Vol. 12(1), pp. 17-25, January-June 2020
DOI: 10.5897/IJPPB2020.0301
Article Number: 896EBD564269
ISSN 2006-9758

http://www.academicjournals.org/IJPPB

International Journal of Plant Physiology and Biochemistry

Full Length Research Paper

Impact of pesticides on the growth of *Coriandrum sativum*

Aniket Naha[1], Dipen Chandra Nath[2] and Soumitra Nath[1]*

[1]Department of Biotechnology, Gurucharan College, Silchar, India.
[2]Soil Science, Krishi Vigyan Kendra, Cachar, Assam, India.

Received 20 April, 2020; Accepted 10 June, 2020

Pest management is a severe constraint in agriculture as pests decrease the plant yield, productivity and also act as vectors causing various plant diseases. Pesticides are used to devour pests; however, irrational usage results in adverse impacts on the ecosystem. The present investigation was aimed to study the effects of fenvalerate, cypermethrin and chlorpyriphos on the growth of *Coriandrum sativum* for 35 days until the plants attained the flowering stage. The study was conducted in triplicates and various growth parameters such as germination rate, shoot height, biomass and moisture content of pesticide-induced plants were calculated and compared with control. On the 35th day, the plants displayed enhanced shoot heights under recommended pesticide dosage of 2.5 mL L^{-1} for cypermethrin (11.41 ± 0.08 cm) and fenvalerate (12.43 ± 0.2 cm) rather than the control plants (9.12 ± 0.06 cm). However, detrimental effects on plant growth and early mortality were observed in chlorpyriphos treated plantlets. Student's t-test revealed a marked difference in plant growth under different pesticide concentration gradients at a 5% level of significance. Analysis of shoot heights and analysis of variance (ANOVA) concluded that there was no significant mean difference of plants grown under cypermethrin and fenvalerate stress at 5.0 and 7.5 mL L^{-1} concentration with plants in control. Hence, the present study establishes an optimal pesticide range of 5.0 ± 2.5 mL L^{-1}, which did not prove injurious to the growth and productivity of *C. sativum*.

Key words: Chloropyriphos, *Coriandrum sativum*, cypermethrin, fenvalerate, germination.

INTRODUCTION

In agriculture, various disease-causing organisms including insects, larvae, pathogenic fungi, viruses and weeds, severely affect the growth and productivity of crops. Organic or inorganic pesticides are xenobiotic compounds that are routinely administered to debar pests from crops. Pesticides comprise fungicide, herbicide, nematicide, molluscicide, germicide, antimicrobial agents and insect or animal repellents (Randall et al., 2013). In

*Corresponding author. E-mail: nath.soumitra1@gmail.com.

Abbreviations: ANOVA, Analysis of variance; **CNS,** central nervous system; **E.C.,** emulsifiable concentrate; **EC,** electrical conductivity; **KVK,** Krishi Vigyan Kendra; **SPSS,** Statistical Package for the Social Sciences; **TA,** Tatafen; **TR,** Tricel; **US,** Ustaad.

most agricultural practices, pesticides are used to increase the yield, productivity and vigour of crops. Pimentel (1995) reported that only 0.1% of the applied pesticide acts against the pest, and 99.9% of the remaining affects the environment. De Oliveira et al. (2012) estimated that annually millions of tons of pesticides are applied to crop fields out of which less than 5% acts against the target organisms while the excess fraction (> 95%) of pesticides target the beneficial soil microflora and leads to the pollution of soil and water bodies (Alavanja, 2012; Carvalho, 2006; Freire et al., 2015; López-Pérez et al., 2006; Meyer et al., 2010; Power, 2010; Turra et al., 2010; Oliveira et al., 2016). India accounts for the maximum usage of insecticides (76%), fungicides (13%), herbicides (10%) and others (1%), as compared to 44% of insecticides usage globally. Most commonly used pesticides in Barak Valley, Assam are organophosphates (dimethoate, chlorpyriphos, monocrotophos, dichlorophos, profenofos); synthetic pyrethroid (fenvalerate, cypermethrin); organochlorides (endosulfan, DDT); and carbamates (carbofuran) (Dey et al., 2013). These pesticides are reported to enter the food chain by the process of biomagnifications affecting the consumers and farmers. González et al. (2011) found traces of pesticides in fruits, vegetable crops and even in other processed food products which signifies that the pesticides are non-recalcitrant compounds, and retain their toxicity even after detoxification and degradation processes. Pesticide sprays can directly hit non-target vegetation or can drift or volatilise from the treated area, and contaminate air, soil and non-target agents (Aktar et al., 2009). Due to extensive agricultural practises in the same cultivable land, pesticides which were applied to the previously grown crops gets accumulated in the soil by the process of leaching which proves detrimental for plant health and human consumption as they are hard to convert into less toxic forms by chemical and biological processes. As a result, high concentrations of pesticides hinder various biological processes of the plants causing chlorosis, nutrient imbalances, oxidative stress and decline in enzyme activity. It also affects seedling germination, reproductive health or flowering and yield.

