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EVALUATION OF CHILLI GENOTYPES AGAINST CHILLI LEAF CURL COMPLEX BASED ON PHENOL AND ISOZYMES STUDY

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ABSTRACT
Thirty seven chilli genotypes were field screened for leaf-curl complex, a malady usually caused by infestation of thrips, yellow mite and leaf-curl virus. Based on Coefficient of Infection (CI) of leaf curl complex, the genotypes were grouped into five categories namely resistant, moderately resistant, moderately susceptible, susceptible and highly susceptible. Bio-chemical factors like leaf phenol content, peroxidase activity and polyphenoloxidase activity of these genotypes were studied. It was observed that genotypes with increased isozyme activity (peroxidase 1.14 to 12.5, polyphenoloxidase 0.03 to 0.18 respectively) resulted in lower values of CI, varying from 93.75 (CUCH-23) to 8.75 (CUCH-4). CI was found negatively correlated with isozyme activity, phenol content and yield where as these traits exhibited significant positive correlation among each other. Genotypes were grouped into three clusters following D^2 analysis employing biochemical traits, CI and Yield. Majority of the least susceptible genotypes (CUCH-4, CUCH-29, CUCH-31, CUCH-34 and CUCH-35) were grouped under Cluster-I having enhanced peroxidase and polyphenoloxidase activity, high phenol content and yield. It can be concluded that genotypes having higher isozyme activity and phenol content are tolerant to leaf-curl complex which may directly be used for commercial cultivation or may be utilized for breeding of leaf curl tolerant chilli lines.

INTRODUCTION

Chilli (*Capsicum annuum* L.) is one of the important crops in the Sundarban region of West Bengal which is cultivated for both green and dry chilli since long back. Chilli proved to be a good choice by the farmers of Sundarbans in the rice fallow situation, due to its tolerance to soil salinity as well as it can be stored as dry chilli when marketing of green chilli becomes a problem due to poor communication system here. But for the last 5 to 7 years, farmers are quitting chilli cultivation due to high incidence of leaf curl problem. Chilli leaf curl usually occurs by infestation of two pests *viz*. yellow mite (*Polyphagotarsonemus latus*) and thrips (*Scirtothrips dorsalis*) and predisposition of chilli leaf curl virus, which has been well documented by Karmakar (1995). The economic yield loss due to mite (*Polyphagotarsonemus latus*) was estimated to be around 11 to 75% quantitatively and 60 to 80% qualitatively in the event of serious infestation (Ghosh *et al*., 2009; Meena *et al*., 2013). External application of pesticides and acaricides does not always provide good control of these causal factors of leaf curl complex. Developing elite genotype(s) having inherent capability to defend these causal factors along with higher yield potential may be a more practicable approach to protect the crop as well as the interest of chilli farmers of Sundarbans. In the present investigation thirty seven diverse chilli genotypes collected from different parts of India were field screened against leaf curl complex and the bio-chemical factors (like phenol and isozymes) undermining the reaction of these genotypes to leaf curl complex were studied.

Plants have the ability to synthesize phenols or their oxygen-substituted derivatives, like phenolic acids, quinones, flavones, flavonoids, flavonols, tannins, terpenoids, essential oils, alkaloids etc. (Chérif *et al*., 2007). In many instances, these substances serve as plant defense mechanisms against predation by insects, herbivores and microorganisms (Beckman, 2000; Cowan, 1999; Williams and Harborne, 1989). Earlier workers suggested that the resistance to different diseases caused by pathogen was attributed to the presence of high amount of phenol in the leaf (Jain and Yadav, 2003; Kushawaha and Narain, 2005; Parashar and Lodha, 2007). A positive correlation between host resistance and the amount of phenols and increased activity of peroxidase and polyphenoloxidase has been recorded in chilli by Jabeen *et al*. (2009). The opposite occurs in the susceptible plants. Tomato varieties resistant to early blight (Bhatia *et al*., 1972), bacterial wilt (Kao *et al*., 1980) and root knot nematode (Narayana *et al*., 1980) were shown to have higher phenol content than susceptible varieties.

