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PLANT-INSECT-ENVIRONMENT INTERACTION FOR *KUSMI* LAC RESIN PRODUCTION ON *BER* (*ZIZIPHUS MAURITIANA*) VARIETIES

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ABSTRACT

Ber is the most preferred host-plant for lac cultivation due to its faster growth and good pruning response among the three common hosts. Exploitation of the potential fruit varieties of *ber* for lac culture is good prepositions because in case of lac crop failure, these will yield marketable fruit. Development of lac-insect on the host-plant is dependent and influenced by various abiotic and biotic factors. Objective of present experiment was to know plant-insect-environment interaction for natural resin production and biochemical changes in host after lac insect inoculation and effect of weather on *kusmi* lac in twenty four fruit varieties of *ber*. Environments interacted linearly with significant interaction of environment with varieties of *ber* for broodlac, scrapedlac, total sugar and soluble protein. All selected varieties of *ber* consistently performed better over environments for lac and biochemical traits. *Kali* had significantly higher broodlac yield (37%) followed by Kaithali and *Banarasi Pebandi* (23% each) as compared to CAZRI *Gola*. *Katha,* Thornless, *Kali* and CAZRI *Gola* had consistent performance better for broodlac yield in good environment ($b_i > 1$) where as *Kaithali, Illaichi, Chhuhara* and *Banarasi Pebandi* performed better in poor environment ($b_i < 1$) also. Small changes were recorded in *Chhuara*, CAZRI *Gola* and *Kali* for total sugar, and Thornless, CAZRI *Gola* and *Bagwadi* for soluble protein as these traits had low regression response with environment (bi < 1). Variety x insect x environment interaction was highly significant for these biochemical traits. High rainfall during initial settlement of crawlers and sex differentiation of lac insect; high relative humidity during life cycle and average maximum temperature during crop period of 2012-13 affected adversely the broodlac yield. Altogether, intrinsic and extrinsic factors of environment played significant role on growth and development of lac insect on fruit *ber* varieties and ultimately production of *kusmi* lac resin.

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INTRODUCTION

Ber (*Ziziphus mauritiana*) along with *palas* (*Butea monosperma*) and *kusum* (*Schleichera oleosa*) is considered as a major lac host-plant in India. *Palas* and *kusum* are suitable for *rangeeni* and *kusmi* strains of lac insect, *Kerria lacca* (Kerr), respectively but *ber* can be utilized for both the strains of lac-insect. It is the most preferred host-plant for lac cultivation due to its faster growth and very good pruning response among the three major hosts. The development of lac-insect on host-plant is dependent and influenced by abiotic and biotic factors. Relative performance of traits of genotype measured in two or more environments can be assessed by genotype to environment interaction. It refers to instances where the joint effects of genotype and environmental risk factors are significantly greater than would be predicted from the sum of the separate effects. The fluctuation in lac yield can be attributed to a certain extent by changes in weather. The abiotic factors emanate from the environment and comprise climatic influences. Influence of different abiotic factors like weather, soil fertility etc. on *ber* plant has been reported earlier in different form in this institute (Ghosal, 2012 a, b and 2013). CAZRI *Gola* is well adapted fruit variety of India and this variety has been reported as most susceptible cultivar to the attack of lac insect followed by *Kaithali* and *Umran* (Lakra and Kher, 1990). There is an immense possibility of increasing lac yield by exploiting varietal preference by lac insect. The real challenge with production scientist is to tap the positive interaction which is the ongoing process in the nature. It is expected that some or the other condition of factors affected lac production will excel over the other. Therefore, it was thought to evaluate if there was any positive interaction with the varieties and weather on *kusmi* lac production. Present experiment was, therefore, planned to know the plant-insect-environment interaction for natural resin production and biochemical changes in host plant after lac insect inoculation and effect of weather on *kusmi* lac in twenty four fruit varieties of *ber*.