The present study aims to understand the effect of the pesticides on the growth patterns of an essential annual herb Coriander (*Coriandrum sativum*), a plant from Apiaceae family, which is often regarded as the "spice of happiness" by Egyptians (Hameed et al., 2017). *C. sativum* is cultivated during the winter months, and maturation or flowering can be achieved within a month, it proved to be a perfect candidate for our study. Being rich in antioxidants, the plant has tremendous health benefits that include antispasmodic, aphrodisiac, hypolipidemic, hypoglycaemic, and antimutagenic properties. The leaves and seeds are commonly consumed which contains lots of mineral oils, and flavouring compounds like limonene, linalool, pinen, terpinen and geraniol (Mahendra and Bisht, 2011; Maroufi et al., 2010; Sahib et al., 2013). The growth patterns of *C. sativum* were studied under three different pesticide application which includes TATAfen (fenvalerate 20% emulsifiable concentrate (E.C.) [a TATA product]; Tricel (Chloropyriphos 20% E.C.) [Excel Crop Care]; and Ustaad (cypermethrin 10% E.C.) [UPL]); which are extensively applied in the crop fields in this region. Fenvalerate falls under the category of synthetic pyrethroids which is applied against a wide range of pests and is of low toxicity to mammals. Short-time exposure to humans causes itching of skin and irritation of eyes, whereas prolonged exposure causes lead to neurological disorders and endocrine dysfunction (Umeda et al., 2016). Chloropyriphos is amongst the widely used organophosphate pesticide which is useful against all biting and chewing pests (Bozdogan et al., 2015). It is effective for longer durations and does not wash off in rainwater due to its higher persistence value and is very toxic to mammals, including humans (Mitran et al., 2017). Cypermethrin is a synthetic pyrethroid pesticide and insect repellent which is effective in killing many pests like aphids, thrips, mites, moths and is extensively used to protect vegetable crops. It is also reported to cause germ cell mutations and potential genotoxic effects in mice models (Aktar et al., 2009; Emam and Abdelhameed, 2017; Dey et al., 2013). Hence, the present study was aimed to understand the effects of three pesticides on the growth parameters of *C. sativum* and finally to establish the pesticide concentration range to which the plants show minimal distortion in growth patterns.

MATERIALS AND METHODS

Study site, sampling and soil analysis

The study was conducted during December to mid-February in the year 2016-2017 in Silchar, Assam (24° 48' N, 92° 47' E). The average temperature that prevailed during this session was 11 to 23°C, with no rainfall recorded during the span of the study. The soil sample was collected by random sampling method from the banks of Barak River, Silchar (24° 5' N and 92° 46' E) from a depth of 10 to 20 cm with no history of pesticide application ever. The soil samples were grinded, shade dried and sieved through 2 mm pore sieve. The soil sample was analysed for soil pH, electrical conductivity (mS cm^{-1}), texture, consistency, moisture content (%), bulk density (g mL^{-1}), particle density (g mL^{-1}), and porosity (%). Estimation of macronutrients (C, N, P, K) and micronutrients (S, Zn, B, Fe) contents were performed at Soil Testing Laboratory, Krishi Vigyan Kendra (KVK), Arunachal, Cachar, Assam (Iwara et al., 2011). The soil used for the present study was dark-brown coloured silt-clay-loamy soil with high moisture content (23.41 ± 4.36%), indicating that the soil was fertile with high organic content (Wall, 2005). The soil pH was recorded as 7.38 ± 0.07 (mildly alkaline), and electrical conductivity (E.C.) was 0.37 ± 0.03 mS cm^{-1}, which means that the soil is critical for salt-sensitive crops (Mitran et al., 2017). Due to high organic content in the soil, the bulk density was low (0.78 ± 0.06 g mL^{-1}) and particle density was medium (1.81 ± 0.37 gmL^{-1}); however, the soil was highly porous (56.21 ± 8.64%), and also showed high drainage capacity and hydraulic conductivity. The presence of macronutrients (C, N, P, K) and micronutrients

Table 1. Physico-chemical properties of various soil samples of pot culture under concentration gradient of three different pesticides.

Sample	pH	E.C. (mS cm^{-1})	Carbon (%)	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})	Sulphur (mg kg^{-1})	Zinc (mg kg^{-1})	Boron (mg kg^{-1})	Iron (mg kg^{-1})
Control	7.40	0.42	2.02	692.90	120.80	343.70	9.62	5.04	0.81	12.30
					US= Ustaad (Cypermethrin, 10% E.C.)					
US (2.5 mL L^{-1})	7.33	0.40	2.00	686.50	99.55	317.70	2.24	4.32	1.65	17.00
US (5.0 mL L^{-1})	7.35	0.37	1.97	680.10	96.44	270.20	5.11	1.44	1.01	8.40
US (7.5 mL L^{-1})	7.38	0.39	1.91	660.90	95.11	314.30	3.47	2.16	1.42	10.40
US (10.0 mL L^{-1})	7.45	0.31	1.97	680.10	92.01	317.70	3.88	3.96	0.73	6.94
US (12.5 mL L^{-1})	7.47	0.37	2.04	699.30	97.77	299.60	4.70	2.16	0.13	8.17
					TA= Tatafen (Fenvalerate, 20% E.C.)					
TA (1.0 mL L^{-1})	7.32	0.33	1.95	673.70	75.15	334.60	5.93	1.80	0.18	7.28
TA (2.5 mL L^{-1})	7.27	0.35	1.91	660.90	79.59	315.40	5.11	2.88	0.23	5.82
TA (5.0 mL L^{-1})	7.32	0.32	1.88	654.40	85.35	327.80	3.47	2.52	0.04	8.96
TA (7.5 mL L^{-1})	7.37	0.37	1.95	673.70	90.23	323.30	2.65	3.60	0.27	15.60
TA (10.0 mL L^{-1})	7.42	0.41	1.93	667.30	89.79	339.10	0.00	1.80	0.36	7.28
TA (12.5 mL L^{-1})	7.46	0.42	2.00	686.50	94.22	331.20	0.00	0.72	0.82	8.96
					TR= Tricel (Chloropyriphos, 20% E.C)					
TR (1.0 mL L^{-1})	7.30	0.34	2.02	692.90	77.81	309.70	0.60	5.40	0.82	8.40
TR (2.5 mL L^{-1})	7.21	0.41	1.91	660.90	94.67	338.00	0.19	3.60	0.41	7.72
TR (5.0 mL L^{-1})	7.38	0.36	1.97	680.10	87.13	330.10	1.01	1.08	0.38	9.96
TR (7.5 mL L^{-1})	7.41	0.40	1.88	654.40	98.21	322.20	1.83	3.60	0.36	9.07
TR (10.0 mL L^{-1})	7.43	0.36	1.95	673.70	96.44	309.70	0.00	1.08	0.23	8.28
TR (12.5 mL L^{-1})	7.45	0.40	1.93	667.30	92.89	333.50	0.00	0.36	0.13	6.04