Selection of suitable genotype(s) having tolerance to leaf curl complex and having optimum yield potential in the Sundarban agro-climate is of utmost importance both for the crop and the farmers as well. Chilli has a rich diversity in our country in the form of local cultivars and land races which may well be utilized to develop high yielding chilli lines having tolerance to leaf curl complex. Genetic diversity with wide array of both

qualitative and quantitative traits is a pre-requisite for development of desirable genotypes which can directly be used in cultivation or may be utilized as genetic material for further breeding programme. The positive association between disease resistance and higher phenols and enzyme activity could be of value for early identification of resistant genotypes during population screening.

Considering these aspects the present investigation was framed with the objective of evaluation of the assembled genotypes for biochemical traits, yield and screening against leaf curl complex under natural infestation by the causal agents.

MATERIALS AND METHODS

Plant materials and agronomic practices

Thirty seven diverse chilli genotypes were assembled from different parts of India. These were grown at the Instructional Farm of Ramkrishna Ashram Krishi Vigyan Kendra, Nimpith, South 24 Parganas, West Bengal, India for two seasons (2010-11 and 2011-12). Pre-soaked seeds of all the genotypes were sown in the seedbed in the first week of November every year. 45 days old seedlings were transplanted in the main field @ 40 plants per plot at a spacing of 45cm X 45cm. Each plot was of 9 sqm size. The experimental plot was laid out in randomized block design having three replications. Well rotten cow dung manure @ 20kg per plot was applied. No chemical fertilizers were applied. Essential intercultural operations (weeding, staking, time bound irrigation etc.) were carried out as and when required.

Data collection on leaf curl complex

Field screening of the assembled genotypes for leaf curl complex was carried out under natural epiphytic condition. No insecticide or acaricide was applied in these plots. Data on leaf curl reaction for each genotype was recorded during the peak period of fruiting which was usually 60 – 70 days after transplanting. Screening of the genotypes for tolerance to leaf curl complex was done on the basis of standard formula developed by Banerjee and Kaloo (1987).

Laboratory analysis of phenol and isozymes

Leaf phenol content, leaf peroxidase activity and polyphenoloxidase activity was estimated at the laboratory of Department of Horticulture, Institute of Agricultural Science, University of Calcutta, Kolkata-19, India.

Leaf phenol content was estimated as per Malick and Singh (1980). 2nd or 3rd leaves from top portion of 60 days old leaf-curl free plant were collected for sample preparation. The absorbance was measured using a spectrophotometer (Makeup Jasco, Model-V630) at 650 nm. Phenol concentration was worked out from a standard curve, prepared using different concentration of catechol.

Peroxidase activity of leaf was analyzed following a method, slightly modified over the method of Hammer-Schimidt *et al.* (1982). 2nd or 3rd leaves from top portion of 60 days old leaf-curl free plant were collected for sample preparation. The absorbance was recorded at 470 nm using the spectrophotometer as mentioned earlier. Reading was taken at every second for 60sec. Inactivated enzyme with substrate served as the blank. The data was expressed as enzyme units/ minutes/g fresh tissue.

$$\text{Enzyme activity units} = \frac{500}{\Delta t} [\Delta t = \text{time required to increase the absorbance by } 0.1]$$

The activity of polyphenoloxidase of leaf was estimated spectro scopically as per Serradell *et al.* (2000). Sample was prepared collecting 2nd or 3rd leaves from top portion of 60 days old leaf-curl free plant. The absorbance was recorded using a spectrophotometer as mentioned above at 410 nm continuously for 60 seconds against enzyme blank. The data was expressed as enzyme units/minutes/g fresh tissue using the formula.

Enzyme units in the test = K X (ÄA/min) {K = 0.272 for catechol oxidase}

Yield

To record green yield of each genotype, five plants were selected randomly from each plot. Green fruits from the periodical pickings of the selected plants were recorded. Cumulative yield of each picking was used to calculate the average yield per plant.

Statistical analysis

Statistical analysis was executed using the standard package of SPSS (16.1). D^2 statistic was used as per Mahalanobis, 1936.

