2011	40.0	6.7	20.8	98	21.8	8.2	16.6	312	44.2	24.0	91
2012	38.0	7.0	21.1	90	22.4	8.0	16.0	306	38.6	20.6	80
2013	36.9	6.8	22.0	92	21.6	8.1	16.2	288	36.6	19.0	78
Carbamate pesticide II											
2007	37.8	7.2	21.9	106	25.5	8.9	18.2	368	43.6	19.2	97
2008	38.4	7.5	22.4	98	25.9	9.0	19.6	344	44.4	18.7	99
2009	39.2	7.8	22.8	100	26.4	9.2	18.4	336	46.8	21.6	112
2010	40.0	7.1	23.4	94	27.0	9.6	20.0	344	48.8	21.0	88
2011	37.8	7.0	21.6	90	26.1	8.8	18.0	324	46.6	20.2	94
2012	37.0	7.2	21.0	90	25.2	8.5	17.6	304	42.4	19.2	84
2013	36.2	6.9	21.7	93	23.9	8.3	18.2	312	39.8	18.4	92
Carbamate pesticide III											
2007	38.3	6.8	22.7	111	27.9	9.0	19.3	336	47.5	19.6	109
2008	37.6	6.6	22.2	114	27.1	8.9	19.0	288	46.9	19.0	98
2009	38.8	6.9	23.4	93	27.8	9.1	19.8	322	48.6	19.9	100
2010	40.2	7.1	24.1	122	29.6	9.3	20.4	358	50.0	20.6	117
2011	39.6	7.0	23.9	138	29.0	9.2	20.0	378	49.2	21.4	106
2012	40.1	7.2	24.3	120	29.6	9.4	21.0	346	50.1	22.0	100
2013	38.6	6.7	22.9	108	28.6	9.0	20.1	308	47.8	20.8	104
Sewage sludge											
2007	38.5	6.8	18.4	185	25.6	8.8	17.1	361	25.9	14.0	110
2008	40.8	7.1	19.2	188	26.7	9.0	17.6	414	26.4	14.4	125
2009	42.3	7.5	20.1	220	27.4	8.9	18.1	442	27.2	13.8	134
2010	40.6	7.6	19.6	200	26.4	8.8	17.6	400	26.6	14.6	120
2011	37.4	7.0	18.9	180	26.0	8.6	17.2	378	26.0	14.0	110
2012	35.8	6.8	17.4	170	25.6	8.5	17.0	336	25.4	14.0	102
2013	35.6	6.4	16.2	158	25.0	8.6	16.6	320	25.8	13.7	105

0.3 g Carbamate pesticide I +Sewage sludge											
2007	43.7	7.3	22.4	142	31.3	9.3	18.9	358	24.7	16.0	110
2008	45.0	7.7	23.8	160	32.8	9.6	20.0	382	26.3	16.8	120
2009	46.5	8.0	25.2	188	33.3	9.8	19.2	396	26.5	17.3	138
2010	45.2	8.0	25.6	152	30.8	9.5	18.8	414	24.6	16.2	116
2011	43.2	7.5	24.1	126	31.6	9.3	18.2	366	23.2	15.6	108
2012	41.8	7.1	22.6	111	30.8	9.2	18.6	334	21.6	15.0	100
2013	41.0	6.8	20.8	110	31.6	8.9	18.0	346	22.8	15.6	110
0.3 g Carbamate pesticide II +Sewage sludge											
2007	44.8	7.5	24.5	124	31.1	8.6	20.0	343	28.6	16.5	104
2008	45.3	7.8	26.2	142	32.8	8.8	21.2	385	30.0	17.0	121
2009	46.2	8.1	27.6	166	33.4	9.1	21.8	414	30.6	17.2	129
2010	46.6	8.0	26.4	144	32.6	8.7	20.9	426	30.1	17.1	120
2011	45.4	8.0	25.1	126	31.0	9.0	20.3	362	28.8	16.7	110
2012	44.0	7.6	26.2	130	30.4	8.5	18.8	340	29.2	16.3	102
2013	44.2	7.2	23.6	112	30.6	8.1	19.0	292	271	16.1	92
0.3 g Carbamate pesticide III +Sewage sludge											
2007	43.4	7.1	23.91	112	31.4	9.2	20.2	260	30.0	16.7	90
2008	44.6	7.0	24.5	124	32.6	9.5	21.0	294	31.0	17.0	99
2009	46.2	7.4	26.0	140	33.4	10.1	22.1	332	32.6	17.4	111
2010	46.9	7.6	26.6	133	33.1	10.0	21.9	302	31.2	17.1	98
2011	45.2	7.3	25.8	130	32.2	9.3	21.2	288	33.2	17.0	94
2012	44.4	7.1	25.2	126	29.4	9.4	21.0	264	30.6	16.6	104
2013	44.8	7.0	24.9	112	31.2	8.7	20.8	222	28.1	16.1	84