*Soil test conducted after 35 days of incubation. pH: Strongly acidic (<4.5 - 5.5), Mild acidic (5.6 - 6.5), Neutral (6.6 - 7.3), Mildly alkaline (7.4 - 8), Strongly alkaline (8.1 - > 9); EC: Normal (< 0.08), Critical for salt-sensitive crops (0.08 - 1.6), Critical for salt-tolerant crops (1.6 - 2.5), Injurious to all crops (> 2.5); Carbon: Very low (< 0.25), Low (0.25 - 0.49), Medium (0.5 - 0.75), High (0.76 - 1), Very high (> 1); Nitrogen: Very low (< 136), Low (136 - 271.9), Medium (272 - 544), High (544.1 - 816), Very high (> 816); Phosphorus: Very low (< 11), Low (11 - 22.4), Medium (22.4 - 56), High (56.1 - 84), Very high (> 84); Potassium: Very low (< 68), Low (68 - 135.9), Medium (136 - 336.9), High (337 - 506), Very high (> 506); Sulphur: Very low (< 5), Low (5 - 9.9), Medium (10 - 15), High (15.1 - 22.5), Very high (> 22.5); Zinc: Deficient (< 0.06); Iron: Deficient (< 4.5); Boron: Deficient (< 0.05).

(S, Zn, B, Fe) was also estimated which are summarised in Table 1. Organic carbon (1.95 ± 0.04%), nitrogen (675.03 ± 12.91 kg ha^{-1}), phosphorus (92.86 ± 9.75 kg ha^{-1}), zinc (2.7 ± 1.44 mg kg^{-1}) and iron (9.37 ± 2.88 mg kg^{-1}) contents were found to be very high amounts; potassium (321.82 ± 16.77 kg ha^{-1}) and boron (0.53 ± 0.44 mg kg^{-1}) were present in moderate ranges while sulphur (3.32 ± 3.44 mg kg^{-1}) content was extremely low.

Pot experimental studies

Pot preparation

Pre-autoclaved soil samples were filled equally in earthen pots (14 cm × 14 cm × 11 cm), labelled and grouped for three different pesticide treatments. Six different concentrations (1.0, 2.5, 5.0, 7.5, 10.0, and 12.5 mL L^{-1}) for each pesticide were chosen, and three replicates for each concentration were allotted for the study. Pots without the presence of pesticide served as control setup (Nath et al., 2013).

Seedling inoculation

Seeds of *C. sativum* were collected under the supervision

Table 2. Germination rate of *Coriandrum sativum* seedlings, inoculated with pesticides at different concentrations.

Concentration (mL L^{-1})	Germination rate (%)		
	Fenvalerate	Cypermethrin	Chloropyriphos
1.0	100	100	100
2.5	100	100	90
5.0	85	90	75
7.5	65	70	55
10.0	50	50	35
12.5	35	40	30

and direction of the personnel of Plant Protection Department, KVK. Seeds were washed and soaked in double-distilled water for 24 h. The seeds that settled at the bottom were considered viable and were selected for the study. Seeds were wrapped in a moist cloth for another 48 h until the seeds swelled, and approximately twenty seeds were sown in each pot and watered daily (Nath et al., 2018).

Pesticide administration

Fenvalerate, cypermethrin and chlorpyriphos were sprayed on the plant leaves using a foliar spray of 1 L capacity in the early morning at an interval of ten days as suggested by the Plant Protection and Soil Science Department, KVK Cachar. Due to pesticides retention in the cultivable lands from previous farming practises, the pesticide concentration remains higher in the crop fields than the recommended dosage of 2.5 mL L^{-1}. Therefore, to mimic the crop field conditions, six different concentrations (1.0, 2.5, 5.0, 7.5, 10.0, and 12.5 mL L^{-1}) were considered for each pesticide ranging below and above the recommended dosage.

Study of growth parameters

The effect of three different pesticides and their effects at different concentrations were studied till maturation, and the flowering stage was attained. Germination rate, shoot height, biomass and moisture content with increasing pesticide concentration were also calculated. Germination rate was estimated using the following formula (Zahoranová et al., 2016):

$$\text{Germination (\%)} = \frac{\text{Germinated seeds}}{\text{Total planted seeds}} \times 100$$

Shoot heights were calculated at an interval of 5 days from the day seeds were sown till 35th day after which the plants were harvested, and the shoots were weighed to estimate the biomass of the plant whereas dry weight was estimated by exposing the plants in a hot air oven at 100°C for 2 h. The moisture content of the plants was calculated by the following formula (Medrano et al., 2015):

$$\text{Moisture content } = 1 - \frac{\text{Dry weight}}{\text{Fresh weight}} \times 100$$

Statistical analysis

Student's t-test was performed in Microsoft Excel to study the independent nature of plant growth, that is, growths of the plants subjected to each pesticide concentration are independent, and they do not have any influence on each other. Statistical analysis was performed with shoot heights expressed as mean ± standard deviation (SD). Software SPSS 16.0 was used to calculate the analysis of variance (ANOVA) and multiple comparison tests, considering the level of significance at $P < 0.05$. The comparison between groups of the plant heights with increasing pesticide concentration was performed assuming equal variances (Tukey's-b test) and unequal variances (Games-Howell test). Therefore, the null hypothesis, H_0 set up for the experiment was, 'with an increase in the pesticide concentration, there is no significant change in the growth parameters of *C. sativum* plants' (Namiki et al., 2018; Nath et al., 2018).