RESULTS AND DISCUSSION

Assembled genotypes showed wide variation for leaf-curl tolerance as indexed by coefficient of infection (CI) ranging from 8.75 (CUCH-4) to 93.75 (CUCH-23) (Table 1). According to CI value, genotypes were categorized into five groups (Table 1 and 2). 'Resistant' group comprised of only one genotype CUCH-4 and 'Moderately Resistant' group was having eight genotypes viz. CUCH-1, CUCH-5, CUCH-6, CUCH-7, CUCH-29, CUCH-31, CUCH-34 and CUCH-35. These 9 better performing genotypes registered CI value below 20, which is only 24.32% of total number of genotypes, suggesting the severity and wide prevalence of this malady. Remaining 28 genotypes having high CI value fell in three susceptible categories (i.e. Moderately Susceptible, Susceptible and Highly Susceptible) of which 15 were designated as 'Highly Susceptible' (CI 70-100). Not a single genotype came under

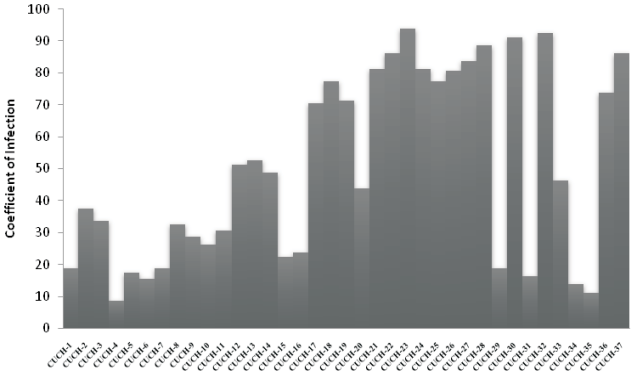

Figure1: Genotype wise variation in leaf curl disease

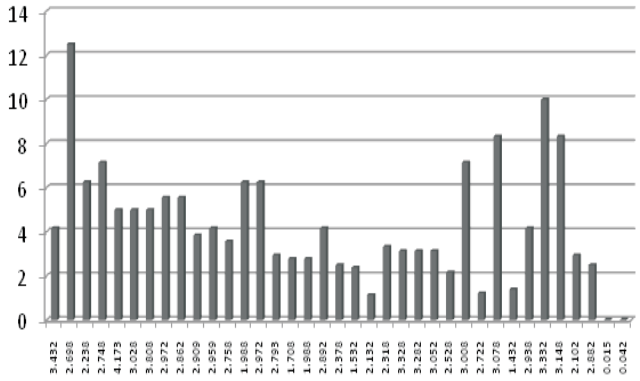

Figure 2: Leaf phenol content(mg/g of leaf)

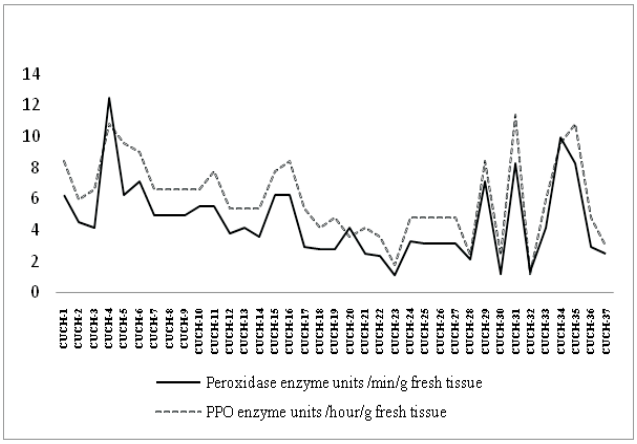

Figure 3: Poly-phenol oxidase and peroxidase activity Curve

Table 1: Reaction of 37 chilli genotypes against leaf curl complex with their respective yield under natural epiphytotic condition (Pooled analysis)