Table:4. Concentration of heavy metals in various parts of tomato plant (mg kg^{-1} dry weight) in presence of different concentration of three carbamate pesticides, sewage sludge and pesticide& sewage sludge

Metals		Pesticide I	Pesticide II	Pesticide III	Sewage sludge	0.3 g pesticide I+ sewage sludge	0.3 g pesticide II+ sewage sludge	0.3 g pesticide III+ sewage sludge
Zn	R	109.4±4.5 (96-134)	111±2.8 (94-128)	112±3.5 (100-128)	139±8.3 (100-164)	151±10 (110-180)	146±12(106-170)	147±11 (118-165)
	S	103.4±3.1 (96-117)	103±2.2 (88-119)	105±2.6 (96-110)	121±7.5 (96-146)	134±8.8 (100-154)	131±9 (102-152)	123± 7 (106-140)
	E	18.4±1.0 (16-21)	17±0.6 (16-18)	17.3±0.6 (16-18)	20±1.6 (16-24)	21±2.2 (17-25)	20.3±1.1 (17-23)	20.7±1.2 (17-24)
Cu	R	28.6±1.4 (26-32)	27.6±1.8 (25-30)	28.7±1.3 (27-32)	32.7±1.8 (27-35)	33.6±2.3 (29-36)	33.4±2.1 (27-36)	33.6±2.4 (29-36)
	S	18.6±0.9 (17-20)	19.7±1.2 (17-22)	21.4±1.5 (17-26)	20.6±1.1 (17-23)	20.1±1.2 (17-22)	20.1±0.8 (17-22)	22±1.2 (19-24)
	E	1.7±0.08 (1.5-1.9)	1.7±0.10 (1.5-1.9)	1.8±0.14(1.6-2.0)	1.9±0.08(1.6-2.1)	2.07±0.14(1.6-2.3)	1.96±0.07(1.6-2.2)	1.96±0.10(1.6-2.2)
Mn	R	63.7±1.8 (56-71)	64±1.9 (56-73)	66.4±2.2 (56-73)	61.3±2.4 (56-78)	73±3.4 (59-80)	69±3.0 (58-76)	70± 2.8 (60-76)
	S	45.6±2.1 (40-50)	46.6±2.2 (40-58)	50±1.6 (40-55)	51.3±2.7 (40-56)	50.1±2.2 (41-56)	50.8±2.5 (43-55)	50±2.2 (44-553
	E	25.4±0.7 (22-29)	23±0.5 (21-25)	24.14±0.6 (22-26)	28.4±1.3 (22-32)	29.3±1.5 (22-34)	29±1.4 (23-32)	28±1.0 (23-31)
Fe	R	339±9 (288-392)	333±8.4 (294-370)	337±10 (300-377)	408±14 (300-463)	432±18 (316-492)	413±12 (300-464)	407±14 (310-464)
	S	300±12 (264-334)	300±9.8 (264-330)	304±9 (264-3334)	367±11 (264-412)	377±13 (288-422)	368±9 (281-408)	369±9.4 (290-410)