RESULTS AND DISCUSSION

Effect of pesticides on plant growth parameters

Germination rate and plant maturity

The germination rate was observed to be affected with an increase in pesticide concentration, while maximum germination was observed in control pots, showing 100% seedling viability. Germination of plants in control and pesticide concentrations of 1.0 and 2.5 mL L^{-1} was observed within 48 h of seedling inoculation, whereas plants with 5.0 and 7.5 mL L^{-1} concentration took three to five days to germinate. However, plants in extreme pesticide concentrations (10.0 and 12.5 mL L^{-1}) germinated after one week of inoculation, which is because plants with an increase in stressed conditions need more time to acclimatise to the condition and its metabolism also slows down; therefore, the rate of germination also varied with concentration (Table 2) (Chaudhry et al., 2002; Rennenberg, 1987). This study is in agreement with Kilic et al. (2015), who demonstrated the toxic effects of chlorantraniliprole pesticide in maize plant, rendering growth reduction in coleoptile and radicle length. Reduced coleoptile growth was also observed by Moore and Kroger (2010) in *Oryza sativa* on exposure to insecticides and herbicides like diazinon, metolachlor, atrazine, lambda-cyhalothrin and fipronil (Moore and Kroger, 2010). The damaging effect of pesticides can be reduced by proper crop management and application of

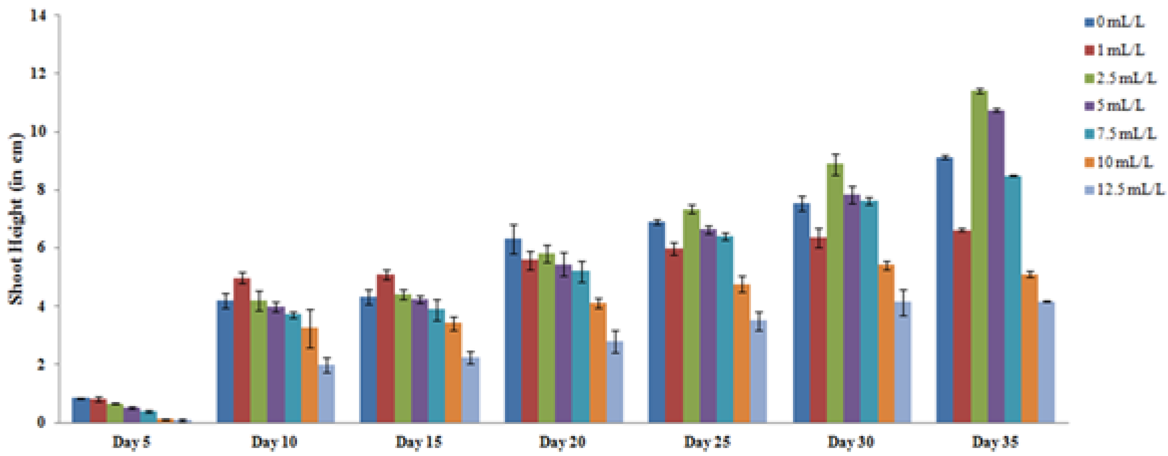

Figure 1. Effect of cypermethrin on the shoot lengths (Mean ± S.D.) of *Coriandrum sativum*.

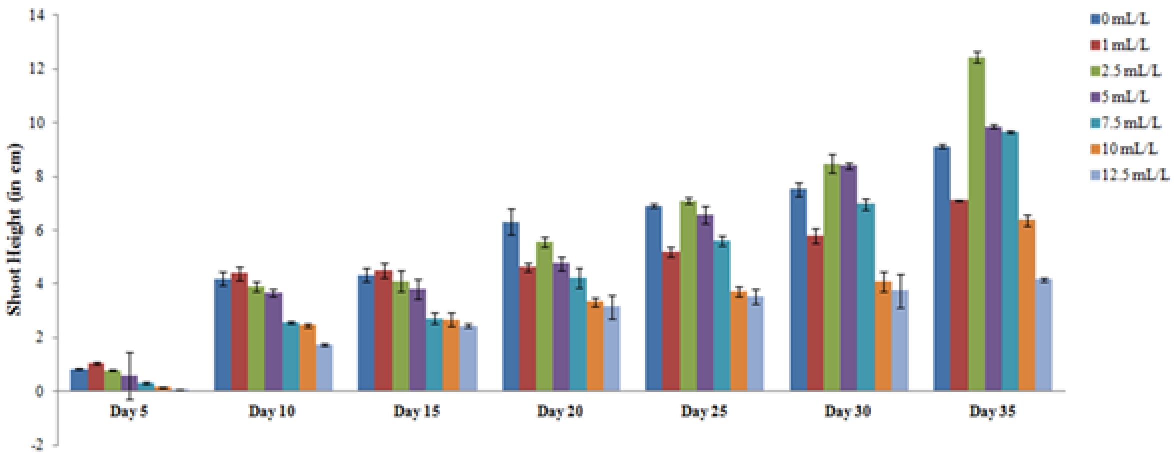

Figure 2. Effect of fenvalerate on the shoot lengths (Mean ± S.D.) of *Coriandrum sativum*.

organic manure and bio-fertiliser in the crop field.

