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Climate change: Effect of weather parameters on production of summer season crop of *rangeeni* strain of Indian lac insect, *Kerria lacca* (Kerr) at Ranchi, Jharkhand

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ABSTRACT

Lac is a natural resin secreted by tiny insects, mainly *Kerria lacca* (Kerr) (Hemiptera: Coccoidea: Tachardiidae). The insect is cultured on tender shoots of several plants called lac-hosts. It derives its nutrition by sucking the phloem sap of the host-plant. *Rangeeni* and *kusmi* are two strains of the lac insect; each completing two cycles in a year - the *rangeeni* strain produces summer season (*baisakhi*) and rainy season (*katki*) crop whereas, *kusmi* strain produces winter season (*aghani*) and summer season (*jethwi*) crop in a year. Jharkhand is a major lac producing state in the country and India is the major lac exporting and importing country in the world. Contribution of the *rangeeni* strain has showed a sharp declining (151.5 tons/year) trend over the years whereas, converse is true for the *kusmi* strain that has shown the increasing (+214.5 tons/year) production trend during 1980-81 to 2012-13 period. Contribution of the *rangeeni* crops in total lac production in Jharkhand has come down to 18-20% during 2008-09 to 2012-13 from 82-88% during 1988-89 to 1997-98. Therefore, performance of the *rangeeni* strain of lac insect, especially in Ranchi, Jharkhand in relation to changes in weather parameters was analyzed. Analysis of weather data revealed that winter months (December and January) have become colder and pre and post winter months (November and February) warmer. These changes in climatic parameters have implication in lac cultivation as it is a critical period of lac insect development (pre-sexual maturity) during the summer season crop. Monsoon and winter rainfall spells and magnitude were also found to affect lac crop performance. Effect of abiotic factors (temperature, rainfall and relative humidity) was correlated with lac production of *rangeeni* crop during 2006-07 to 2012-13. It was observed that maximum temperature had a significantly negative (-0.911* and -0.837*) and RH a positive significant (0.850* and 0.800*) correlation with lac production during the critical crop period (March and April) of development in summer season (*baisakhi*) crop whereas, during rainy season (*katki*) crop, minimum temperature had a significant negative (-0.765*) correlation with lac production. The vulnerability level of lac insect is high during and prior to sexual maturity stage in summer crop, thus post-winter season is the critical period for lac insect survival and any undesired variability in weather parameters in this stage can impact adversely on lac productivity.

Keywords: *Kerria lacca,* climate change, weather parameters, lac production

INTRODUCTION

Lac is a natural resin secreted by tiny insects, mainly *Kerria lacca* (Kerr) (Hemiptera: Coccoidea: Tachardiidae) (Chamberlin, 1923; Varshney, 1977). The insect is cultured on tender shoots of several plants called lac-hosts. It derives its nutrition by sucking the phloem sap from the host-plant. There are two bivoltine strains of the lac insect *viz.*, *rangeeni* and *kusmi*; each completing two cycles in a year - the *rangeeni* strain produces summer season (*baisakhi*) and rainy season (*katki*) crops whereas, *kusmi* strain produces winter season (*aghani*) and summer season (*jethwi*) crops in a year. The lac insect being phyto-succivorous and sedentary in nature cannot, therefore, resort to avoidance behaviour towards direct sunlight, heat, rains, etc. Since it is parasitic on the plant, its survival is also dependent on the health of the plant, which in turn can be affected by climatic vicissitudes. Deviations from the normal patterns of climatic parameters are seen more commonly in recent years affecting cropping and agricultural productivity; lac is no exception to this. Like any other agricultural crop, lac culture is vulnerable to insect pests and vagaries of weather as it remains permanently attached to host plants from which it derives its nutrition.

Jharkhand is a major lac producing state in the country and India is the major lac exporting and importing country in the world. National lac production of the country is the summation of four crops, contributed by two crops each of *rangeeni* and *kusmi* strains annually. Earlier, *rangeeni* crops contributed more in total lac production; however, the trend has changed in recent years. In Jharkhand, contribution of the *rangeeni* crops in total lac production has fallen to 18-20% during 2008-09 to 2012-13 from 82-88% during 1988-89 to 1997-98 periods, clearly indicating Jharkhand as the worst affected state in *rangeeni* lac cultivation in recent years.