Genotypes*	Severity Grade '0'			Severity Grade '1'			Severity Grade '2'			Severity Grade '3'			Severity Grade '4'			Disease Reaction		Yield
	RV	No. of plants	PDI	RV	No. of plants	PDI	RV	No. of plants	PDI	RV	No. of plants	PDI	RV	No. of plants	PDI	CI	Reac-tion	(g/plant)
CUCH-1	0.00	16	40	0.25	18	45	0.50	6	15	0.75	0	0	1.00	0	0	18.75	MR	135.8
CUCH-2	0.00	2	5	0.25	22	55	0.50	10	25	0.75	6	15	1.00	0	0	37.5	MS	118.4
CUCH-3	0.00	10	25	0.25	14	35	0.50	8	20	0.75	8	20	1.00	0	0	33.75	MS	124.6
CUCH-4	0.00	28	70	0.25	10	25	0.50	2	5	0.75	0	0	1.00	0	0	8.75	R	168.5
CUCH-5	0.00	22	55	0.25	10	25	0.50	6	15	0.75	2	5	1.00	0	0	17.5	MR	140.8
CUCH-6	0.00	21	52.5	0.25	13	32.5	0.50	6	15	0.75	0	0	1.00	0	0	15.63	MR	155.5
CUCH-7	0.00	14	35	0.25	22	55	0.50	4	10	0.75	0	0	1.00	0	0	18.75	MR	139.8
CUCH-8	0.00	0	0	0.25	28	70	0.50	12	30	0.75	0	0	1.00	0	0	32.5	MS	114.0
CUCH-9	0.00	8	20	0.25	20	50	0.50	10	25	0.75	2	5	1.00	0	0	28.75	MS	134.7
CUCH-10	0.00	12	30	0.25	18	45	0.50	6	15	0.75	4	10	1.00	0	0	26.25	MS	132.9
CUCH-11	0.00	0	0	0.25	31	77.5	0.50	9	22.5	0.75	0	0	1.00	0	0	30.63	MS	150.2
CUCH-12	0.00	0	0	0.25	12	30	0.50	14	35	0.75	14	35	1.00	0	0	51.25	S	105.3
CUCH-13	0.00	0	0	0.25	12	30	0.50	12	30	0.75	16	40	1.00	0	0	52.5	S	102.2
CUCH-14	0.00	0	0	0.25	14	35	0.50	14	35	0.75	12	30	1.00	0	0	48.75	S	109.5
CUCH-15	0.00	10	25	0.25	24	60	0.50	6	15	0.75	0	0	1.00	0	0	22.5	MS	151.6
CUCH-16	0.00	6	15	0.25	30	75	0.50	4	10	0.75	0	0	1.00	0	0	23.75	MS	154.4
CUCH-17	0.00	0	0	0.25	3	7.5	0.50	6	15	0.75	26	65	1.00	5	12.5	70.63	HS	75.4
CUCH-18	0.00	0	0	0.25	0	0	0.50	6	15	0.75	24	60	1.00	10	25	77.5	HS	110.3
CUCH-19	0.00	0	0	0.25	0	0	0.50	15	37.5	0.75	16	40	1.00	9	22.5	71.25	HS	113.7
CUCH-20	0.00	0	0	0.25	19	47.5	0.50	12	30	0.75	9	22.5	1.00	0	0	43.75	S	80.4
CUCH-21	0.00	0	0	0.25	0	0	0.50	8	20	0.75	14	35	1.00	18	45	81.25	HS	129.2
CUCH-22	0.00	0	0	0.25	0	0	0.50	6	15	0.75	10	25	1.00	24	60	86.25	HS	119.9
CUCH-23	0.00	0	0	0.25	0	0	0.50	0	0	0.75	10	25	1.00	30	75	93.75	HS	87.9
CUCH-24	0.00	0	0	0.25	0	0	0.50	4	10	0.75	22	55	1.00	14	35	81.25	HS	89.5
CUCH-25	0.00	0	0	0.25	0	0	0.50	6	15	0.75	24	60	1.00	10	25	77.5	HS	107.4
CUCH-26	0.00	0	0	0.25	0	0	0.50	2	5	0.75	27	67.5	1.00	11	27.5	80.63	HS	112.7
CUCH-27	0.00	0	0	0.25	0	0	0.50	4	10	0.75	18	45	1.00	18	45	83.75	HS	99.6
CUCH-28	0.00	0	0	0.25	0	0	0.50	0	0	0.75	18	45	1.00	22	55	88.75	HS	72.3
CUCH-29	0.00	14	35	0.25	22	55	0.50	4	10	0.75	0	0	1.00	0	0	18.75	MR	170.1
CUCH-30	0.00	0	0	0.25	0	0	0.50	0	0	0.75	14	35	1.00	26	65	91.25	HS	109.8
CUCH-31	0.00	14	35	0.25	26	65	0.50	0	0	0.75	0	0	1.00	0	0	16.25	MR	238.4
CUCH-32	0.00	0	0	0.25	0	0	0.50	0	0	0.75	12	30	1.00	28	70	92.5	HS	105.5
CUCH-33	0.00	0	0	0.25	16	40	0.50	16	40	0.75	6	15	1.00	2	5	46.25	S	107.0
CUCH-34	0.00	18	45	0.25	22	55	0.50	0	0	0.75	0	0	1.00	0	0	13.75	MR	195.5
CUCH-35	0.00	22	55	0.25	18	45	0.50	0	0	0.75	0	0	1.00	0	0	11.25	MR	202.8
CUCH-36	0.00	0	0	0.25	0	0	0.50	4	10	0.75	34	85	1.00	2	5	73.75	HS	89.1
CUCH-37	0.00	0	0	0.25	0	0	0.50	0	0	0.75	22	55	1.00	18	45	86.25	HS	85.2