Estimation of shoot height

Plants which were grown under different concentrations of fenvalerate (Figure 1) and cypermethrin (Figure 2) showed a steady declining growth in the initial 15 to 20 days of the experiment whereas plantlets with pesticide dosage of 1.0 mL L^{-1} were observed to have enhanced growth than the control plantlets. It may be because, at low concentration, the plants used the pesticides as a source of nutrition, and below the recommended dosage (2.5 mL L^{-1}), pesticides cannot prove detrimental to plant growth (Ait Barka et al., 2004). On 20th day onwards, when the plants reached the flowering stage, the plants at 2.5 mL L^{-1} showed better growth than plants in control and 1.0 mL L^{-1} of pesticide. This proves that the recommended dosage of pesticides has minimal effect in the retardation of plant growth. On the other hand, the plants subjected to chlorpyriphos treatment showed a steady declining growth curve for the entire period of the experiment, and early mortality was observed in the plants (Figure 3). The average shoot lengths of plants on 15th day (before flowering) in control were 4.33 ± 0.25 cm, and plants under 2.5 mL L^{-1} concentration of pesticides were 4.40 ± 0.17 cm (cypermethrin), 4.1 ± 0.39 cm (fenvalerate) and 2.4 ± 0.08 cm (chlorpyriphos). However, a considerable decline in the shoot length was observed at higher pesticide amendments (12.5 mL L^{-1}), which was noted as 2.25 ± 0.21, 2.45 ± 0.07 and 1.4 ± 0.45 cm for cypermethrin, fenvalerate and chlorpyriphos induced plants, respectively. After attaining the flowering stage on 35th day, maximum growth was noted in the recommended dosage of 2.5 mL L^{-1} concentration of cypermethrin and fenvalerate, exhibiting shoot length of 11.41 ± 0.08 and 12.43 ± 0.2 cm, respectively. Plants in control treatment also showed moderate shoot length of

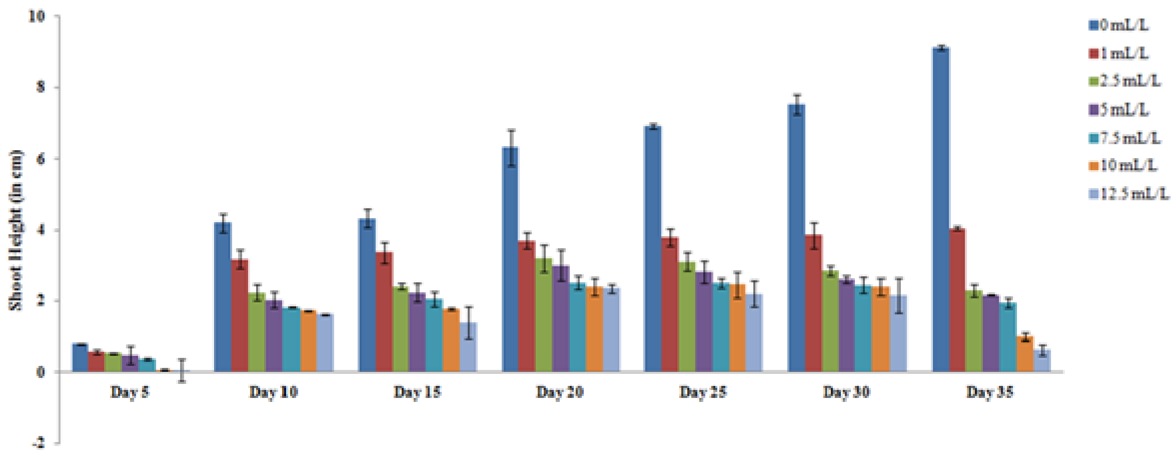

Figure 3. Effect of chloropyriphos on the shoot lengths (Mean ± S.D.) of *Coriandrum sativum*.

9.12 ± 0.06 cm. However, steep retardation in shoot length under 12.5 mL L^{-1} concentration of pesticides was observed, measuring 4.17 ± 0.02 cm, 4.16 ± 0.05 cm in cypermethrin and fenvalerate induced plants. Interestingly, the plants under chlorpyriphos treatment produced harmful effects on plant growth parameters and even failed to attain maturity. The detrimental effects were also visually observed, which includes reduced vigour, retarded shoot growth, drooping leaves, less branching and chlorosis. The resulting order of decreased shoot length of plants supplemented with pesticide at day 35 was: fenvalerate > cypermethrin > chlorpyriphos, which revealed that fenvalerate showed least retarding effect on the growth of plants.

Statistical inference

The t-test analysis of *C. sativum* shoots heights supplemented with cypermethrin, fenvalerate and chlorpyriphos showed a marked difference, at a 5% level of significance on both the 15th and 35th days. The tabulated value at 5% level of significance for 6 and 40 degrees of freedom was 2.336 whereas the calculated value was higher in case of cypermethrin (t (46) = 18.573, $p < 0.05$), fenvalerate (t (46) = 16.123, $p < 0.05$) and chlorpyriphos (t (46) = 39.127, $p < 0.05$). A similar trend was observed on the 35th day, where the tabulated values for cypermethrin, fenvalerate and chlorpyriphos were t (46) = 8.014, $p < 0.05$; t (46) = 9.490, $p < 0.05$; and t (46) = 20.195, $p < 0.05$, respectively. The calculated value was found to be greater than the tabulated value on both 15th and 35th days; we, therefore, reject the null hypothesis and conclude that there is a significant effect in the plant's growth with the change in pesticide concentration.

Multiple comparison studies of the shoot heights of *C. sativum* between control and other concentrations of pesticides were calculated after 15th and 35th days of inoculation at $P < 0.05$ which revealed that on the 35th day; almost all the plants subjected to cypermethrin, fenvalerate and chlorpyriphos displayed a significant mean difference among each other at $P < 0.05$. On 35th day of inoculation, cypermethrin and fenvalerate at 2.5 mL L^{-1} concentration marked a significant mean difference with plants in 1.0, 10.0 and 12.5 mL L^{-1} while chlorpyriphos displayed significant mean difference with plants in control (6.57 ± 1.15 cm), 1.0 mL L^{-1} (1.52 ± 0.1 cm), 10.0 mL L^{-1} (1.46 ± 0.11 cm) and 12.5 mL L^{-1} (1.7 ± 0.11 cm). The result signifies that the plants can resist the pesticide stress at 5.0 and 7.5 mL L^{-1} as no significant mean difference was observed at these concentrations (Tables 3 to 5). The shoot heights of plants grown under cypermethrin at 5.0 and 7.5 mL L^{-1} were recorded as 10.74 ± 0.05 and 8.48 ± 0.02 cm, respectively while for fenvalerate at 5.0 and 7.5 mL L^{-1} shoot heights were 9.86 ± 0.05 and 9.66 ± 0.05 cm, respectively. This result clearly illustrates that plants under 5.0 and 7.5 mL L^{-1} of pesticides showed no much difference as compared to plants in control with shoot heights of 9.12 ± 0.06 cm.

