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SPATIO-TEMPORAL VARIABILITY IN SOIL CHARACTERISTICS AND ITS INFLUENCE ON THE RETENTION OF CHLORPYRIPHOS AND QUINALPHOS IN CARDAMOM GROWING SOILS OF IDUKKI DISTRICT, KERALA

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ABSTRACT

A study was conducted for a period of one year to evaluate the zonal and seasonal variations in the physico-chemical characteristics of soil and their influence on the retention of pesticides like chlorpyriphos and quinalphos. Fifty four soil samples were collected from large and medium sized cardamom plantations falling in three zones of Cardamom Hill Reserve during pre-monsoon, monsoon and post-monsoon seasons and analysed for various physico-chemical properties and residues of chlorpyriphos (*O, O-diethyl O-3, 5, 6- trichloro-2-pyridyl phosphorothioate*) and quinalphos (*O, O-diethyl O-quinoxalin-2-yl phosphorothioate*) following standard methods. The extent of pesticide residues in the study area were then correlated with soil characteristics and meteorological data.

Cardamom growing soils from the study area are of sandy clay loam type with acidic nature. Spatio-temporal variation was observed in the residues of chlorpyriphos and quinalphos. Seasonal variability was noticed in the concentration of pesticide residues and total phosphorus content, whereas it was not much reflected in organic matter content and cation exchange capacity of soil samples. Pesticide residues in soil were positively correlated with clay content in all seasons except monsoon. Soil organic matter has not found to have any influence on the retention of pesticide residues in soil. Low soil pH, high clay content and rainfall pattern has great influence in the persistence and leaching of pesticide residues in soils of the Cardamom Hill Reserve.

Keywords: Chlorpyriphos, Quinalphos, total phosphorus, persistence.

INTRODUCTION

Kerala, the land of spices, surrounded by Western Ghats in the east and Lakshadweep Sea in the west (between 8^0 to 12^0 N and 74^0 to 77^0 E) enjoys humid tropical climate. The major land forms are highland, midland and lowland, each with its own geomorphic features. Idukki district of Kerala is famous for its scenic beauty and largest area under forest cover. It is situated completely under Western Ghat region. The annual average rainfall is 3555.6 mm and temperature is 21.33^0C (Premachandran, 2007). The district is popularly known as the spice district of Kerala, owing to the cultivation of high yielding varieties of spices such as cardamom, pepper, turmeric, ginger etc. together with other plantation crops. All these crops demand the usage of considerable quantity of chemicals for crop protection and production.

Synthetic pesticides have become one of the important parts of integrated pest management for last few decades. A wide range of chemicals are being used in this category. Major pesticide consuming crops in India are rice and cotton. Cardamom is not an exemption. Various chemicals are frequently applied in cardamom plantations either as foliar spray or through soil drenching (George et al. 2013). Among such chemicals, Chlorpyriphos is the widely used organophosphorus insecticides in cardamom plantations. Chlorpyriphos is used both by soil drenching and foliar spray for the control of root grub and root borers. Quinalphos is yet another pesticide widely used for the management of cardamom trips and other pests.

On the basis of soil productivity and other factors governing yield, cardamom hill reserve of the state of Kerala is divided into three zones; zone A, B, and C. Zone A having highest productivity, which includes Peerumedu Taluk excluding Peruvanthanam and Kokkayar villages and Chakkupallam, Ayyappankovil and Vandenmedu villages of Udumbanchola taluk. Zone B has comparatively lower productivity and includes Chathurangappara, Rajakkad, Santhanpara, Pampadumpara, Parathode and Udumbanchola villages of Udumbanchola taluk. The rest of cardamom growing area comes under zone C (MSSRF, 2008).