MATERIALS AND METHODS

Experimental locale

Kusmi strain of lac insect was inoculated on twenty-four *ber* varieties for winter crop in two consecutive years. These *ber* varieties have been released for different climatic zones in India for fruit purpose. The experiment was conducted at Institute Research Farm (IRF) of ICAR-Indian Institute of Natural Resins and Gums (IINRG), Ranchi during 2012-13 and 2013-14. It is located at 23.35ºN latitude and 85.33ºE longitude. Its elevation from sea level is 2140 feet. Climate is characterized by hot summer from March to May and well distributed rain fall during southwest monsoon from June to October. Winter season in the area is marked by dry and cold weather during the month of November to February. Generally, the climate of Ranchi is moderate due to hilly region and dense deciduous forest. The normal annual rainfall data indicate that average rainfall is 1394 mm. Maximum rainfall has been observed from June to October months. About 90% of the total annual rainfall is received to the monsoon period. Soil is formed from the disintegration of rocks and stones. Soil type is alfisols and ultisols having light textured, slightly acidic, poor in nitrogen and phosphorus and fairly rich in potash. CAZRI *Gola* is well adapted fruit variety of India and this variety was used as check as this variety is susceptible to lac insect.

Data recording

Lac attributing traits like initial settlement density and sex ratio were measured by counting number of lac insect per square centimeter in three positions of three branches per variety. Average from each plant was taken for data analysis. Harvested brood lac was weighed in gram for each variety. The resinous cover was scraped off from the twigs, weighed in gram as scrapedlac. Based on lac parameters twelve varieties were selected for biochemical analysis in inoculated and control plants to assess the plant-insect-environment interaction. Total sugar in leaves of inoculated and control plant of each variety was determined by Nelson arsenomolybdate (Nelson, 1944) and soluble protein in leaves were estimated by using Lawrey's method (Lowrey *et al.* 1952) improved copper reagent of Somogyi, 1952. Three factors analysis (variety - lac insect - environment) was computed for biochemical traits in inoculated and control plants with three replications with online opstat package to know different interactions. Genotype by environment interaction and stability parameters in lac attributes and biochemical traits were computed in *ber* varieties using Eberhart and Russel, 1966 model from SPAR 2.0 package. Data on rainfall were taken for crop period from July to February and at two critical stages of lac culture, *i.e.*, initial settlement and sex differentiation stages (Fig. 1). Regression responses were computed for broodlac yield with total rainfall for crop period, one week from inoculation at initial settlement, 45-52 days from inoculation at sex differentiation and other weather parameters from SPSS 10 for windows.

RESULTS AND DISCUSSION

Effect of environment on lac culture

Varieties have different genetic potential to express their phenotypes in different environment as varieties were significantly different for lac components, total sugar and soluble protein. Intrinsic and extrinsic environmental factors behaved linearly, interact significantly with varieties of *ber* and played significant role in lac production and biochemical property of *ber* varieties as variety x environment (linear) interaction was highly significant for all four traits under investigation (Table 1). A variety with unit regression coefficient ($bi_{H''}$ 1) and deviation from regression not significantly different from zero ($sd_i^2{}_{H''}$ 0) is said to be stable one (Singh and Chaudhary, 1985). Regression (bi) greater than one means genotype responded in favourable environment, less than one means responded in unfavourable (poor) environment and nearby unity means responded in average environment (Nadarajan and Gunasekaran, 2005). Among stable genotypes high mean value has been considered while recommending varieties for particular environment. All selected twelve varieties of *ber* performed consistently over environment for all traits. *Kali* had significantly higher broodlac yield (37%) followed by *Kaithali* and *Banarasi Pebandi* (23% each) as compared to CAZRI *Gola*. *Kaithali*, *Chhuara, Illaichi* and *Banarasi Pebandi* performed better in average (all) environment ($bi_{H''}$1), but *Katha*, Thornless, CAZRI *Gola* and *Kali* performed well in above average (favourable) environment (bi > 1) (Table 2). *Kaithali, Kali, Illaichi* and *Banarasi Pebandi* had higher scrapedlac with significantly higher yield in *Illaichi* only (29%). The high scrapedlac in

Table 1: Genotype environment interaction in *ber* varieties for lac and biochemical traits

Source of Variation	DF	Mean sum of square		DF	Mean sum of square	
		Broodlac	Scrapedlac		Total sugar	Soluble protein
Varieties	23	178291.9**	39892.1**	11	207.7**	1363.5**
Env + (Var x Env)	24	367434.2**	39811.4**	12	698.5**	1034.3**
Env (Linear)	01	5799312.1**	368301.0**	01	6257.9**	1392.0**
Variety x Env (Linear)	23	131265.6**	25529.2**	11	193.1**	1001.8**
Pooled error	96	26480.9	5886.1	48	11.2	17.1