Biomass and moisture content

Biomass reduction of shoots after 35 days of seedling inoculation displayed similar trends with shoot heights. Biomass of plants in control was calculated to be 7.403 g, and the moisture content was recorded as 84.141%. Maximum biomass was recorded at 2.5 mL L^{-1} concentration of cypermethrin (5.324 g) and fenvalerate (5.517 g). However, with a further increase in pesticide concentration, there was a declining trend in biomass for both cypermethrin and fenvalerate. However, there is a gradual declining trend in the moisture contents of plants under the treatment of cypermethrin and fenvalerate. The moisture content recorded at the recommended dosage

Table 3. Multiple comparison tests and mean difference between the shoot lengths of *C. sativum* under cypermethrin stress after 15 days and 35 days of seedling inoculation.

Parameter ($mL\ L^{-1}$)	After 15 days of seedling inoculation						
	Control	**1.0 $mL\ L^{-1}$**	**2.5 $mL\ L^{-1}$**	**5.0 $mL\ L^{-1}$**	**7.5 $mL\ L^{-1}$**	**10.0 $mL\ L^{-1}$**	**12.5 $mL\ L^{-1}$**
Control	**0**	0.75 ± 0.31	0.07 ± 0.26	0.09 ± 0.24	0.43 ± 0.3	0.91 ± 0.2*	2.08 ± 0.25
1.0	2.51 ± 1.43	**0**	0.68 ± 0.32	0.84 ± 0.31	1.18 ± 0.36	1.66 ± 0.28*	2.83 ± 0.32*
2.5	2.31 ± 1.31	4.82 ± 1.06*	**0**	0.16 ± 0.26	0.5 ± 0.32	0.98 ± 0.23*	2.15 ± 0.27*
5.0	1.67 ± 1.21	4.18 ± 0.94*	0.64 ± 0.73	**0**	0.34 ± 0.3	0.82 ± 0.2*	1.99 ± 0.25*
7.5	0.61 ± 1.52	1.9 ± 1.31	2.92 ± 1.17	2.28 ± 1.06	**0**	0.48 ± 0.28	1.65 ± 0.31*
10.0	3.87 ± 1.23	1.36± 0.96	6.18 ± 0.76*	5.54 ± 0.58*	3.26 ± 1.08	**0**	1.17 ± 0.22*
12.5	4.89±1.26*	2.38±0.1	7.2±0.81*	6.56±0.63*	4.28±1.11	1.02±0.66	**0**
	After 35 days of seedling inoculation						

Shoot heights of *C. sativum* at *P < 0.05 (ANOVA). The results are expressed as the means ± standard deviations of three independent replicates.

Table 4. Multiple comparison tests and mean difference between the shoot lengths of *C. sativum* under fenvalerate stress after 15 days and 35 days of seedling inoculation.

Parameter ($mL\ L^{-1}$)	After 15 days of seedling inoculation						
	Control	**1.0 $mL\ L^{-1}$**	**2.5 $mL\ L^{-1}$**	**5.0 $mL\ L^{-1}$**	**7.5 $mL\ L^{-1}$**	**10.0 $mL\ L^{-1}$**	**12.5 $mL\ L^{-1}$**
Control	**0**	0.19 ± 0.23	0.23 ± 0.18	0.53 ± 0.26	1.61 ± 0.2*	1.65 ± 0.23*	1.88 ± 0.48
1.0	1.95 ± 1.21	**0**	0.42 ± 0.17	0.72 ± 0.25	1.8 ± 0.19*	1.84 ± 0.22*	2.07 ± 0.48*
2.5	3.53 ± 1.41	5.48 ± 0.89*	**0**	0.3 ± 0.2	1.38 ± 0.12*	1.42 ± 0.16*	1.65 ± 0.45
5.0	0.81 ± 1.31	2.76 ± 0.74	2.72 ± 1.03	**0**	1.08 ± 0.22*	1.12 ± 0.25*	1.35 ± 0.49
7.5	0.65 ± 1.17	2.60 ± 0.44*	2.88 ± 0.84	0.16 ± 0.67	**0**	0.04 ± 0.19	0.27 ± 0.46
10.0	2.87 ± 1.3	0.92 ±0.71	6.40 ± 1*	3.68 ± 0.87*	3.52 ± 0.64*	**0**	0.23 ± 0.47
12.5	4.87 ± 1.16*	2.92 ± 0.41*	8.40 ± 0.82*	5.68 ± 0.65*	5.52 ± 0.27*	2 ± 0.61	**0**
	After 35 days of seedling inoculation						

Shoot heights of *C. sativum* at *P < 0.05 (ANOVA). The results are expressed as the means ± standard deviations of three independent replicates.

Table 5. Multiple comparison tests and mean difference between the shoot lengths of *C. sativum* under Chloropyriphos stress after 15 days and 35 days of seedling inoculation.