Pesticides, in addition to their activity on target organisms, will have multi-dimensional impacts on non-target organisms. They may even persist in associated domains like soil, water and air for a longer period of time. Cardamom growing regions of Kerala have an undulating terrain. Moreover they also form catchment basins of important rivers. Surveillance on the persistence and reactivity of applied chemicals is a major concern in most agro ecosystems. Hence a study has been undertaken to assess the spatio-temporal variation in the physico-chemical characteristics of soils and to assess their impact on the retention of major pesticides such as chlorpyriphos and quinalphos in cardamom growing ecosystems.

MATERIALS AND METHODS

Soil samples were collected from cardamom plantations in zone A, B, and C, for a period of one year at bimonthly intervals during 2014-15 (figure.1). Soil samples were collected from root zone area of cardamom plants, according to the cardamom package of practices of Spices Board, Cochin. Each soil sample has been collected from a 5acre plot, leaving 30 cm from plant base. Selected sites for sampling were cleaned from weeds, dry leaves and other mulch materials. Soil was taken using a spade, after cutting and removing a V shaped hole at a depth of 15 cm with the help of a spatula. Soil was scraped from both the sides of V shaped pit in a thin layer of 2 cm along the cutting of the full length (Jackson, 1973). From each 5 acre plot, 10 sub samples were collected diagonally and samples were gathered in a polythene sheet. It was then mixed well, removed all plant materials and spread in a square shape in thin layer and sectioned to four quarters by drawing diagonal lines. The two quarters falling opposite were discarded. The process was continued till the sample become 500 g. From each sample, 10g was taken for the determination of moisture content. The soil sample thus collected from the field was dried under shade and sieved using 2mm sieve. The material on the sieve was again ground and sieved till all the aggregate particles were fine enough to pass through and only stones and organic matter remain on the sieve. The whole samples were kept in plastic containers. Accordingly, three soil samples were collected from each zone at bimonthly interval for a period of one year. Altogether 54 soil samples were collected. The samples were then analysed for soil physical constants and texture (Clarson, 2002), chemical properties such as pH, electrical conductivity, organic matter content, cation exchange capacity and total phosphorus content (Jackson, 1973) and residues of chlorpyriphos and quinalphos following extraction (Kumari et al., 2008). The extracted pesticides were estimated using GC –FPD.

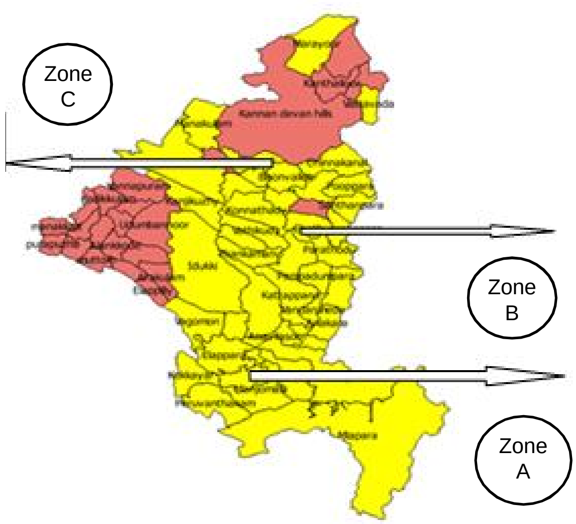


Figure 1. Cardamom cultivating areas in Idukki district

Pesticide concentrations were measured using Shimadzu GLC 2014 equipped with Flame Photometric detector and a RESTEK 30 m x 0.25 mm RTX -5 fused silica capillary column with 0.25 µm film of phenyldimethylpolysiloxane. The injector was kept at 290 ^{0}C throughout the analysis within a split ratio of 1:10. The column head pressure of

Table 1. Seasonal variation in soil physical properties of cardamom cultivating zones in Idukki.