* Total number of plants per plot in each genotype = 40; RV = Response value;PDI = (No. of diseased plant / total no of pl(40))*100;R = Resistant0;MR = Moderately Resistant;MS = Moderately Susceptible;S = Susceptible;HS = Highly Susceptible;CI (Coefficient of Infection) = " [(Response Value $_{0.00-1.00}$) X Respective PDI

'Highly Resistant' category (CI <4). Rameash *et al.* (2015) reported that out of 71 chilli accessions only 22.54% were found resistant or moderately resistant against leaf curl caused by broad mite (*Polyphagotarsonemus latus*). Rest 39 accessions were found susceptible and 16 were highly susceptible to this infestation.

Yield of the assembled genotypes varied widely from 72.35 g

Table 2: Grouping of Chilli genotypes as per reaction to leaf curl complex

Grouping according to CI	No. of Genotypes	Name of the genotypes	Avg. CI Value	Avg. Yield (g/plant)
Highly Resistant (0-4)	-	-	-	-
Resistant (5-9)	1	CUCH-4	8.75	168.50
Moderately Resistant (10-19)	8	CUCH-1, CUCH-5, CUCH-6, CUCH-7, CUCH-29, CUCH-31, CUCH-34, CUCH-35	16.33	172.34
Moderately Susceptible(20-39)	8	CUCH-2, CUCH-3, CUCH-8, CUCH-9, CUCH-10, CUCH-11, CUCH-15, CUCH-16	29.45	135.10
Susceptible (40-69)	5	CUCH-12, CUCH-13, CUCH-14, CUCH-20, CUCH-33	48.50	100.88
Highly Susceptible (70-100)	15	CUCH-17, CUCH-18, CUCH-19, CUCH-21, CUCH-22, CUCH-23, CUCH-24, CUCH-25, CUCH-26, CUCH-27, CUCH-28, CUCH-30, CUCH-32, CUCH-36, CUCH-37	82.42	100.50

Table 3: Isozyme activity analysis of Peroxidase and Polyphenol oxidase

Accession no.	Leaf phenol (mg/g of leaf)	Peroxidase enzyme units /min/g fresh tissue	PPO enzyme units / min/g fresh tissue
CUCH-1	3.262	6.25	0.14
CUCH-2	1.912	4.55	0.1
CUCH-3	3.432	4.17	0.11
CUCH-4	2.698	12.5	0.18
CUCH-5	2.238	6.25	0.16
CUCH-6	2.748	7.14	0.15
CUCH-7	4.173	5	0.11
CUCH-8	3.028	5	0.11
CUCH-9	3.808	5	0.11
CUCH-10	2.972	5.56	0.11
CUCH-11	2.862	5.56	0.13
CUCH-12	2.909	3.85	0.09
CUCH-13	2.959	4.17	0.09
CUCH-14	2.758	3.57	0.09
CUCH-15	1.988	6.25	0.13
CUCH-16	2.972	6.25	0.14
CUCH-17	2.793	2.94	0.09
CUCH-18	1.708	2.78	0.07
CUCH-19	1.988	2.78	0.08
CUCH-20	2.892	4.17	0.06
CUCH-21	2.378	2.5	0.07
CUCH-22	1.532	2.38	0.06
CUCH-23	2.132	1.14	0.03
CUCH-24	2.318	3.33	0.08
CUCH-25	3.328	3.13	0.08
CUCH-26	3.282	3.13	0.08
CUCH-27	3.052	3.13	0.08
CUCH-28	2.528	2.17	0.04
CUCH-29	3.008	7.14	0.14
CUCH-30	2.722	1.22	0.04
CUCH-31	3.078	8.33	0.19
CUCH-32	1.432	1.39	0.02
CUCH-33	2.938	4.17	0.1
CUCH-34	3.332	10	0.16
CUCH-35	3.148	8.33	0.18
CUCH-36	2.102	2.94	0.08
CUCH-37	2.882	2.5	0.05
SEm	0.015	0.011	0.004
CD (0.05)	0.042	0.03	0.01