There has been a significant rise in the frequency of extreme weather events in recent years affecting the lac production in general and summer *rangeeni* lac crop in particular. The summer crop of *rangeeni* has been showing unusually high mortality rate during recent years, especially during January-March, which occurs before the sexual maturity stage of the lac insects. This had resulted in crop failures. Predictive nature of certain climatic factors on the survival and performance of lac insects affecting the production is evident (Ramani, 2010). Therefore, performance of the the *rangeeni* strain of lac insect, especially in Ranchi, Jharkhand in relation to changes in weather parameters was analyzed.

MATERIALS AND METHODS

This study was conducted at ICAR-Indian Institute of Natural Resins and Gums (IINRG), Ranchi, Jharkhand at an altitude of 650 m above mean sea level, 23°23" N latitude and 85°23" E longitude during the period August, 2011 to September, 2014 under National Initiative on Climate Resilient Agriculture (NICRA) (Indian Council of Agricultural Research). Lac production data was collected from the bulletin of IINRG, Ranchi: Lac, Plant Resins and Gums Statistic - At a Glance. Weather parameters *viz.*, temperature (Maximum and Minimum), relative humidity (Minimum and Maximum) and rainfall were collected from Argo-Meteorology Unit of IINRG, Ranchi. Strain-wise and crop-wise national lac production was analyzed for the period (1980-81 to 2012-13) and analysis of weather data of Ranchi was done for the period (1984-2012). Weather parameters were correlated with lac production data for the period 2006-07 to 2012-13 and finally a comparison was made between good summer season *(baisakhi)* crop producing year (2005) and the poor summer lac producing year (2008) and were also correlated with relative humidity and temperature. The data were analyzed using statistical package SPSS version 11.5.

RESULTS AND DISCUSSION

Lac production scenario and weather parameters

National lac production trends in India during 1980-81 to 2012-13 showed inconsistence and fluctuating production (Fig. 1a). Contribution of the *rangeeni* strain has showed a sharp declining (151.5 tons/year) trend over the years whereas, converse is true for the *kusmi* strain that has shown the increasing (+214.5 tons/year) production trend during 1980-81 to 2012-13 period (Fig. 1a). About 25-30 years ago, major contribution in total lac production came from the *rangeeni* strain (80-85%) in comparison to 15-20% by *kusmi* strain; but in recent years, relative contribution of the *kusmi* crops has been significantly increased (52%). This change is attributed to promoting the *kusmi* lac production, especially on *ber* during winter season (*aghani*) crop and drastic decline in the production of summer season lac crop of the *rangeeni* strain, which used to be the major lac crop. Analysis of the relative contribution of both the *rangeeni* crops revealed a sharp decline in total production of *baisakhi* crop (180 tons / year), whereas rainy season (*katki*) crop showed an increasing (28.6 tons / year) trend (Fig. 1b). Further, analysis of relative contribution of *rangeeni* and *kusmi* crops in total lac production of the country and the three states (Jharkhand, Madhya Pradesh and West Bengal) during last 25 years (1988-89 to 2012-13) revealed that the *rangeeni* crops contributed more than 80% to annual national lac production till 1997-98 which decreased sharply and the figure stands only about 48% (2008-09 to 2012-13). In Jharkhand, contribution of the *rangeeni* strain was about 82-88% in total lac production during 1988-89 to 1997-98 which fell to 18-20% during 2008-09 to 2012-13 period (Fig. 1c), clearly indicating Jharkhand as the worst affected state in *rangeeni* lac cultivation in recent years. Therefore, the performance of the *rangeeni* strain of lac insect, especially in Ranchi, Jharkhand in relation to changes in temperature (maximum and minimum), relative humidity (maximum and minimum) and rainfall was analyzed (Fig. 2). Analysis of weather data revealed that the winter months (December and January) have become colder and pre and post (November and February) winter months warmer. Monsoon and winter rainfall spells and magnitude also

found to be associated with lac crop performance. These changes in climatic parameters have implication in lac cultivation as it is a critical period of lac insect development (pre-sexual maturity) during the summer season crop. The decline in summer (*baisakhi*) crop production and improvement in that of rainy (*katki*) season crop has been shown to be associated with concomitant changes in certain weather parameters during critical growth period of lac insects. Ramani (2009) also observed a negative trend of summer crop and a positive trend for the rainy season lac crop production.