Zone	pH			Moisture content (%)			Electrical conductivity (dS/cm)		
	PRM	M	POM	PRM	M	POM	PRM	M	POM
A	4.85 ±0.16	5.37 ±0.23	4.80 ±0.0	19.04 ±3.2	20.72 ±1.0	15.15 ±3.5	0.276 ±0.01	0.238 ±0.06	0.221 ±0.01
B	4.94 ±0.37	5.15 ±0.12	5.22 ±0.09	18.78 ±2.4	17.95 ±1.2	14.62 ±0.0	0.217 ±0.01	0.166 ±0.04	0.205 ±0.0
C	5.01 ±0.18	5.62 ±0.12	5.46 ±0.41	22.76 ±0.5	20.74 ±0.1	18.43 ±0.1	0.195 ±0.02	0.145 ±0.03	0.157 ±0.04

PRM - Pre Monsoon; M - Monsoon; POM - Post Monsoon

carrier gas (nitrogen) was maintained at 169.7 kPa. The oven temperature was initially maintained at 200 ^{0}C for 1 min and then increased and held at 290 ^{0}C for 15 min. Pesticide residues (µg g^{-1}) in soil samples were calculated as per George et al. (2013).

RESULTS AND DISCUSSION

The results of pH, moisture content and electrical conductivity of soil samples are presented in Table 1. Seasonal changes in soil organic matter and cation exchange capacity are given in Table 2 and those of bulk density, particle density and water holding capacity in Table 3. Spatial variation in soil texture is depicted in Table 4.

pH value of soils collected from the study area ranged from very acidic to near normal range (4.80 to 5.62). Soil samples collected during pre-monsoon season showed low pH compared to monsoon and post monsoon seasons. Samples from zone A was more acidic and average pH was only 5.01, where as that of zone B and zone C were 5.29 and 5.36, respectively.

The moisture content of soil samples varied over the period of study. The average moisture content was almost similar in all zones and was about 20% in pre monsoon and monsoon seasons. Lowest moisture content in soil was noted in zone B. Cardamom plants are very sensitive to moisture and air temperature. In order to regulate soil moisture and temperature, irrigation starts from January to May at an interval of 10 to 15 days until the onset of monsoon. Since flowering season commences from February onwards, irrigation is essential for flower setting and yield setting. Hence most of the cardamom plantations are under irrigation. The soil moisture remains constant throughout the year due to constant irrigation practices.

Table 2. Seasonal changes in soil chemical properties in cardamom growing zones

Zone	Organic matter (%)			Cation exchange capacity (meq/100g soil)		
	PRM	M	POM	PRM	M	POM
A	3.96 ±0.26	4.17 ±0.50	4.39 ±0.50	17.84 ±0.42	16.68 ±5.42	18.18 ±0.93
B	4.27 ±0.11	4.33 ±0.80	4.85 ±0.33	16.67 ±1.69	18.84 ±6.19	17.06 ±1.92
C	5.11 ±0.65	4.40 ±1.02	4.61 ±0.71	18.54 ±0.70	19.35 ±0.43	18.05 ±0.17

PRM - Pre Monsoon; M - Monsoon; POM - Post Monsoon

Organic matter content is a measure of soil health. Since cardamom plants grow under canopy, organic matter content in these plantations will be comparatively higher than any other crop. The optimum soil organic carbon content for cardamom cultivation is 1.5 to 2.0 %, which corresponds to 2.6 to 3.5 % of soil organic matter. The analytical data shows that all soil samples from the study site have high organic matter content.

Decomposition of organic matter is an integral part of any natural process. Microbial decomposition of litter contributes a major portion of organic matter. Slow rate of decomposition of organic matter in high acidic soils and at higher elevation are reported by Firsova (1967). Despite these facts, the present study areas reported higher extent of soil organic matter. Usually in these agro ecosystems, planters apply 1 kg neem cake and 10 kg farm yard manure per plant for enhancing soil physical qualities. The repeated application of farm yard manure is likely to improve soil humus, which might have reflected in high organic matter content associated with the cardamom ecosystems.