** = significant at 1% probability levels

Tabel 2: Stability performance of *ber* varieties for *kusmi* lac resin, total sugar and soluble protein

Ber variety	Broodlac		Scrapedlac		Total sugar		Soluble protein	
	X	b_i	X	b_i	X	b_i	X	b_i
Jogia	875	0.168^x	367	0.238^x	23.0	1.140	114.5*	-1.442^x
Kaithali	1171*	0.947	483	0.543^x	29.0	1.068	143.9*	4.265$^+$
Seb x *Gola* (F_1)	943	1.314	466	1.127	37.3	0.978	92.6*	2.009$^+$
Katha	1133	1.582$^+$	425	1.867$^+$	46.5	1.103	76.5*	1.166
Banarsi Karaka	888	-0.060^x	338	-0.170^x	32.2	1.536$^+$	89.8*	-2.095^x
Thornless	1118	1.489$^+$	437	1.700$^+$	21.9	1.049	92.7*	0.044^x
CAZRI *Gola*	954	1.498$^+$	447	1.256	52.4	0.244^x	61.1	0.097^x
Chhuhara	1076	1.177	407	0.994	45.3	-0.125^x	91.0*	4.378$^+$
Kali	1302*	2.038$^+$	488	1.809$^+$	25.4	0.254^x	69.9*	1.030
Illaichi	1040	1.322	575*	1.397$^+$	43.9	1.295	74.6*	-3.557^x
Bagwadi	902	1.338	429	1.147	38.1	2.047$^+$	62.3	-0.513^x
Banarsi Pebandi	1171*	1.331	571	1.544$^+$	27.5	1.413$^+$	129.8*	6.618$^+$
Mean	857	1.000	348	0.916	35.2	1.000	91.5	1.000
CD at 5%	220.78		84.06		6.68		8.19	

* = significantly superior than check, CAZRI *Gola*, + = regression greater than one, x = regression less than one

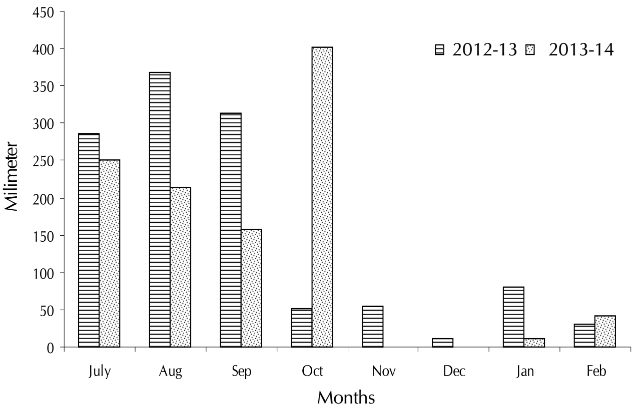

Figure 1: Monthly rainfall during crop period 2012-13 and 2013-14

Table 3: Plant-insect-environment interaction⁺ for biochemical parameters in *ber* varieties

Source of Variation	DF	Mean sum of Squares Total sugar	Soluble protein
Environment (A)	1	47,306.3**	19489.2**
Lac insect inoculation (B)	1	1,107.8**	42.1^{ns}
Interaction A X B	1	553.0**	2320.6**
Varieties of *ber* (C)	11	1,312.0**	7245.2**
Interaction A X C	11	967.0**	4836.0**
Interaction B X C	11	78.3*	353.6**
Interaction A X B X C	11	108.3**	292.1**
Error	94	38.5	71.3

+ indicates 12 varieties, inoculation vs control condition and two environments; ** and * = significant at 1% and 5% probability levels, respectively

