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Contribution of weather factors to the population fluctuation of major pests on small cardamom (*Elettaria cardamomum* Maton)

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Abstract
Cardamom crop was found infested with number of pests *viz.*, thrips, shoot borer, shoot fly and red spider mite during 2013, 2014 and 2015. The seasonal incidence of cardamom thrips peaked during January to March; shoot borer during March to May; shoot fly during April to June and red spider mite during March- April. Thrips population showed negative correlation with rainfall and morning relative humidity whereas, positive correlation with sunshine hours. Similar associations were observed in shoot borer and mite. But in the case of shoot fly, rainfall positively influenced its occurrence and temperature had negative association. Rainfall is the deciding factor in lowering thrips to a maximum of 41 per cent. Maximum temperature hampered shoot borer population to an extent of 35 per cent. Relative humidity (evening) contributed about 18 per cent in enhancing shoot fly occurrence. Minimum temperature influenced the mite incidence positively to 38 per cent.

Keywords: cardamom, insect and mite pests, population dynamics, weather factors, correlation and multiple regression analyses

1. Introduction

Small cardamom (*Elettaria cardamomum* Maton) proudly known as queen of spices, which is used as spice, is in fact a dried fruit of a tall perennial herbaceous plant. India is a major producer, consumer and exporter of small cardamom and is mainly cultivated in Kerala (60%), Karnataka (30%) and Tamil Nadu (10%) [11]. Small cardamom is one of the most expensive spices in the world. Cardamom production in the country during 2015-16 was estimated at 22 thousand tonnes compared to 18 thousand tonnes in 2014-15, an increase of 4 thousand tonnes. The turnaround in cardamom prices since 2006-07 continued up to 2010-11 reaching the highest level, but thereafter the prices have fluctuated. During 2015-16 (August-June), the prices increased by 107.33 per kg to reach 754.00 per kg. Meanwhile in Kerala, cardamom production has increased by 21.8 per cent in 2015-16 despite the area under cultivation remaining stagnant [5].

The low yield of cardamom may be attributed to many reasons, among which the scourge by insect pests is of paramount importance. The key insect pests of cardamom are thrips (*Sciothrips cardamomi* Ramk.), shoot, panicle and capsule borer (*Dichocrocis punctiferalis* Guen.), Shoot fly (*Formosina flavipes* Mall.), red spider mite (*Tetranychus urticae* Koch.), coconut scale insect (*Aspidiotus destructor* Sign.), aphids (*Pentalonia nigronervosa* Coquerel), lacewing bugs (*Stephanitis typicus* Dist.) and whitefly (*Dialeurodes cardamomi* David and Subr.). Cardamom thrips and borers are the most destructive pests and a yield loss up to 60% is experienced if populations are not controlled with chemicals [18]. There has been an urgency to understand their population dynamics under field condition so that, timely management practices can be done. A thorough knowledge on seasonal activity of pests determines the predisposing climatic factors affecting their population dynamics. Minimum work has been done on the infestation of pests in cardamom with relation to weather parameters (temperature, relative humidity & sunshine hours and rainfall). Keeping in view the importance of the crop and losses caused by different insect pests, the present study was made to assess the population dynamics of pests on cardamom.

2. Material and methods

The study was undertaken on 2013, 2014 and 2015 in fixed plots. Four panchayats were selected that are located within 25 km aerial distance from the meteorological observatory at CRS, Pampadumpara in Idukki district of Kerala (Fig. 1). The weather data such as maximum and minimum temperature, morning and evening relative humidity, sunshine hours and rainfall were collected from representative station. Observations on the pest incidence were made from the selected plots at biweekly intervals throughout the year. The four panchayats *viz*., Pampadumpara, Kattappana, Erattayar and Kamakshy are nearby ones and in comparatively high altitude areas. Each selected plot has six year old green gold (*Njallani*) variety plants. Due care was taken to keep these experimental plots devoid of any pesticide spray during the experimental period. Ten cardamom plants were selected and tagged in each plot. Every plant served as a replication. Nine leaves per plant were selected covering three leaves each from top, middle and bottom canopy for observation. The thrips incidence was recorded at fortnightly intervals by direct counting of adults and nymphs with hand lens between pseudo stem and leaf sheaths. The per cent dead hearts due to shoot borer and shoot fly was worked out based on the number of plants per plot and the number of plants showing dead heart symptoms.