Table 4: Correlation between CI, enzyme activity, leaf phenol content and yield

	Peroxidase	PPO	CI	Yield
Phenol	0.340**	0.375**	-0.448**	0.256**
Peroxidase		0.897**	-0.866**	0.787**
PPO			-0.888**	0.805**
CI				-0.722**

** Correlation is significant at the 0.01 level

(CUCH-28) to 238.35 g (CUCH-31) (Table 1). Three best yielding genotypes were CUCH-31 (238.35g), CUCH-35 (202.80g) and CUCH-34 (195.48g) belonged to 'Moderately Resistant' group. The genotype CUCH-4 though registered 'Resistant' disease reaction, recorded a yield (168.46g) far below the top three yielders. Average yield of resistant or moderately resistant genotypes was between 168.5g to 172.34g, where as it was 135.1g for moderately susceptible group, 100.88g for susceptible group and 100.5g for highly susceptible group (Table 2). As compared to resistant or moderately resistant groups, yield loss in moderately to highly susceptible genotypes ranged from 21.61% to 41.69%.

Table 5: Clustering of genotypes on the basis of biochemical parameters, coefficient of infection (CI) of leaf curl complex and yield

Cluster	No. of Genotypes	Name of the genotypes
Cluster I	5	CUCH-4, CUCH-29, CUCH-31, CUCH-34, CUCH-35
Cluster II	12	CUCH-1, CUCH-2, CUCH-3, CUCH-5, CUCH-6, CUCH-7, CUCH-8, CUCH-9, CUCH-10, CUCH-11, CUCH-15, CUCH-16
Cluster III	20	CUCH-12, CUCH-13, CUCH-14, CUCH-17, CUCH-18, CUCH-19, CUCH-20, CUCH-21, CUCH-22, CUCH-23, CUCH-24, CUCH-25, CUCH-26, CUCH-27, CUCH-28, CUCH-30, CUCH-32, CUCH-33, CUCH-36, CUCH-37

Table 6: Intra and Inter cluster distance

	Cluster - I	Cluster - II	Cluster - III
Cluster - I	22.203		
Cluster - II	60.176	13.639	
Cluster - III	112.959	60.708	21.388

Table 7: Cluster Mean values

Parameters	Phenol (mg/g leaf tissue)	Peroxidase (units/min/g tissue)	PPO (units/min/g tissue)	CI	Yield (g/plant)
Cluster - I	3.05	9.41	0.17	13.40	196.66
Cluster - II	2.95	5.62	0.13	25.34	137.80
Cluster - III	2.53	2.87	0.07	73.93	101.51

Average yield loss in chilli due to leaf curl problem was 34.14% (Ahmad *et al*., 1987), however in extreme conditions the yield loss was more than 90% (Kumar, 1995). So, it is clear that incidence of leaf curl has a direct positive effect on yield reduction in chilli. Genetic diversity study through isozyme variation have extensively been utilized in different vegetable crops like tomato (Evans and Allridge, 1965; Gunaseelan *et al*., 2011), potato (Beatriz *et al*., 2001), brinjal (Ali *et al*., 2011) etc. In the present study, leaf phenol content and isozyme (peroxidase and polyphenoloxidase) activity recorded high variability for the thirty seven genotypes (Table 3). The activity of both peroxidase and polyphenoloxidase was highest in the resistant genotype CUCH-4 (12.50 and 0.18 unit/minute/g fresh tissue respectively) and lowest in the highly susceptible genotype CUCH-23 (1.14 and 0.03 unit/minute/g fresh tissue respectively). Moderately resistant genotypes registered peroxidase activity value between 5.00 (CUCH-7) to 10.00 (CUCH-34) and between 0.11 (CUCH-7) to 0.19 (CUCH-31) for polyphenoloxidase activity. In highly susceptible group, peroxidase and polyphenoloxidase activity value ranged between 1.14 to 3.33 and 0.02 to 0.09 respectively. In case of susceptible group the same were between 3.57 to 4.17 and 0.06 to 0.10 respectively for peroxidase and polypheno loxidase activity where as in moderately susceptible genotypes it was between 4.17 to 6.25 and 0.10 to 0.14. Leaf phenol content also varied widely from 1.432 mg/g (CUCH-32) to 4.173 mg/g (CUCH-7),' but in majority of the cases the variation was not in accordance with leaf curl incidence. In resistant genotype CUCH-4, phenol content was 2.698 mg/g, where as in few highly susceptible genotypes (CUCH-25, CUCH-26, CUCH-27) it was above 3 mg/g. However, most of the least susceptible genotypes recorded leaf phenol content above 3 mg/g and almost all the genotypes with lower leaf phenol content (d£2 mg/g) were from highly susceptible group. So, it is clear that with increase in phenol content and isozyme activity, susceptibility of chilli genotypes to leaf curl complex gradually decreased. A positive correlation between host resistance and increased amount of phenols and activity of peroxidase and polyphenoloxidase has been recorded in chilli by Jabeen *et al*. (2009). Plants have the ability to synthesize phenols or their oxygen-substituted derivatives (Chérif *et al*., 2007). These substances serve as plant defense mechanisms against insects, herbivores and microorganisms (Beckman, 2000; Cowan, 1999; Williams and Harborne, 1989). In Tomato polyphenoloxidase activity increased in *Pseudomonas syringae* infected plants, but it's increment was significantly higher in resistant plants (Bashan *et al*., 1987).