Cation Exchange Capacity (CEC) of all soil samples from the present study area was relatively high. Soil organic matter has charge properties and that make it a site for ion exchange. Generally 1 % Soil organic matter contributes to 2 meq. The mean value of CEC in the present study ranged from 16.68 to 19.35 meq /100g soil. The CEC of zone A samples declined during monsoon. This phenomenon was not observed in zone B & C. Zone C has recorded high CEC during pre-monsoon and monsoon. CEC of soils vary with pH, organic matter content and clay content of soils. The higher CEC associated with soil samples from the present study area can be attributed to higher organic matter. It is being

Table 3. Changes in physical attributes of soil collected from cardamom growing zones in Idukki

Zone	Bulk density (g/cc)			Particle density (g/cc)			Water holding capacity (%)		
	PRM	M	POM	PRM	M	POM	PRM	M	POM
A	0.99 ±0.1	0.95 ±0.1	1.0 ±0.6	2.20 ±0.6	2.60 ±0.3	2.43 ±0.1	65.3 ±10.6	72.18 ±3.5	63.56 ±0.7
B	1.22 ±0.2	1.04 ±0.1	1.08 ±0.1	1.94 ±0.8	2.57 ±0.2	2.43 ±0.1	56.51 ±3.3	63.18 ±2.9	62.77 ±2.9
C	0.06 ±0.1	1.06 ±0.1	1.13 ±0.1	1.13 ±0.1	1.63 ±0.7	1.67 ±0.2	60.84 ±11.2	63.91 ±0.6	55.36 ±0.1

PRM - Pre Monsoon; M - Monsoon; POM - Post Monsoon

reported that the open pores in kaolinite type of clay minerals can exchange calcium and magnesium ions with other ions (Lal and Shukla, 2004). Continuous rain could have accelerated leaching of calcium and magnesium ions with other ions. This might have resulted in low CEC of soil samples from certain zones under study during monsoon season.

Bulk density of samples from zone A was lower than zone B & C. The lowest levels of bulk density were recorded in samples from zone A collected during monsoon. Highest bulk density was observed in soil samples collected from zone B during pre-monsoon. Even though there was slight variation in individual values, bulk density of all soil samples were around 1.0. Bulk density of zone C samples was higher from pre monsoon to post monsoon. Bulk density was reported to be inversely related to organic matter (Korschens and Greilich, 1981). Organic matter enhances water holding capacity, decreases soil compaction, breaking strength and bulk density (Cherreau, 1975; Ushakumari, 1987). Close association between organic matter and aggregation was reported by Singhal et al. (1976). The results of the present study are also in agreement with the previous findings.

Usually particle density of mineral soils varies from 2.6 to 2.8 with an average of 2.65 g/cc. If soil organic matter is high, particle density even goes below 2.5 (Donahue, 1961). Particle density of soil samples in the present study ranged from 1.63 to 2.67. Zone A samples have higher particle density than other zones. Particle density was more in samples collected during monsoon, followed by post monsoon. Mulching of plant base with organic materials and tillage might have contributed to the decline in particle density during pre-monsoon.

Water holding capacity ranged from 55.36 to 72.18%. Higher water holding capacity was noticed in zone A samples during monsoon. This trend has been noticed for the entire samples studied. In pre monsoon, minimum water holding capacity was observed in zone B samples, where it was low for zone C samples in post monsoon.

Air and water have dynamic relationship in occupying pore space of soil. Water present in saturated soil drain rapidly and can quickly bring back to saturation during heavy rainfall. The presence of more organic matter in soil during monsoon also would have contributed to the increase in water holding capacity. Significant positive relationship was observed between water and organic carbon, clay and porosity, and negative relationship was found with pH, bulk density, sand and silt content (Deb et al., 2014).