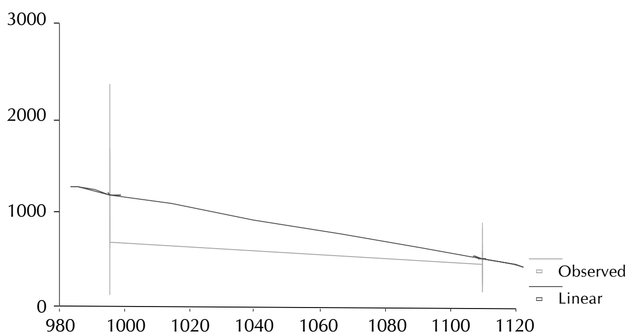

Figure 2A: Effect of total rainfall on broodlac

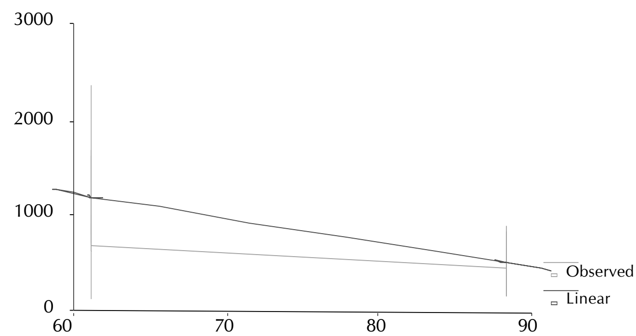

Figure 2B: Effect of rainfall at initial settlement on broodlac

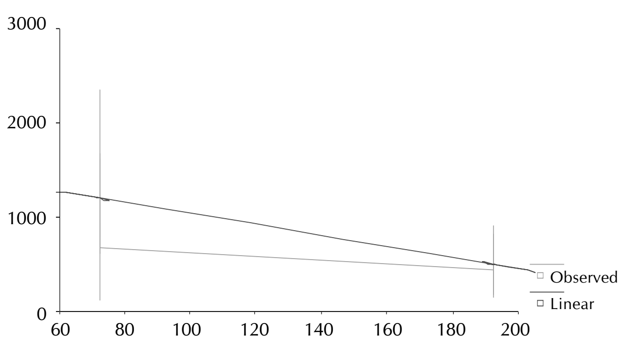

Figure 2C: Effect of rainfall at sex differentiation on broodlac

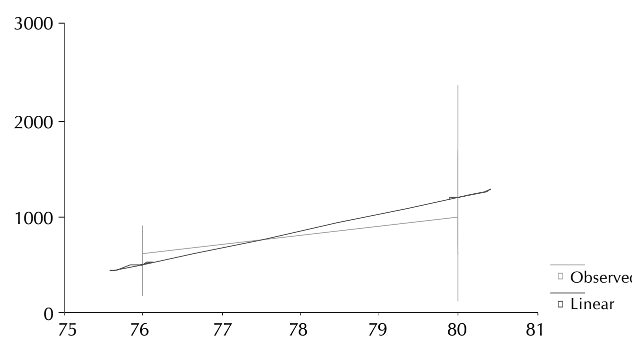

Figure 2D: Effect of average relative humidity on broodlac

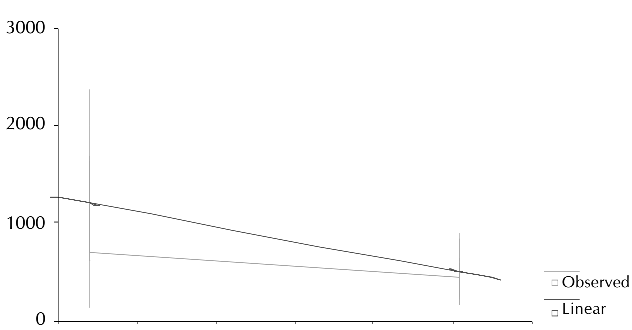

Figure 2E: Effect of maximum temperature on broodlac

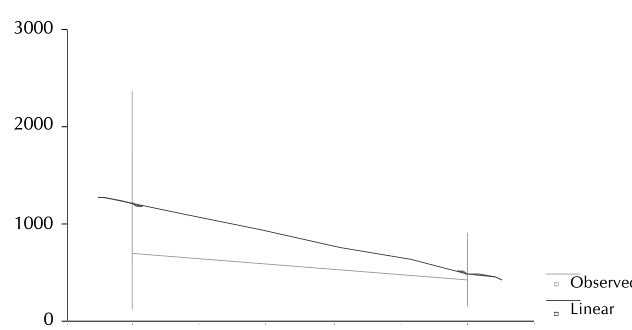

Figure 2F: Effect of minimum temperature on broodlac

Katha, *Kali, Illaichi, Thornless* and *Banarasi Pebandi* was due to favourable environment. Total sugar and soluble protein in phloem sap are important for lac-insect that utilizes the transported fluid as their major nutrient source. *Katha*, CAZRI *Gola*, *Chhuhara* and *Illaichi* have good amount of total sugar. In contrast, *Jogia*, *Kaithali*, *Seb x Gola* (F_1), *Katha*, *Banarasi Karaka*, Thornless, *Chhuhara*, *Kali*, *Illaichi* and *Banarasi Pebandi* had significantly better status for soluble protein in leaves. Small changes were recorded in CAZRI *Gola*, *Chhuhara* and *Kali* for total sugar and *Banarasi Karaka*, Thornless, CAZRI *Gola*, *Illaichi* and *Bagwadi* for soluble protein due to low response of environments (bi < 1). *Banarasi Karaka*, *Bagwadi* and *Banarasi Pebandi* performed consistently better for total sugar and, *Kaithali, Seb x Gola* (F_1), *Chhuhara* and *Banarasi Pebandi* for soluble protein in favourable environment (bi > 1). In contrast, *Jogia*, *Katha* and *Kali* showed good performance for soluble protein in average environment. Altogether, *Kaithali*, *Kali* and *Banarasi Pebandi* had significantly higher broodlac yield and soluble protein, and *Katha,* CAZRI *Gola*, *Chhuhara* and *Illaichi* for higher broodlac and total sugar. Lac insect inoculation verses control over environment differed significantly for total sugar and soluble protein (Table 3). Varieties responded differently with lac inoculation for these traits.

Effect of extrinsic factor (weather) on lac culture

The fluctuation in lac yield can also be attributed to a certain extent by changes in weather. The abiotic factors emanate from the environment and comprise climatic influences. The crawlers of lac-insect move upward on host-plant after inoculation. Majority of crawlers settled on tender shoots within seven days. They became static after inserting proboscis in phloem for getting food from it. Heavy rainfall (88.3 mm) during initial settlement of crawlers in 2012 had reduced settlement density. Settlement of larvae in variant with the desired number affected