$$\text{Dead heart \% due to shoot borer / shoot fly} = \frac{\text{Number of plants with dead hearts per plot}}{\text{Total number of plants per plot}} \times 100$$

The incidence of phytophagous and predatory mite's population was recorded as the number of mite's population per 2.5cm^2 leaf area while for predatory mite was counted as the whole area of leaf as described by [21]. Data on seasonal occurrence of pest at fixed plots has been presented as mean data on standard week basis. This data was correlated with weather parameters. Microsoft Office Excel 2007 was used to conduct the statistical analysis of simple correlation and multiple regression coefficients.

3. Results

The seasonal abundance, simple correlation co-efficients and multiple regressions were estimated between the major insect and mite pests *viz.*, thrips, shoot, panicle and capsule borers, shoot flies and red spider mite infestations with the weather parameters *viz*., maximum and minimum temperatures, morning and evening relative humidities, sunshine hours and rainfall of appropriate weeks in four different panchayats for the three subsequent years 2013, 2014 and 2015 are furnished here in detail.

Thrips (*S. cardamomi*)

It is evident from the data that the population of thrips remained active in four panchayats during 2013, 2014 and 2015. The incidence of thrips for the year 2013 was first noticed during 1st standard week (January) and came to peak at 13th week (March last week) and found a decline from 17th week (April). During 2014, the occurrence was found on two seasons. The first season commenced on 1st standard week itself (January) and came to a peak during 5th standard week (January–February) and thereafter declined with no incidence at 11th standard week (March). Then the second season was initiated on 13th standard week (March) and ended at 17th standard week (April). On 2015, similar occurrence of thrips was noticed at 1st standard week itself (January), came to a peak during 9th standard week (February) and thereafter declined.

The correlation analyses revealed that, negative association was observed with rainfall in all the three years (Table 1). In addition to this, morning and evening relative humidity were also deciding factors in diminishing thrips population during 2014 and 2015. On the other hand, the thrips incidence had positive association with sunshine hours for years 2013 and 2014. From these available reports it is clearly indicated that, high sunshine hours with comparatively low rainfall and relative humidity favours thrips incidence and vice versa.

Multiple regression analyses showed that, sunshine hours and rainfall influenced the thrips population by 35 per cent (R^2 = 0.3513) and a unit increase in sunshine hours and a unit decrease in rainfall increased the thrips population by 0.90 and 0.04 number, respectively in the year, 2013. During 2014, rainfall alone contributed about 35 per cent (R^2 = 0.3476) in influencing the thrips population and a unit increase in rainfall hindered the thrips population by 0.07 number. On 2015, similar trend was pronounced with rainfall by 41 per cent (R^2 = 0.4090) in affecting thrips occurrence with a unit increase in rainfall inhibited the thrips population by 0.10 number (Table 2a).

Shoot, panicle and capsule borers (*D. punctiferalis*)

The occurrence of shoot, panicle and capsule borers for the year 2013 was first seen during 1st standard week (January) and came to peak in 13th week (March) and showed a steady decline with no incidence at 35th to 39th weeks (August–September). On 2014, the pest was first commenced at 1st standard week itself (January) came to a peak during 21st standard week (May) and the incidence was seen throughout the study. Similar trend was examined during 2015 as the activity was seen at 1st standard week itself (January) came to a peak at 39th standard week (September) and thereafter declined.