Sand, silt and clay are the three standard fractions determining soil texture. In all the samples, sand and clay contributes the major portion. Silt content was only 10%. There was marked variation in texture properties of all the three cardamom cultivating zones. Zone A samples were low in sand content but noticeable difference was not observed in zone B & C. Samples collected during monsoon has recorded low sand content in all the three zones. Soil interaction with environment depends mainly on soil texture and soil physico-chemical properties. All the soil properties are determined by geochemical formations. Low sand content in zone A attributes to fine weathering of parent rock and it was supported by more amount of clay particles having Silt content in zone A was almost same in all the seasons, whereas in zone B, average silt content has increased over a period of time from pre monsoon to post monsoon. Similar observations were obtained in zone C also. Clay content in zone A has ranged from 34.25 to 34.70 %. A slight increase in clay content was noticed during monsoon. Marked difference in clay content was not obtained from the analytical values of clay in zone B, whereas clay content has increased from 31.10 to 39.21% in zone C.

Sand and silt particles are crystalline mineral matter of soils having high particle density. During rainy season, the secondary materials such as clay and organic matter might have lost from plough layer through runoff, which was supported by decrease in soil organic matter content in zone C from pre monsoon to post monsoon. As the clay minerals are amorphous, its lattice is built as stacked

Table 4. Spatial variation in soil texture in different cardamom growing areas in Idukki

Zone	Sand content (%)			Silt content (%)			Clay content (%)		
	PRM	M	POM	PRM	M	POM	PRM	M	POM
A	37.49 ±1.5	36.96 ±3.2	41.04 ±3.25	9.67 ±0.26	9.70 ±0.8	10.31 ±0.0	34.7 ±2.5	37.83 ±2.1	34.25 ±2.8
B	42.75 ±6.6	41.60 ±2.9	43.27 ±1.5	9.72 ±2.85	10.03 ±1.1	12.76 ±2.9	36.2 ±10.0	33.92 ±4.6	33.35 ±3.4
C	46.57 ±3.7	34.39 ±5.1	39.88 ±3.6	10.6 ±1.3	11.26 ±0.1	12.12 ±0.8	31.1 ±6.5	36.23 ±2.5	39.21 ±4.5