The above findings have been well established through correlation study, where Coefficient of Infection of leaf curl complex (CI) recorded significant negative correlation with leaf phenol content, peroxidase activity, polyphenoloxidase activity and yield (Table 4). Significant positive correlation was observed among leaf phenol content, peroxidase activity, polyphenoloxidase activity and Yield.

D^2 analysis employing biochemical traits, leaf curl incidence and yield grouped the genotypes into three clusters (Table 5). Cluster I consisted of 5 genotypes, one from 'Resistant' category (CUCH-4) and four from 'Moderately Resistant' category (CUCH-29, CUCH-31, CUCH-34, CUCH-35). Rest members of 'Moderately Resistant' category and all members of 'Moderately Susceptible' category were grouped under Cluster II while 'Susceptible' and 'Highly Susceptible' members formed Cluster III. It was also noted here that four members of 'Moderately Resistant' category, that falls under Cluster I, are considerably better yielder than the rest four members of that category. So, it can be said that there exists a similarity pattern in grouping of the genotypes following leaf-curl incidence and D^2 analysis employing biochemical traits that perhaps govern the resistance against leaf curl problem.

REFERENCES

Ahmad, K., Mohamed, M. G. and Murthy, N. S. R. 1987. Yield losses due to various pests in hot pepper. *Capsicum Newslett*. **6:** 83-84.

Ali, Z., Xu, Z. L., Zhang, D. Y., He, X. L., Bahadur, S. and Yi, J. X. 2011. Molecular diversity analysis of eggplant (*Solanum melongena*) genetic resources. *Genet. Mol. Res*. **10(2):** 1141-1155.

Banerjee, M. K. and Kalloo, G. 1987. A scale for classifying disease reaction of *Lycopersicon* species to tomato leaf curl virus. *Theor. Appl. Genet*. **73:** 707-710.

Bashan, Y., Okon, Y. and Henis, Y. 1987. Peroxidase, polyphenol-oxidase and phenols in relation to resistance against *Pseudomonas syringae* pv. *tomato* in tomato plant. *Canad. J. Bot*. **65:** 366-372.

Beatriz, H. G. R., Augustin, E., Da-Silva, J. B. and Viégas, J. 2001. Isoenzymatic variability in wild potatoes. *Pesq. Agropec. Bras*. **36(5):** 781-791.

Beckman, C. H. 2000. Phenolic-storing cells: keys to programmed cell death and periderm formation in wilt disease resistance and in general defence responses in plants. *Physiol. Mol. Plant Path*. **57:** 101-110.

Bhatia, I. S., Uppal, D. S. and Bajaj, K. L. 1972. Study of phenolic contents of resistant and susceptible varieties of tomato (*Lycopersicon esculentum*) in relation to early blight of tomato. *Indian Phytopathol.* **25:** 231-234.

Chérif, M., Arfaoui, A., and Rhaiem, A. 2007. Phenolic compounds and their role in bio-control and resistance of chickpea to fungal pathogenic attacks. *Tunisian J. Plant Protec.* **2:** 7-21.