The correlation studies showed positive association of the pest with maximum temperature and sunshine hours during 2013 and 2014 and negatively related to the rainfall in all the studied three years and remaining parameters doesn't significantly influenced the occasion of the pest (Table 1).

The multiple regression analyses exposed that, rainfall influenced the shoot borer population by 0.48 per cent (R^2 = 0.0048) only and a unit decrease in rainfall increased the borer population by 0.006 number during the year, 2013. On 2014, maximum temperature contributed about 35 per cent (R^2 = 0.3518) in deciding the borer population and a unit increase in maximum temperature hiked the insect population by 0.67 number. Similarly during 2015, rainfall subscribed 22 per cent (R^2 = 0.2244) and a unit increase in rainfall hampered the borer population by 0.10 number (Table 2b).

Shoot fly (*F. flavipes*)

The evident of shoot fly on the year 2013 was novice during 11th standard week (March) and came to peak at 17th week (April) and no occurrence from 26th week onwards. During 2014, the pest was noticed between 19th to 39th standard weeks (May–September). The highest pest population was observed during 25th standard week (June). At 2015, incidence of shoot fly was found negligible.

Correlation between weather factors and shoot fly occurrence clearly indicated that, there was a positive binding of the pest with rainfall and negative association with the sunshine hours in the entire three years studied (Table 1).

Multiple regression analysis revealed that, maximum temperature influenced the shoot fly population by 7.25 per cent (R^2 = 0.0725) and a unit increase in maximum temperature decreased the shoot fly population by 0.1 number in the year, 2013. During 2014, evening relative humidity contributed about 18 per cent (R^2 = 0.1833) in influencing the shoot fly population and a unit increase in evening relative humidity increased the shoot fly population by 0.01 number. On 2015, minimum temperature by 0.4 per cent (R^2 = 0.0039) in affecting shoot fly occurrence and a unit increase in minimum temperature raised the shoot fly population by 0.004 number (Table 2c).

Red spider mite (*T. urticae*)

The data on the incidence of red spider mite was available for two years *viz.* 2014 and 2015. During 2014, the mite occurrence was first observed during 8-10th standard week (February- March) and came to peak in 16th week (April) and showed a decline in 30th week (July). On 2015, mite incidence was high during two seasons in a year. First season was started in 10th standard week (March), came to a peak in 14th & 16th standard week (March- April) and declined during 24th standard week (June). The second season was started in 34th standard week (August) came to peak in 46th standard week (November) and showed decline thereafter.

The correlation analyses showed that mite occurrence had positive relationship with the maximum and minimum temperatures and sunshine hours (Table 1). Similar trend was noticed in the two years observed. On the other hand, negative association was seen with the morning relative humidity and others had no significant difference.

Multiple regression analyses revealed that, minimum temperature influenced the mite population by 38 per cent (R^2 = 0.3753) and a unit increase in minimum temperature increased the mite population by 2.8 numbers in the year, 2014. During 2015, rainfall contributed about 23 per cent (R^2 = 0.2316) in influencing the mite population and a unit increase in rainfall decreased the mite population by 0.08 number (Table 2d).

4. Discussion

The present investigation encompasses the influence of weather parameters on the occurrence of pests on cardamom. The results from the present investigation are discussed below.

Population dynamics

The population dynamics is the aspect of population ecology dealing with factors affecting changes in population densities. Weather plays a crucial role in the development of diseases and growth of pests. Usually, the pest and disease organisms are always present at a low level of intensity and can multiply rapidly when the weather conditions are favourable and the plant susceptible to attack [14]. Due to variation in the agro climatic conditions of different regions, insects show varying trends in their incidence also in nature and extent of damage to the crop [17]. The best way to avoid pest outbreak is to predict the occurrence of such outbreak so that the timely preventive measures can be taken.