	E	180±7 (168-212)	175±5.2 (162-188)	188±5.8 (168-200)	209± 9 (168-236)	209±9 (184-230)	215±10 (182-236)	218±8.2 (190-236)
Cr	R	1.64 ±0.06 (1.5-1.8)	1.67 ±0.04 (1.6-1.8)	1.71 ±0.06 (1.6-1.9)	1.9 ±0.06 (1.6-2.0)	2.04 ±0.10 (1.7-2.2)	1.93 ±0.06 (1.7-2.1)	1.98±0.05 (1.8-2.1)
	S	1.33±0.02(1.2-1.4)	1.26±0.03 (1.2-1.3)	1.33±0.03 (1.1-1.4)	1.64±0.08 (1.3-1.8)	1.68±0.08 (1.3-1.9)	1.50±0.03 (1.3-1.6)	1.60±0.05 (1.4-1.7)
	E	0.4±0.02 (0.3-0.5)	0.33±0.02 (0.3-0.4)	0.34±0.01 (0.3-0.4)	0.46±0.03 (0.3-0.6)	0.48±0.06 (0.3-0.6)	0.46±0.03 (0.3-0.5)	0.41±0.03 (0.3-0.5)
Ni	R	1.11±0.05 (1.0-1.3)	1.1±0.03(1.0-1.2)	1.2±0.03 (1.1-1.3)	1.36±0.07 (1.1-1.5)	1.4±0.10 (1.1-1.6)	1.27±0.08 (1.1-1.4)	1.34±0.06 (1.2-1.5)
	S	0.73±0.03 (0.7-0.8)	0.67±0.03 (0.6-0.8)	0.7±0.02 (0.6-0.8)	0.86±0.06 (0.7-1.0)	0.90±0.05 (0.7-1.0)	0.76±0.01 (0.7-0.8)	0.83±0.04 (0.7-0.9)
	E	0.23±0.03 (0.2-0.3)	0.24±0.04 (0.2-0.3)	0.24±0.03 (0.2-0.3)	0.30±0.03 (0.2-0.4)	0.26±0.02 (0.2-0.3)	0.27±0.02 (0.2-0.3)	0.26±0.03 (0.2-0.3)
Pb	R	1.63±0.04 (1.5-1.7)	1.69±0.06 (1.6-1.8)	1.7±0.04 (1.6-1.8)	2.03±0.07 (1.6-2.3)	2.19±0.10 (1.6-2.5)	2.06±0.09 (1.7-2.3)	2.0±0.05 (1.8-2.2)
	S	1.26±0.04 (1.1-1.4)	1.17±0.04 (1.2-1.3)	1.17±0.03 (1.1-1.3)	1.47±0.08 (1.1-1.6)	1.54±0.08 (1.1-1.7)	1.57±0.07 (1.3-1.8)	1.52±0.03 (1.2-1.6)
	E	0.23±0.02 (0.2-0.3)	0.23±0.02 (0.2-0.3)	0.26±0.03 (0.2-0.3)	0.30±0.06 (0.2-0.4)	0.30±0.03 (0.2-0.4)	0.26±0.02 (0.2-03)	0.27±0.02 (0.2-03)

R= Root; S= Stem; E= Edible part; ± values are SD; values in bracket denote range

Table: 5. Concentration of heavy metals in various parts of brinjal plant (mg kg^{-1} dry weight) in presence of different concentration ofthree carbamate pesticides, sewage sludge and pesticide& sewage sludge