may also change gender ratios in some pest species such as thrips and potentially affecting reproduction rates (Lewis 1997). Mean annual relative humidity and rainfall decreased by 6.2% and 64.6 mm respectively. The months of January to June became more dry (11.6%) during the period and January to June got more rainfall while July-December got lesser rainfall than the normal. Complete mortality took place in the surviving population of lac insects in the month of April on both *ber* and *palas* during *baisakhi* crop 2013-14 at IRF, IINRG, Ranchi probably except for November, wherein, the gap was reduced. Temperature is one of the key factors that can impact insect physiology and development directly or indirectly through the physiology or existence of hosts. Depending on the development "strategy" of an insect species, temperature can exert different effects (Bale *et al.*, 2002). Some insects take several years to complete one life cycle and these insects (cicadas, arctic moths) tend to moderate temperature variability over the course of their life history. It has been estimated that with a 2°C temperature increase insects might experience one to five additional life cycles per season (Yamamura and Kiritani, 1998). Temperature

Table 1. Correlation of weather parameters with lac production in summer season (*baisakhi*) crop during 2006-07 to 2012-13

Crop / Month	Temperature (°C)		Total rainfall(mm)	Relative humidity (%)	
	Maximum	Minimum		Maximum	Minimum
Summer *season (Baisakhi)* crop	-0.684(30.0)	-0.379(14.0)	0.923**(191.0)	0.902** (64.0)	0.857* (48.0)
December	-0.530(25.4)	-0.365(7.3)	0.415(4.6)	0.855*(70.9)	0.514(52.3)
January	-0.263(23.5)	-0.489(7.2)	0.022(16.5)	-0.031(69.8)	0.203(46.7)
February	-0.273(28.0)	0.324(11.1)	0.430(13.4)	0.556(65.5)	0.519(48.9)
March	-0.911* (32.8)	-0.272 (15.7)	0.454(20.4)	0.649(52.3)	0.850* (39.0)
April	-0.837* (37.4)	-0.564 (20.4)	0.690(20.0)	0.711(48.1)	0.800* (35.8)
May	-0.362 (38.4)	0.366 (22.1)	0.286(67.8)	0.362(56.9)	0.383(42.4)

** P<0.01, * P<0.05, Figures in parentheses are mean values for the period

Analysis of weather data of Ranchi, Jharkhand

Weather parameters *viz.*, temperature, relative humidity and rainfall were analyzed (Fig. 2) for the period 1984-2012 of Ranchi, Jharkhand which revealed that the average mean temperature increased by 0.23°C at Ranchi; February to July months became hotter while December and January colder during this period. Difference between the mean minimum and the mean maximum temperature widened during January to May while not much difference was observed during the rest of the period

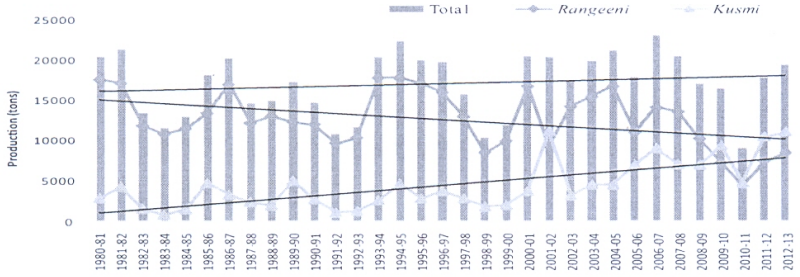

Fig. 1a: National lac production and strain-wise contribution (1980-81 to 2012-13)

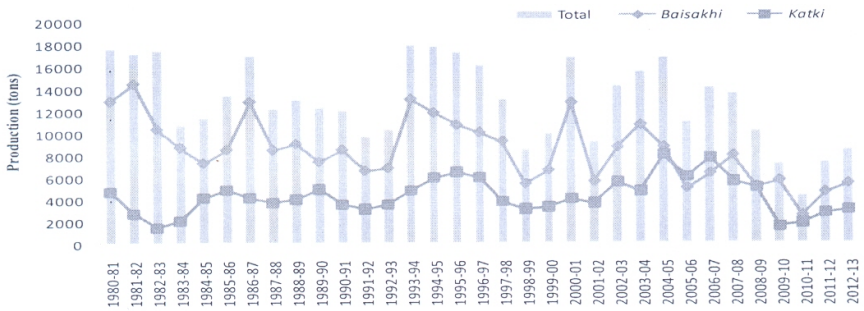

Fig. 1b: Crop-wise lac production of *rangeeni* strain (1980-81 to 2012-13)