The present investigation on seasonal abundance of thrips on cardamom was in accordance with [19] as the maximum population was recorded during January-February, November-December and lowest was in June to August. On contradiction to our study, [9] given that, the highest abundance of onion thrips was in late July and early August of the years 2004 and 2005. Only at 2003, the maximum number of thrips reached was observed in the campus during September. In the case of cardamom shoot and capsule borers, the damage is noticed throughout the year, but is high during December to May [4]; the incidence is noticed throughout the year but they occur in enormous number in four periods, December-January, March-April, May-June and September-October and their abundance synchronizes with the panicle production, fruit formation and new tiller production [12]. The cardamom shoot fly activity starts during November and is at its peak in March-April [4]. The pest incidence is generally severe during the post monsoon period and young plants in new plantations with inadequate shade are seriously affected [15]. Cardamom spider mite assumes the status of a serious pest during summer [4].

Correlation and multiple regressions between meteorological parameters and pest populations

The occurrence and progress of all the insect pests are much dependent upon the customary environmental factors such as, temperature, relative humidity and precipitation [3]. In order to precisely assess the relative importance of selected weather parameters in explaining the variation of population of pest, the partial regression coefficients of pest on weather parameters were computed taking population of pests as dependent variables and maximum and minimum temperatures, relative humidity and rainfall as independent variables [23].

The present findings on thrips incidence were in accordance with the result given by [19]. The thrips population exhibited a significant positive correlation with temperature (maximum) and sunshine hours and also significant negative correlation was recorded with rainfall, relative humidity and temperature (minimum). Relatively high temperature and lack of rainfall have been associated with increase in onion and cotton thrips population, while high relative humidity and rainfall reduce thrips population [16, 10 and 25].

The weather factors like minimum temperature, evening relative humidity, rainy days and sunshine hours showed positive correlation on the per cent damage of *C. punctiferalis* [20]. This is in line with our present investigation on shoot borer incidence. Supporting result was also obtained from [6] in castor, as shoot and capsule borer significantly negatively correlated only with maximum temperature of same fortnight. Whereas, correlation of larval population with weather parameters of one fortnight before, was significantly positively correlated with morning relative humidity and evening relative humidity. Also a unit increase in relative humidity resulted in 2.73% increase in damage by *C. punctiferalis* in castor, thus favouring the pest [22]. This finding partially confirms our result.

The present investigation on shoot fly was in accordance with [2] who brought out significant positive correlation between per cent dead hearts and rainfall with sorghum shoot fly. An opposing fact was given by [8] as rainfall has been found to cause substantial mortality in adult flies. Similarly [13] revealed that reductions in activity were observed during the peak periods and appeared to be caused by heavy or continuous rain. However, according to [20], rainfall intensity had detrimental effect on egg laying and adult population.

This might be due to washing effect of eggs with high intensity.

Abhishek and Radadia opined that correlation studies between red spider mite populations in carnation with abiotic factors showed that there is a positive significant correlation between spider mite population and average temperature, while a significant negative correlation exist between spider mite populations and average relative humidity [1]. Tomar studied the correlation between mite incidence and abiotic factors and found significant positive correlation with maximum temperature, a non-significant positive correlation with minimum temperature and negative correlation with morning and evening relative humidity [23]. Our findings derive the support from [7]. An increase in maximum temperature by 1°C there was a proportionate increase of two spotted spider mite population by 1.184 per cent. Nevertheless for an increase in relative humidity by one per cent there was a decrease in mite population by 0.218 per cent, and for every 1mm increase in rainfall, the mite population declined by 0.195 per cent.