Metals		Pesticide I	Pesticide II	Pesticide III	Sewage sludge	0.3 g pesticide I+ sewage sludge	0.3 g pesticide II+ sewage sludge	0.3 g pesticide III+ sewage sludge
Zn	R	86±2.5 (76-90)	91±3.6 (84-96)	92±3.2 (84-99)	114±7.8 (84-134)	112±10 (96-124)	110±12 (94-125)	119.6±13 (100-136)
	S	76±1.4 (70-82)	77.6±1.5 (72-83)	77.4±3.9 (72-83)	94.6±6.1 (72-141)	96±5.8 (84-112)	95±5.0 (85-102)	99±4.2 (93-110)
	E	13.8±0.08(13-14)	14.1±0.6(13-15)	14.6±0.6(12-16)	16±1.1 (13-18)	15.4±2.1 (13-17)	17.3±1.9 (14-20)	16±1.7 (13-19)
Cu	R	26.6±1.1 (25-30)	28.4±1.2 (26-31)	28.0±1.9 (26-31)	30.4±1.2 (26-32)	29.6±2.0 (26-33)	30.6±1.8 (27-33)	29.3±2.0 (26-33)
	S	16.6±0.7 (15-18)	17.0±0.5 (15-18)	16.8±0.6 (15-18)	17.3±1.2 (15-18)	17.3±1.2 (16-19)	18.1±1.1 (16-20)	17.6±1.1 (16-19)
	E	1.74±0.08 (1.6-1.9)	1.71±0.06 (1.6-1.9)	1.81±0.06 (1.6-2.0)	1.8±0.06(1.6-2.0)	1.80±0.04 (1.7-1.9)	1.83±0.08(1.6-2.0)	1.83±0.05 (1.6-2.1)
Mn	R	65.7±1.7 (58-71)	64.0±1.6 (58-69)	65.0±1.7 (58-70)	71.6±2.6 (58-77)	69.3±2.5 (61-76)	70.7±3.2 (61-79)	69.6±2.6 (60-77)
	S	46.3±1.3 (44-48)	49.0±1.8 (44-54)	46.0±1.0 (44-48)	50.7±2.0 (44-54)	54.1±3.2 (45-60)	56±3.0 (45-63)	57.0±3.8 (44-64)
	E	24.1±0.5 (23-26)	26.1±0.7 (23-28)	25.7±0.7 (23-28)	25.3±1.2 (23-27)	26.3±1.1 (24-29)	27±1.3 (23-29)	27.0±1.3 (23-29)
Fe	R	335±7.8(316-358)	334±15.2(286-380)	347±13.2(316-392)	392±11 (316-454)	397±13 (330-456)	404±13 (336-444)	369±11 (326-410)
	S	300±5.2(284-316)	292±8.4(254-320)	308±8.5(284-330)	343±9 (284-390)	363±16 (286-444)	339±11 (300-376)	320±9 (284-356)
	E	184±5 (174-190)	181±7 (170-208)	200±7 (182-216)	236± 12 (182-276)	230±10 (199-250)	234±10 (210-272)	222±8.4 (200-243)
Cr	R	1.74 ±0.04 (1.7-1.8)	1.77±0.05 (1.6-1.9)	1.86±0.07 (1.7-2.0)	1.9 ±0.06 (1.7-2.0)	1.96±0.08 (1.8-2.2)	1.84±0.06 (1.7-2.0)	1.81±0.07 (1.6-2.0)
	S	1.30±0.04 (1.2-1.4)	1.36±0.06 (1.2-1.5)	1.48±0.06 (1.3-1.6	1.53±0.06 (1.3-1.7)	1.60±0.04 (1.4-1.7)	1.73±0.05 (1.3-1.9)	1.40±0.05 (1.2-1.6)
	E	0.32±0.02 (0.3-0.4)	0.36±0.05 (0.3-0.5)	0.34±0.02 (0.3-0.4)	0.36±0.02 (0.3-0.4)	0.34±0.02 (0.3-0.5)	0.36±0.01 (0.3-0.4)	0.34±0.02 (0.3-0.4)
Ni	R	1.31±0.08 (1.1-1.5)	1.34±0.08 (1.1-1.5)	1.31±0.04 (1.1-1.5)	1.33±0.03 (1.1-1.5)	1.54±0.10 (1.2-1.8)	1.63±0.12 (1.3-1.8)	1.43±0.10 (1.2-1.6)
	S	0.83±0.09 (0.7-1.0)	0.83±0.09 (0.7-1.0)	0.78±0.02 (0.7-0.9)	0.77±0.04 (0.7-0.9)	0.77±0.06 (0.6-0.9)	0.73±0.02 (0.6-0.8)	0.67±0.04 (0.6-0.8)
	E	0.30±0.05 (0.2-0.4)	0.27±0.04 (0.2-0.4)	0.28±0.02 (0.2-0.4)	0.26±0.02 (0.2-0.3)	0.26±0.04 (0.0-0.5)	0.27±0.02 (0.2-0.3)	0.20±0.03 (0.0-0.3)
Pb	R	1.77±0.08 (1.6-1.9)	1.76±0.07 (1.6-2.0)	1.78±0.06 (1.6-2.0)	1.94±0.05 (1.6-2.1)	1.86±0.05(1.7-2.0)	2.0±0.02 (1.8-2.2)	1.61±0.05 (1.5-1.7)
	S	1.18±0.03 (1.1-1.3)	1.34±0.05 (1.2-1.6)	1.27±0.04 (1.2-1.4)	1.23±0.03 (1.2-1.3)	1.34±0.04 (1.2-1.5)	1.47±0.04 (1.3-1.6)	1.27±0.04 (1.2-1.4)
	E	0.26±0.02 (0.2-0.3)	0.24±0.02 (0.2-0.3)	0.28±0.04 (0.2-0.4)	0.24±0.02 (0.2-0.3)	0.31±0.03 (0.2-0.4)	0.46±0.05 (0.3-0.6)	0.26±0.04 (0.0-0.4)