Parameter ($mL\ L^{-1}$)	After 15 days of seedling inoculation						
	Control	**1.0 $mL\ L^{-1}$**	**2.5 $mL\ L^{-1}$**	**5.0 $mL\ L^{-1}$**	**7.5 $mL\ L^{-1}$**	**10.0 $mL\ L^{-1}$**	**12.5 $mL\ L^{-1}$**
Control	**0**	0.97 ± 0.24*	1.93 ±0.28*	2.09 ± 0.21*	2.27 ± 0.24*	2.55 ± 0.26*	2.93 ± 0.2*
1.0	5.05 ± 1.15*	**0**	0.96 ± 0.29	1.12 ± 0.22*	1.30 ± 0.25*	1.58 ± 0.26*	1.96 ± 0.2*
2.5	6.57 ± 1.15*	1.52 ± 0.1*	**0**	0.16 ± 0.26	0.34 ± 0.28	0.62 ± 0.3	1 ± 0.25*
5.0	6.89 ± 1.15*	1.84 ± 0.12*	0.32 ± 0.14	**0**	0.18 ± 0.22	0.46 ± 0.23	0.84 ± 0.17*
7.5	6.97 ± 1.16*	1.92 ± 0.14*	0.4 ± 0.15	0.8 ± 0.17	**0**	0.28 ± 0.26	0.66 ± 0.2
10.0	8.03 ± 1.15*	2.98 ± 0.09*	1.46 ±0.11*	1.14 ± 0.13*	1.06 ± 0.14*	**0**	0.38 ± 0.22
12.5	8.27 ± 1.15*	3.22 ± 0.09*	1.7 ± 0.11*	1.38 ± 0.13*	1.3 ± 0.14*	0.24 ± 0.1	**0**
	After 35 days of seedling inoculation						

Shoot heights of *C. sativum* at *P < 0.05 (ANOVA). The results are expressed as the means ± standard deviations of three independent replicates.

of 2.5 mL L^{-1} concentration of cypermethrin and fenvalerate was calculated to be 75.8 and 73.68%, respectively. Since early mortality was observed for plants under chlorpyriphos stress, its harvest was negligible at the end of the study period. Therefore, biomass and moisture content for these plants could not be estimated (Table 6). The present study is in agreement with Carrascosa et al. (2015) who also reported biomass reduction of plants treated with fenamiphos and oxamyl nematicides; however, with the application of organic or bio-pesticides with nematophagous fungi augmented with neem paste displayed a significant

Table 6. Biomass and moisture content of *Coriandrum sativum* under cypermethrin and fenvalerate stress.

Pesticide concentration (mL L^{-1})	Biomass content of shoot (in g)		Moisture content of plant (in %)	
	Cypermethrin	Fenvalerate	Cypermethrin	Fenvalerate
Control (0)	7.403		84.141	
1.0	0.835	0.721	77.48	81.27
2.5	5.324	5.517	75.80	73.68
5.0	3.006	4.329	68.82	70.24
7.5	1.825	1.677	60.27	61.24
10.0	1.388	0.907	48.55	37.81
12.5	0.116	0.651	43.96	28.57

increase in the biomass content. Therefore, pesticide-contaminated fields should be substituted by bio-fertilisers and bio-pesticides to reduce the harmful effects of the pesticides and restore the soil nutritive value as well as soil microbiota which play a pivotal role in plant growth, nutrient uptake and other functioning.

Conclusion

The study revealed that among the three different pesticides used, chlorpyriphos proved lethal to *C. sativum* at the recommended dosage of 2.5 mL L^{-1}, thereby causing substantial mortality of plants before the maturation stage. However, cypermethrin and fenvalerate enhanced the growth of plants at 2.5 mL L^{-1}, but with an increase in the pesticide concentration, there was a significant gradual decline in the plant growth parameters. The most striking results of the study revealed that on increasing the pesticide concentration to 5.0 and 7.5 mL L^{-1}, no marked difference in plant productivity was observed as compared to plants in control. The study establishes an optimal pesticide window range of 5.0 ± 2.5 mL L^{-1}, which did not cause any adverse effects in the growth parameters of *C. sativum*. As pesticides concentration elevates in the soil due to its longer retention capacity, subsequent cropping on the same cultivable land causes retardation in plant growth even if the soil is highly fertile and conducive for farming. Abiding by the recommended pesticide dosage is, therefore, the key for enhancing and maintaining good productivity and vigour of crops.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The authors acknowledge the Department of Biotechnology (DBT), New Delhi for establishing Institutional Biotech Hub and Bioinformatics Centre in Gurucharan College, Silchar. They are also grateful to all staff members of KVK, Cachar, Assam for providing necessary arrangements for soil testing.

REFERENCES

Ait Barka E, Eullaffroy P, Clément C, Vernet G (2004). Chitosan improves development, and protects *Vitis vinifera* L. against *Botrytis cinerea*. Plant Cell Reports 22(8):608-614.

Aktar W, Sengupta D, Chowdhury A (2009). Impact of pesticides use in agriculture: Their benefits and hazards. Interdisciplinary Toxicology 2(1):1-12.

Alavanja MCR (2012). Occupational pesticide exposures and cancer risk. A review. Journal of Toxicology and Environmental Health 15(4):238-263.

Bozdogan AM, Yarpuz-Bozdogan N, Tobi I (2015). Relationship between environmental risk and pesticide application in cereal farming. International Journal of Environmental Research 9(3):1047-1054.

Carrascosa M, Sánchez-Moreno S, Alonso-Prados JL (2015). Effects of organic and conventional pesticides on plant biomass, nematode diversity and the structure of the soil food web. Nematology 17(1):11-26.

Carvalho FP (2006). Agriculture, pesticides, food security and food safety. Environmental Science and Policy 9(7-8):685-692.

Chaudhry Q, Affairs R, Hutton S, Kingdom U, Food T, Europe E (2002). Persistent Pesticides Prospects and Limitations of Phytoremediation for the Removal of Persistent Pesticides in the Environment. Environmental Science and Pollution Research 9(1):4-17.

De Oliveira TA, Ronchi-Teles B, Da Fonseca CRV, Da Silva SLR, Santos PA, Nunez CV (2012). Insecticidal activity of *Vitex cymosa* (Lamiaceae) and *Eschweilera pedicellata* (Lecythidaceae) extracts against *Sitophilus zeamais* adults (Curculionidae). Emirates Journal of Food and Agriculture 24(1):49-56.