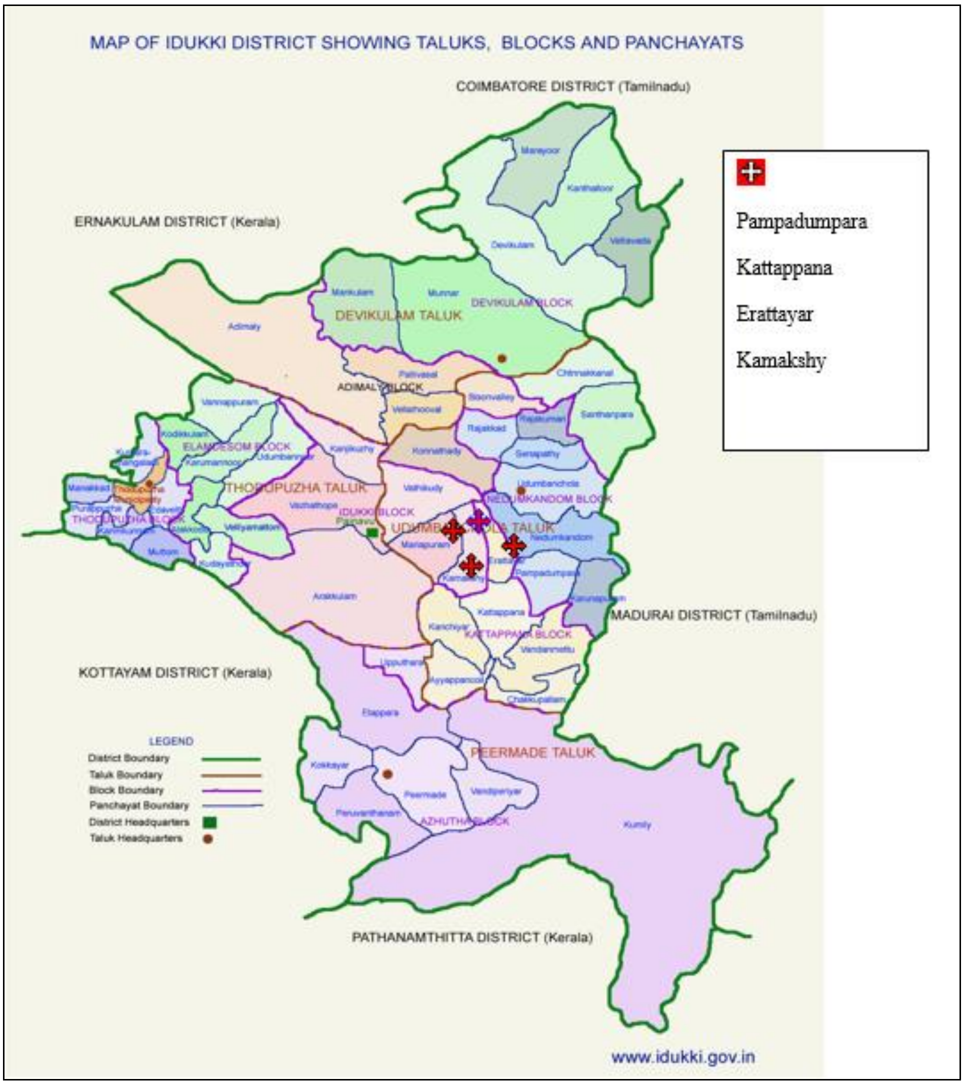

Fig 1: Map showing four selected panchayats for the study

5. Conclusion

Thus from available reports it's clear that most of the pests in cardamom except shoot fly likely to be highest in high temperature regime. This was evident in the present investigation also. Temperature is an important unique meteorological parameter that influences the pest infestation. This study gives us the indication of the impact of extreme climatic conditions. Similarly, rainfall had washed out effect of most of the pests and that was not a case in shoot fly, which induces its occurrence. Knowing the behavior of this pest under variable climatic factors, this study may be helpful in re-scheduling the pesticide use and modification of some available control options to infestation of this pest in cardamom. Those planters who make the best use of the basics of integrated pest management such as field monitoring, pest forecasting and choosing economically and environmentally sound control measures will be successful dealing with the effects of climatic factors.