PRM - Pre Monsoon; M - Monsoon; POM - Post Monsoon

Figure. 2 . Seasonal variations in Total phosphorus content of soil

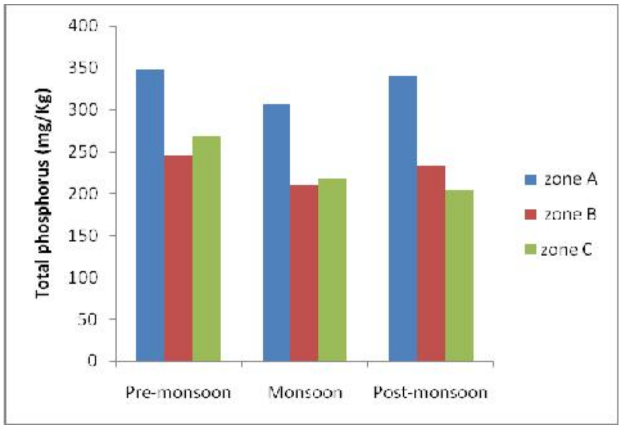


Figure.3. Chlorpyriphos content in cardamom growing soils of Idukki

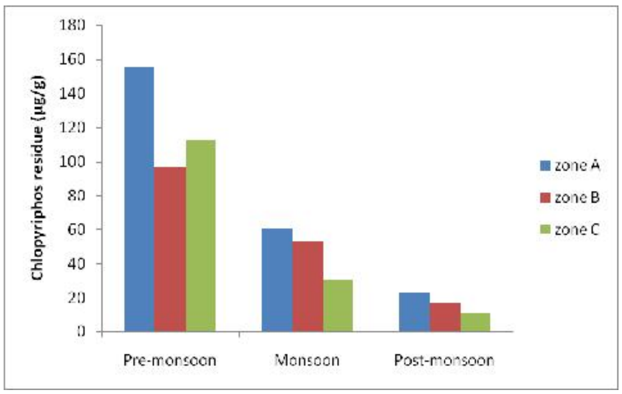


Figure.4. Quinalphos content in cardamom growing soils of Idukki

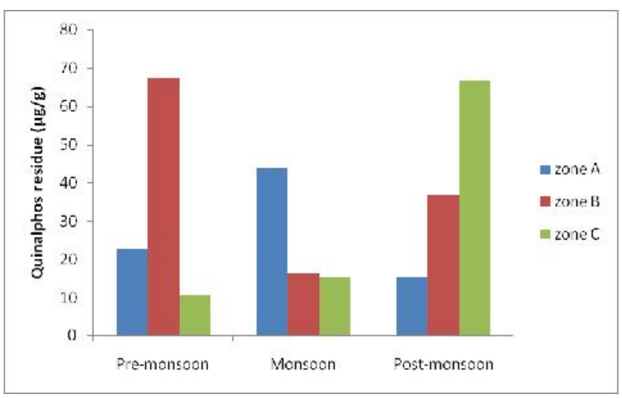
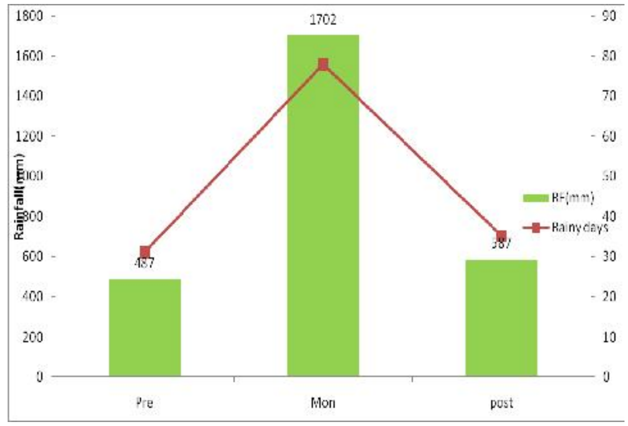


Table 5. Correlation coefficient values between pesticide residues and clay content

	Clay content (R^2 values)					
	Seasons			Zone		
	PRM	M	POM	A	B	C
Chlorpyriphos	0.476*	-0.536*	0.669**	0.306	0.43	-0.597**
Quinalphos	0.395	0.189	0.276	0.478*	0.067	0.158

PRM - Pre Monsoon; M - Monsoon; POM - Post Monsoon

Figure.5. Rainfall and rain days in cardamom cultivating areas in Idukki during study period



layer of oxygen and hydroxyl ions. Cations of silicon and aluminium can be bonded between the layers. In Kaoline group of clay minerals, cations can be substituted with other cations. Hence clay minerals are very reactive part of soil. Organic matter and silt content have direct relationship with moisture retention (Verma et al. 1990).

Total phosphorus content in soil samples were analyzed using acid digestion method. Total phosphorus includes all inorganic and organic phosphorus compounds including residues of pesticides by exhaustive digestion.

The average concentration of total phosphorus in zone A has ranged from 306.3 mg Kg^{-1} to 348 mg Kg^{-1} (Figure 2). The average total phosphorus content was recorded very high in zone A, where as it was almost same in zone B & C. Seasonal variation was also observed in the case of total phosphorus content. Pre monsoon samples have high total phosphorus content than other two seasons. Pre monsoon samples were having relatively high total phosphorus than other seasons.

Normally in cardamom plantations, fertilizer application will be initiated from the onset of monsoon. Due to acidic nature of cardamom growing soils, all available phosphorus in the form of calcium phosphate will converted to plant unavailable form of iron and aluminum phosphate. If the total phosphorus estimated would have extracted from soil fixed phosphorus of rock phosphates, total phosphorus estimated should have been more in monsoon and post monsoons. Hence it can be presumed that soil bound residues of pesticides also might have contributed to the high value of total phosphorus in soil.