Dey KR, Choudhury P, Dutta BK (2013). Impact of pesticide use on the health of farmers: A study in Barak valley, Assam (India). Journal of Environmental Chemistry and Ecotoxicology 5(10):269-277.

Emam HE, Abdelhameed RM (2017). In-situ modification of natural fabrics by Cu-BTC MOF for effective release of insect repellent (N,N-diethyl-3-methylbenzamide). Journal of Porous Materials 24(5):1175-1185.

Freire C, Koifman RJ, Koifman S (2015). Hematological and hepatic alterations in brazilian population heavily exposed to organochlorine pesticides. Journal of Toxicology and Environmental Health - Part A: Current Issues 78(8):534-548.

González-Rodríguez RM, Rial-Otero R, Cancho-Grande B, Gonzalez-Barreiro C, Simal-Gándara J (2011). A review on the fate of pesticides during the processes within the food-production Chain. Critical Reviews in Food Science and Nutrition 51(2):99-114.

Hameed OB, Shafi F, Jan N (2017). Studies on nutritional composition of coriander leaves by using sun and cabinet drying methods. International. Journal of Chemical Studies 5(6):12-14.

Iwara AI, Gani BS, Njar GN, Deekor TN (2011). Influence of Soil Physico-chemical Properties on the Distribution of Woody Tree/Shrub Species in South-Southern Nigeria. Journal of Agricultural Sciences 2(2):69-75.

Kilic S, Duran RE, Coskun Y (2015). Morphological and physiological responses of maise (*Zea mays* L.) seeds grown under increasing concentrations of chlorantraniliprole insecticide. Polish Journal of Environmental Studies 24(3):1069-1075.

López-Pérez GC, Arias-Estévez M, López-Periago E, Soto-González B, Cancho-Grande B, Simal-Gándara J (2006). Dynamics of pesticides in potato crops. Journal of Agricultural and Food Chemistry 54(5):1797-1803.

Mahendra P, Bisht S (2011). Coriandrum sativum: A daily use spice with great medicinal effect. Pharmacognosy Journal 3(21):84-88.

Maroufi K, Farahani HA, Darvishi HH (2010). Importance of coriander (*Coriandrum sativum* L.) between the medicinal and aromatic plants. Advances in Environmental Biology 4(3):433-436.

Medrano H, Tomás M, Martorell S, Flexas J, Hernández E, Rosselló J, Pou A, Escalona J-M, Bota J (2015). From leaf to whole-plant water use efficiency (WUE) in complex canopies: Limitations of leaf WUE as a selection target. Crop Journal 3(3):220-228.

Meyer A, Koifman S, Koifman RJ, Moreira JC, De Rezende Chrisman J, Abreu-Villaça Y (2010). Mood disorders hospitalisations, suicide attempts, and suicide mortality among agricultural workers and residents in an area with intensive use of pesticides in Brazil. Journal of Toxicology and Environmental Health - Part A: Current Issues 73(13-14):866-877.

Mitran T, Mani PK, Basak N, Biswas S, Mandal B (2017). Organic Amendments Influence on Soil Biological Indices and Yield in Rice-Based Cropping System in Coastal Sundarbans of India. Communications in Soil Science and Plant Analysis 48(2):170-185.

Moore MT, Kröger R (2010). Effect of Three Insecticides and Two Herbicides on Rice (*Oryza sativa*) Seedling Germination and Growth. Archives of Environmental Contamination and Toxicology 59(4):574-581.

Namiki S, Otani T, Motoki Y, Seike N (2018). The influence of *Brassica rapavar* perviridisgrowth conditions on the uptake and translocation of pesticides. Journal of Pesticide Science 43(4):248-254.

Nath S, Deb B, Sharma I (2018). Isolation of toxic metal-tolerant bacteria from soil and examination of their bioaugmentation potentiality by pot studies in cadmium- and lead-contaminated soil. International Microbiology 21(1-2):35-45.

Nath S, Sharma I, Deb B, Singh V (2013). Isolation of Heavy Metal Resistant Bacteria for Sustainable Crop Production. International Journal of Bio-Resource and Stress Management 4(2):266-269.

Oliveira RS, Ma Y, Rocha I, Carvalho MF, Vosátka M, Freitas H (2016). Arbuscular mycorrhizal fungi are an alternative to the application of chemical fertiliser in the production of the medicinal and aromatic plant *Coriandrum sativum* L. Journal of Toxicology and Environmental Health - Part A: Current Issues 79(7):320-328.

Pimentel D (1995). Amounts of pesticides reaching target pests: Environmental impacts and ethics. Journal of Agricultural and Environmental Ethics 8(1):17-29.

Randall C, Hock W, Crow E, Hudak-Wise C, Kasai J (2013). National pesticide applicator certification core manual. National Association of State Departments of Agriculture Research Foundation.

Rennenberg H (1987). Aspects of glutathione function and metabolism in plants. Aspects of Glutathione Function and Metabolism in Plants 140:279-292.

Sahib NG, Anwar F, Gilani AH, Hamid AA, Saari N, Alkharfy KM (2013). Coriander (*Coriandrum sativum* L.): A potential source of high-value components for functional foods and nutraceuticals- A review. Phytotherapy Research 27(10):1439-1456.

Umeda K, Kotake Y, Miyara M, Ishida K, Sanoh S, Ohta S (2016). Methoxychlor and fenvalerate induce neuronal death by reducing GluR2 expression. Journal of Toxicological Sciences 41(2):255-264.

Wall A (2005). Soil water-retention characteristics and fertility of afforested arable land. Dissertationes Forestales 2005(14). https://doi.org/10.14214/df.14

Zahoranová A, Henselová M, Hudecová D, Kaliňáková B, Kováčik D, Medvecká V, Černák M (2016). Effect of Cold Atmospheric Pressure Plasma on the Wheat Seedlings Vigor and on the Inactivation of Microorganisms on the Seeds Surface. Plasma Chemistry and Plasma Processing 36(2):397-414.