R= Root; S= Stem; E= Edible part; ± values are SD; values in bracket denote range

Table:6. Concentration of heavy metals in various parts of potato plant (mg kg^{-1} dry weight) in presence of different concentration ofthree carbamate pesticides, sewage sludge and pesticide& sewage sludge

Metals		Pesticide I	Pesticide II	Pesticide III	Sewage sludge	0.3 g pesticide I+ sewage sludge	0.3 g pesticide II+ sewage sludge	0.3 g pesticide III+ sewage sludge
Zn	R	79± 2.7 (70-88)	81± 2.4 (76-86)	82± 3.4 (76-89)	96± 4.8 (76-110)	88± 4.8 (77-98)	81± 2.4 (72-88)	86± 3.4 (75-96)
	S	53±1.9 (47-59)	53±1.7 (48-58)	53.6±1.7 (48-60)	58.0±2.2 (48-66)	56±2.2 (47-62)	54.0±2.1 (48-58)	49.7±1.8 (46-55)
	E	8.9±0.12 (8-10)	9.6±0.8 (8-11)	9.4±0.4 (8-10)	10.8±0.8 (8-13)	10.3±0.7 (8-12)	9.9±0.4 (8-11)	11.6±0.6 (9-14)
Cu	R	27.6±1.2 (25-30)	26.8±1.1 (25-29)	27.3±1.3 (25-30)	30±1.5 (25-33)	30.1±1.2 (26-33)	29±1.4 (26-32)	28.6±1.1 (26-32)
	S	15.1±0.4 (13-17)	15.0±0.3 (13-16)	15.1±0.4 (13-17)	15.4±0.4 (13-17)	14.8±0.3 (13-16)	15.3±0.4 (13-17)	15.1±0.3 (14-17)
	E	1.41±0.06 (1.3-1.5)	1.37±0.05 (1.3-1.5)	1.44±0.06 (1.3-1.6)	1.50±0.06 (1.3-1.7)	1.43±0.04 (1.3-1.5)	1.44±0.04 (1.3-1.5)	1.76±0.06 (1.5-2.0)
Mn	R	65.6±1.8 (50-78)	64.7±1.6 (56-75)	65.6±1.6 (56-73)	65.6±1.6 (56-73)	69.4±2.7 (58-78)	68.1±2.5 (57-78)	70±1.8 (60-79)
	S	45.7± 1.7 (40-53)	42.4± 1.3 (38-47)	43.0± 1.0 (40-46)	44.0± 1.0 (40-48)	47.4± 2.2 (41-52)	43.4± 1.8 (40-53)	48.3± 1.6 (42-55)
	E	18.7±0.6 (17-22)	17.1±0.5 (15-19)	18.1±0.4 (17-20)	19.3±0.4 (17-22)	20.3±0.6 (18-24)	19.7±0.4 (17-22)	21±0.7(18-24)
Fe	R	293± 12 (260-320)	300± 15 (260-336)	299± 11 (260-330)	321± 18 (260-385)	315± 13 (252-356)	339± 15 (268-394)	337± 12 (290-375)