Table 1: Estimated correlation co-efficient between weather parameters and incidence of pests

Pest	Year	Temperature (°C)		Relative Humidity (Morning)	Relative Humidity (Evening)	Sunshine hours	Rainfall (mm)
		Maximum	Minimum				
Thrips	2013	0.3619 ^{NS}	-0.2483 ^{NS}	-0.3166 ^{NS}	-0.0248 ^{NS}	0.6257**	-0.6311**
	2014	0.5235**	0.0228 ^{NS}	-0.7608**	-0.7665**	0.7839**	-0.5896**
	2015	0.1080 ^{NS}	-0.2971 ^{NS}	-0.4100*	-0.4406*	0.2107 ^{NS}	-0.5315**

Shoot and capsule borer	2013	0.6825**	0.0251^{NS}	-0.4241*	-0.1784^{NS}	0.9730**	-0.5688**
	2014	0.5931**	0.2473^{NS}	-0.4981**	-0.57289**	0.8412**	-0.4535*
	2015	0.1119^{NS}	-0.0543^{NS}	-0.2034^{NS}	-0.2221^{NS}	0.1128^{NS}	-0.4737*
Shoot fly	2013	-0.2693^{NS}	-0.0257^{NS}	0.2209^{NS}	0.1912^{NS}	-0.2866^{NS}	0.7326**
	2014	-0.3702^{NS}	-0.0328^{NS}	0.3978*	0.4281*	-0.4381*	0.8741**
	2015	-0.2047^{NS}	0.0625^{NS}	0.1597^{NS}	0.1511^{NS}	-0.1564^{NS}	0.7725**
Red spider mite	2014	0.6049**	0.6126**	-0.6262**	-0.5789**	0.5792**	-0.2249^{NS}
	2015	0.5197**	0.3975*	-0.4268*	-0.3799^{NS}	0.2675^{NS}	-0.4813*

Correlation Co-efficient 1% = 0.496, 5% = 0.388

* - Significant at 5% level

** - Significant at 1% level

^{NS} – Non Significant

Table 2a. Influence of weather parameters on thrips during 2013, 2014 and 2015

Year	Variable	Mean	Regression Coefficient	Standard error	t stat	Probability	Intercept	R^2 value
2013	Sunshine hours	3.91	0.8981	0.3856	2.3294	0.0290	3.3391	0.35131
	Rainfall	43.3	-0.0428	0.0178	-2.3967	0.0251		
2014	Rainfall	42.11	-0.0703	0.0197	-3.5763	0.0015	8.3756	0.3476
2015	Rainfall	40.78	-0.1015	0.0351	-2.8921	0.0082	26.6651	0.4090

Table 2b. Influence of weather parameters on shoot borer during 2013, 2014 and 2015

Year	Variable	Mean	Regression Coefficient	Standard error	t stat	Probability	Intercept	R^2 value
2013	Rainfall	43.31	-0.0055	0.0049	-1.1182	0.2750	0.7550	0.0048
2014	Max. temp.	24.17	0.6657	0.1845	3.6088	0.0014	-7.3592	0.3518
2015	Rainfall	40.78	-0.0167	0.0063	-2.6351	0.0145	6.9797	0.2244

Table 2c. Influence of weather parameters on shoot fly during 2013, 2014 and 2015

Year	Variable	Mean	Regression Coefficient	Standard error	t stat	Probability	Intercept	R^2 value
2013	Max. temp.	25.67	-0.1000	0.7267	-1.3701	-0.1834	2.8644	0.0725
2014	RH (Eve.)	81.80	0.0109	0.0047	2.3209	0.0291	-0.6506	0.1833
2015	Min. temp	17.90	0.0043	0.0141	0.3070	0.7615	0.0039	0.0039

Table 2d. Influence of weather parameters on red spider mite during 2013, 2014 and 2015

Year	Variable	Mean	Regression Coefficient	Standard error	t stat	Probability	Intercept	R^2 value
2014	Min. temp.	18.51	2.8071	0.7393	3.7969	0.0009	-45.6249	0.3753
2015	Rainfall	40.78	-0.078	0.0290	-2.6896	0.0128	9.7976	0.2316

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