lac production adversely (Fig. 2B). Another critical stage of lac culture is the stage of sex differentiation and fertilization. Winter *kusmi* strain took 45 to 50 days for sex differentiation after settlement. Male contributes very little to lac yield but they are essential to fertilize female for a healthy and good crop. The rate of resin secretion by females increases rapidly only after fertilization (Sharma and Jaiswal, 2011). Heavy rainfall of 192.6 mm in 2012 during this period adversely affected fertilization and ultimately broodlac yield (Fig. 2C). Altogether, heavy rainfall during winter crop especially in these crucial stages affected significantly the broodlac yield (Fig. 2A). Heavy rainfall during winter is unfavourable for lac crop (Bhagat and Mishra, 2011). Ghosal, 2012a reported that lac yield decreased significantly with intensity of rainfall, number of consecutive weeks with 50 mm rain, amount of rainfall received after sexual maturity etc. The humidity of the atmospheric air is also an important factor in determining the limit of quality of lac-insects. Average relative humidity up to 80% during crop period of 2013-14 favoured lac production (Fig. 2D). An optimum temperature range of 24°C to 27°c has been found the best in lac culture (Bhagat and Mishra, 2011). Comparatively higher rainfall after male emergence (in September) might have created favourable condition for the growth of sooty mold (biotic factor) and caused considerable damage to lac crop (Ghosal, 2012b). Saxena and Murti, 2014 predicted incidence of aphid population on mustard in low maximum, minimum temperature and high relative humidity. High average maximum temperature of 27.2^{0}C during crop period of 2012-13 significantly reduced broodlac yield (Fig. 2E). Similarly, high average minimum temperature of 15^{0}C during the winter crop of 2012-13 affected adversely on broodlac yield (Fig. 2F). There is always a minimum and maximum limit of effective temperature, known as 'temperature threshold' within which the organism became active. Beyond this limit, the organism becomes dormant and still beyond; the dormancy is terminated to death. Extreme heat and cold might be injurious to health but it may also be due to physiological activity of the host-plant, which is adversely affected by drought condition. The scarcity of food and moisture stress is the main reason of such a heavy mortality of lac insects indicating an indirect effect of temperature rather than direct effect (Bhagat and Mishra, 2011). All these weather parameters had significant effect on growth and development of lac insects on 24 fruit cultivar of *ber*.

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