Cowan, M. M. 1999. Plant products as antimicrobial agents. *Clinical Microbiol. Rev*. **12:** 564-582.

Evans, J. J. and Allridge, N. A. 1965. The distribution of peroxidases in extreme dwarf and normal tomato (*Lycopersicon esculentum*). *Phytochemistry*. **8:** 499-503.

Ghosh, A., Chatterjee, M. L., Chakraborti, K. and Samanta, A. 2009. Field Evaluation of Insecticides against Chilli Thrips (*Scirtothrips dorsalis*). *Ann. Plant Protect. Sci*. **17:** 69-71.

Gunaseelan, C., Suganyadevi, P., Rajasabapathy, R. and Ruban, P. 2011. Differentiation of Hybrid (COTH2) and wild (CO3) varieties of tomato (*Lycopersicon esculentum*) using protein and peroxidase isozyme profile. *Res. & Rev*. **1(2):** 1-5.

Hammer-Schimidt, R., Nuckles, M. E. and Kuc, J. 1982. Association of enhanced peroxidase activity with induced systemic resistance of cucumber to *Colletrotricum lagenarium*. *Physiological Pl. Path*. **20:** 73-82.

Jabeen, N., Ahmed, N., Muzafar, Y. G. and Parvez, A. S. 2009. Role of phenolic compounds in resistance to chilli wilt. *Commun. Biometry Crop Sci*. **4(2):** 52–61.

Jain A. K. and Yadav H. S. 2003. Biochemical constituents of finger millet genotype associated with resistant to blast caused by *Pyricularis grisea*. *Ann. Pl. Protec. Sci*. **11:** 70- 74.

Kao, J. Y. and Hsiao, J. Y. 1980. *J. Sci. Engg*. **17:** pp.295. Write in full

Karmakar, K. 1995. Comparative symptomology of chilli leaf curl disease and biology of tarsonemid mite, *Polyphagotarsonemus latus* (Banks) (Acari: Tarsonemidae). *Annals Entomology*. **13(2):** 65-70.

Kushwaha, K. P. S. and Narain, U. 2005. Biochemical changes to pigeon pea leaves infected with *Alternaria tenuissinia*. *Ann. Pl. Protec. Sci*. **13:** 415-417.

Kumar, N. K. K. 1995. Yield loss in chilli and sweet pepper due to *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae). *Pest* Mgnt. *Hort. Ecosys*. **1(2):** 61-69.

Mahalanobis, P. 1936. On the generalized distance in statistics. *Proc. Nat. Inst. Sci.* (India). **12:** 49-55.

Malick, C. P. and Singh, M. B. 1980. In: *Plant Enzymology and Histo Enzymology*, Kalyani Publishers, New Delhi, p.286.

Meena, R. S., Ameta, O. P. and Meena, B. L. 2013. Population dynamics of sucking pests and their correlation with weather parameters in chilli, *Capsicum annum* L. Crop. *The Bioscan*. **8:** 177-180.

Narayana, Y. D. and Reddy, D. D. R. 1980. The role of nitrogen, amino acids and phenols in resistance of tomato to root-knot nematode. *Nematol. Medit*. **8:** 51-57.

Parashar, A. and Lodha, P. 2007. Phenolics estimation in *Foeniculum Vulgare* infected with Ramularia blight. *Ann. Pl. Protec. Sci*. **15:** 396-398.

Rameash, K., Pandravada, S. R., Sivaraj, N., Sarath Babu B. and Chakrabarty S. K. 2015. Screening chilli (*Capsicum annuum* l.) genotypes for resistance to broad mite (*Polyphagotarsonemus latus* Banks) and analysing the geographic distribution of resistance through diva-gis. *The Ecoscan*. **8:** 13-19.

Serradell, M. A., Rozenfeld, P. A., Martinez, G. A., Civello, P. M., Chaves, A. R. and Arnon, M. C. 2000. Polyphenol oxidase activity from strawberry fruit (Fragaria X Ananassa, Duch., Cv. Selva): Characterization and paertial purification. *J. Sci. Food Agric*. **80:** 1421-1427.

Williams, C. A. and Harborne, J. B. 1989. Isoflavonoids. In: Methods in Plant Biochemistry, Vol. 1, Academic Press. pp. 421-449.