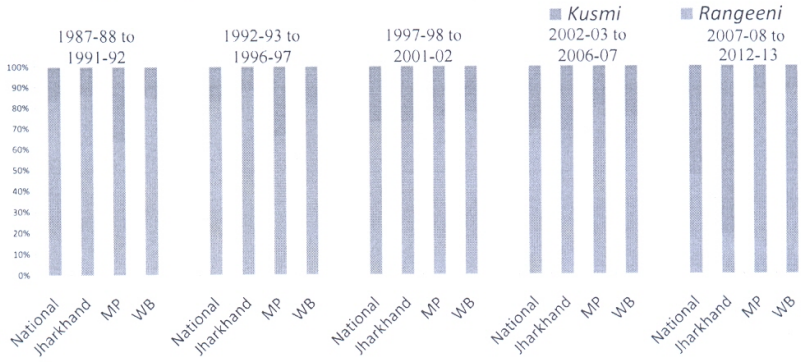

Fig. 1c: Relative contribution of lac crops for the period (1988-89 to 2012-13)

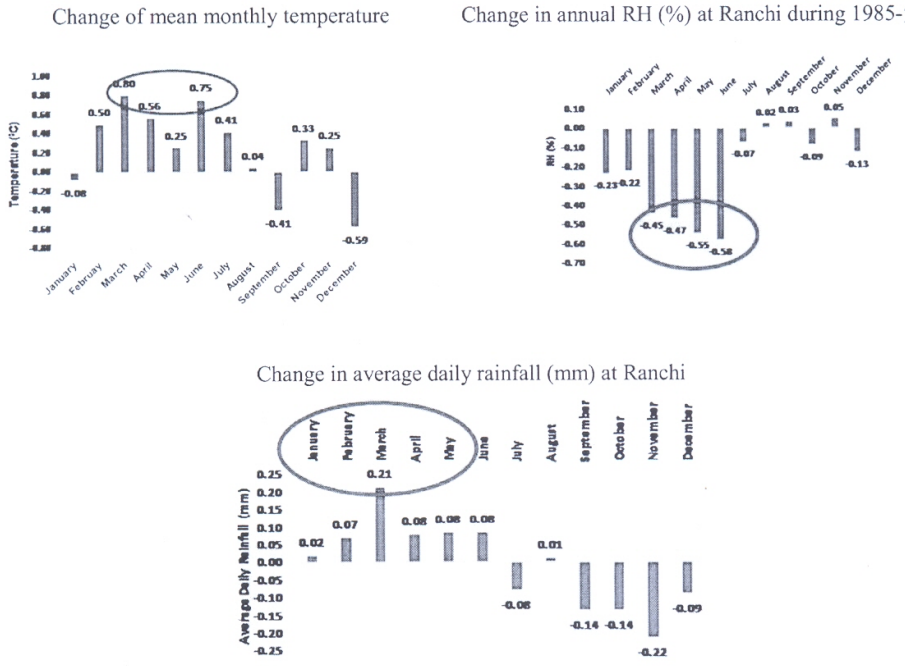

Fig. 2: Change in weather parameters at Ranchi during 1984-2012

Table 2. Correlation of weather parameters with lac production in rainy season (*katki*) crop during 2006-07 to 2012-13

Crop / Month	Temperature (°C)		Total rainfall(mm)	Relative humidity (%)	
	Maximum	Minimum		Maximum	Minimum
Rainy season *(Katki)* crop	-0.575(31.0)	0.015(21.5)	0.485(1254.1)	0.361(81.6)	0.525 (72.4)
July	-0.387(30.8)	-0.023(22.7)	0.673(318.8)	0.490(86.8)	0.611(78.8)
August	0.148(30.1)	-0.765*(22.2)	0.127(361.2)	0.585(90.1)	0.706(80.5)

** P<0.01, * P<0.05, Figures in parentheses are mean values for the period

due to drastic changes in weather parameters e.g. heavy rainfall (115.2mm, Feb, 2014) received during sexual maturity period (Mohanasundaram and Monobrullah, 2014). Some insects are sensitive to precipitation and are killed or removed from crops by heavy rains, this consideration is important when choosing management options for onion thrips (Vincent *et al.*, 2003). One would expect more frequent and intense precipitation events forecasted with climate change to negatively impact these insects (Mavean and Dixon, 2001).