With regard to the estimation of pesticides, the residue of chlorpyriphos was detected in all soil samples in various quantities (figure 3). There was seasonal variation in the residue of chlorpyriphos in soil samples. Chlorpyriphos residue was recorded more in pre monsoon season in zone A & B. The highest quantity of chlorpyriphos residue detected in post monsoon soil samples collected from zone C was 254.3µg/g. Average chlorpyriphos residue estimated in all locations were low during monsoon. It was also noted that, out of nine plantations, only one plantation had very low content of chlorpyriphos residue, irrespective of seasonal variation. In all other cardamom plantations, chlorpyriphos might have applied in any of the seasons for the control of pests like root grub or shoot borers. Drenching of 3-4 litre of Chlorpyriphos (0.04 % a.i.) is recommended as per the Package of Practices by Kerala Agricultural University (2007) during May - June and September – October seasons every year for the control of root grub / shoot borers. The analytical results of chlorpyriphos in soil samples of the present study are in agreement with these recommendations.

The residue of quinalphos was also detected in all soil samples throughout the year. Quinalphos content was more in monsoon season in zone A and B (figure.4). In zone C, quinalphos residue was more during post monsoon. Moreover, in one location in zone C, the residue was extremely high. Among the two pesticides studied, residue of quinalphos in soil was less than that of chlorpyriphos. Peak season of cardamom productivity is monsoon, during which quinalphos is sprayed in cardamom plantations to control pests like shoot borer, shoot fly, cardamom thrips and other minor pests.

While examining the concentration of the residues of various pesticides in soil, it has been noticed that the chemicals which were used for controlling pests persisted in the soil samples throughout the year. The concentration of pesticide applied through soil drenching has persisted in the soil for longer period of time than sprays. The persistence of these pesticides in soil and associated environments for a longer period of time is a matter of serious health concern seeking immediate attention.

Pesticides and their degradation products are directly related to the ecology of agro ecosystems in many ways. SPSS statistical software was used in the present study to select the best interaction of soil physico-chemical properties with the residues of chlorpyriphos and quinalphos, to explain their seasonal and zonal variation. Separate analysis was carried out for both pesticides and seasons. Tests of Pearson’s correlation were done by testing null hypothesis according to significance level at 0.01. Seasonal and zonal variation in pesticide residues and soil properties are presented in table 5.

Interaction between residues of individual pesticides and most related soil properties were analysed. Residues of chlorpyriphos and quinalphos were correlated with soil organic matter content, Total phosphorus content, pore space and clay content. Correlation of pesticide residues with soil organic matter, total phosphorus and pore space were not significant and negatively correlated. Irrespective of seasonal variation, residues of chlorpyriphos and quinalphos in soil were positively correlated to clay content (table 6).

Residues of pesticides were not correlated with other soil properties, except for clay, in all the three zones. Zonal variation was not affected in the interaction with clay. Mineral soils perform as sink to retain nitrogen within the ecosystem (Huntington et al. 1988). Soil organic carbon content influences positively on the degradation of pesticides (Kah et al. 2007). Adsorption of soil organic matter was reported as reverse process (Carringer et al. 1975). Soil organic matter had little effect on the persistence of pesticides in soil, but clay mineral content is a leading factor in sorption of pesticide in soil (Spark and Swift, 2002). Bound residues of pesticides play a major role in immobilization of soil applied chemicals in environment.

Residue of chlorpyriphos and quinalphos content were compared with meteorological parameters like rainfall and rain days obtained during 2014-15 in Idukki (figure. 5). Residue of chlorpyriphos was more in pre-monsoon period, whereas quinalphos was detected in both pre-monsoon and post-monsoon seasons. Climatic variations in cardamom hills of Idukki might have demanded the frequent application of pesticides to control cardamom pests.

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