	S	174±7.2 (160-189)	164±5.8 (150-176)	176±6.8 (160-192)	191±5.6 (160-210)	169±5.2 (150-194)	183±5.9 (158-210)	182±5.0 (166-199)
	E	122±2.4(118-130)	125±2.1(120-130)	131±3.3(120-142)	137±2.9(120-156)	132±2.5(110-154)	142±3.1(120-158)	131±2.3(122-142)
Cr	R	1.77±0.05 (1.7-1.9)	1.70±0.04 (1.5-1.8)	1.68±0.04 (1.6-1.8)	1.86±0.04 (1.7-2.0)	1.74±0.04 (1.6-1.9)	1.6±0.04 (1.5-1.7)	1.67±0.03 (1.5-1.8)
	S	1.06±0.04 (1.0-1.2)	1.08±0.04 (1.0-1.2)	1.04±0.03 (1.0-1.2)	1.08±0.04 (1.0-1.2)	1.0±0.03 (0.9-1.1)	1.04±0.04 (1.0-1.1)	1.10±0.03 (1.0-1.2)
	E	0.13±0.02 (0.0-0.2)	0.13±0.02 (0.1-0.2)	0.14±0.02 (0.0-0.2)	0.13±0.02 (0.1-0.2)	0.14±0.04 (0.0-0.3)	0.16±0.03 (0.1-0.2)	0.11±0.04 (0.0-0.2)
Ni	R	1.40±0.07 (1.2-1.5)	1.23±0.03 (1.2-1.3)	1.17±0.05(1.0-1.3)	1.27±0.04(1.2-1.4)	1.19±0.04(1.1-1.3)	1.21±0.03(1.1-1.3)	1.11±0.05(1.0-1.2)
	S	0.60±0.04 (0.5-0.7)	0.47±0.02 (0.4-0.5)	0.51±0.03 (0.5-0.6)	0.51±0.04 (0.4-0.6)	0.51±0.04 (0.4-0.6)	0.51±0.04 (0.4-0.6)	0.53±0.04 (0.5-0.7)
	E	0.11±0.02 (0.0-0.2)	0.07±0.01 (0.0-0.1)	0.10±0.02 (0.0-0.2)	0.09±0.01 (0.0-0.10)	0.11±0.04 (0.0-0.2)	0.14±0.03 (0.1-0.2)	0.13±0.03 (0.0-0.2)
Pb	R	1.06±0.04 (1.0-1.2)	1.04±0.03 (1.0-1.1)	1.07±0.04 (1.0-1.2)	1.06±0.04 (1.0-1.2)	1.07±0.04 (0.9-1.2)	1.06±0.04 (1.0-1.2)	1.11±0.05 (1.0-1.3)
	S	0.53±0.02 (0.5-0.6)	0.53±0.02 (0.5-0.6)	0.53±0.02 (0.5-0.6)	0.53±0.02 (0.5-0.6)	0.46±0.03 (0.4-0.5)	0.51±0.02 (0.4-0.6)	0.51±0.02 (0.4-0.6)
	E	0.08±0.04 (0.0-0.2)	0.10±0.03 (0.0-0.2)	0.06±0.01 (0.0-0.1)	0.11±0.02 (0.0-0.2)	0.11±0.02 (0.0-0.2)	0.16±0.03 (0.1-0.2)	0.10±0.02 (0.0-0.2)

R= Root; S= Stem; E= Edible part; ± values are SD; values in bracket denote range

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