Analysis of lac production data vs weather parameters

Effects of abiotic factors (temperature, rainfall and relative humidity) were correlated with lac production of *rangeeni* crop during 2006-07 to 2012-13 (declining years). It was observed that maximum temperature had a significantly negative (-0.911* and -0.837*) correlation and minimum RH a significant positive (0.850* and 0.800*) correlation with lac production during critical development period of the crop (March and April) during summer season (Table 1). During rainy season, minimum temperature had a significant negative (-0.765*) correlation with lac production (Table 2). The vulnerability level of lac insect was high during and prior to sexual maturity stages in summer season (*baisakhi*) crop and at crop maturity stage in rainy season (*katki*) crop. Thus, post-winter and mid monsoon were analyzed to be critical periods for lac insect survival and any variability in weather parameters during this period could impact lac productivity adversely. Performance of the *rangeeni* form of *K. lacca* in India especially in Jharkhand when analyzed in relation to long-and-short term changes in climatic parameters (Ramani, 2009 and 2010), it was reported that the concomitant changes in certain weather parameters during critical period of lac insects attributed to the decline in summer crop production.

Comparison between good and bad lac producing years

A comparison between good summer season *(baisakhi)* crop producing year (2005) and poor producing year (2008) showed, positive correlation of RH with summer production (Fig. 3) and an inverse relationship with monthly mean temperature during January to April (critical growth stage of lac insect). High rainfall during January month showed negative impact on summer lac crop. Decrease in mean relative Humidity particularly during January to June (11.6%) had also negative impact on lac production. Low temperature during winter months and high temperature during post winter and summer months was recorded in bad year (2008) (Fig. 4).

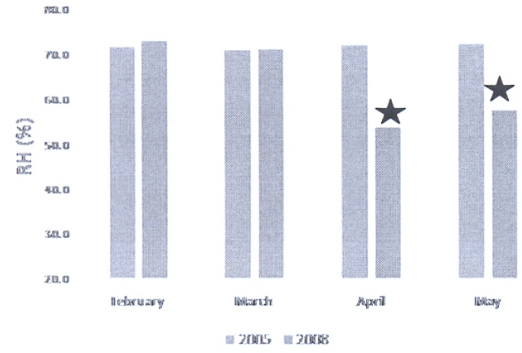

Fig. 3. Comparison of RH during critical development period during good *v/s* bad lac production years.

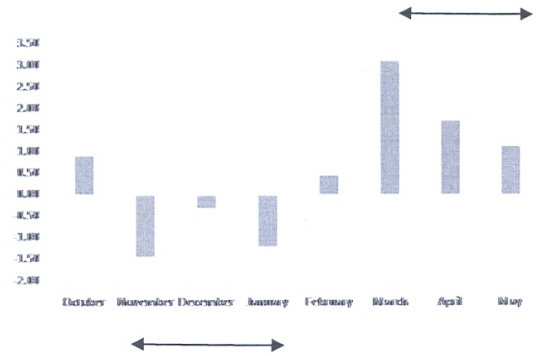

Fig. 4. Average monthly mean temperature difference between the bad and the good lac production years.

CONCLUSION

Lac contribution of *rangeeni* strain showed a sharp decline in total production (151.5 tons per annum) wherein, its relative contribution decreased from 85% to 15 % over a period of last 30 years. A positive correlation of RH with summer season (*baisakhi)* crop production and an inverse relationship with monthly mean temperature during January to April was observed. Very high or poor rain spells during critical growth period negatively effects *baisakhi* production. The weather data analysis of last 28 years for Ranchi revealed increase in annual mean temperature of 0.23^{0}C, decrease in mean RH of 6.2% and decrease in rainfall of 64.6 mm. The increase in gap between mean maximum and mean minimum temperature was evident for last three decades. The current understanding on impact of lac insect performance especially during summer can be reduction in RH concomitant with the rise in temperature, which leads to decreased lac production.

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