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Linking Farmers' Perception of Climate Change to the Changing Agricultural Pest Problems: A Case Study of Cotton Mealybug *Phenacoccus solenopsis* Tinsley in Maharashtra, India

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A B S T R A C T

There is growing global evidence that the changes in climatic conditions are exacerbating the pest problems in agroecosystems, thereby adversely affecting agricultural productivity. The recent example is serious outbreak of polyphagous species of mealybug *Phenacoccus solenopsis* Tinsley witnessed by cotton crop in India and Pakistan during 2005-09. This study investigates farmers' perceptions about changes in climatic variables and incidence of mealybug in cotton. The coping and adaptation strategies of the farmers are linked to a very large extent with their perception about mealybug incidence. The study was carried out in four cotton growing districts distributed among two agro-ecological zones of Maharashtra state of India. The cross sectional research design was used for study. A multistage stratified random sampling procedure was adopted to select districts, villages and farmers. A total of 160 cotton farmers were randomly interviewed from sixteen villages. The Statistical Package for the Social Sciences (SPSS) was used in analyzing the cross sectional data. The findings revealed that there is a significant correlation between farmers' knowledge on climate-mealybug relationship and adoption of appropriate management strategies. The information and knowledge factors like education, farming experience, localite sources and mass media are significantly affecting the perception of mealybug infestation by cotton farmers. It is also felt that there is need for development of appropriate strategies for enhancing farmers' knowledge on climate-pest interactions. The analysis of adaptation practices and constraints at farmer level will help facilitate formulation and implementation of policies appropriate to the climate change adaptation planning.

Introduction

In the recent times agricultural pest scenario is changing more frequently due to rapidly changing cropping environments, consequently the pests of formerly minor importance are assuming status of economically important major pests (Dhaliwal and Koul, 2010). The changes in land use, especially habitat fragmentation and agricultural intensification due to large scale adoption of monocultures, invasive species, pesticide use and global climate change are the major culprits to be blamed for negative impacts on flora and dependent fauna at both temporal and spatial scales (Fand *et al.*, 2012). This may lead to high levels of damage to agricultural crops resulting in significant yield losses, if pest management strategies to cope with the changing situations are not well in place (Estay *et al.,* 2009; Fand *et al.,* 2014).

Cotton ecosystem in India had witnessed a phenomenal change in pest scenario after the introduction of commercial transgenic Bt cultivars from 2002 onwards. Presently area under Bt cotton in India exceeds 92% of the total cotton area (Kranthi, 2013). Bt cotton has played a key role in suppressing destructive bollworm pest complex of cotton, thereby improving the cotton yields. However, recently management of sap feeders has become a critical issue in Bt cotton, as the cultivars used for developing Bt transgenics succumb to the attack of sucking insect pests. Due to suppression of major niche competitors *i.e.* bollworms, the sucking pests like whiteflies, thrips, jassids, mealybugs, aphids and mirids which were minor pests in cotton ecosystem are assuming status of major pests, thereby limiting the yield potential of Bt cotton (Kranthi *et al.,* 2009).

The cotton mealybug *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) is one such recent example known to cause large scale epidemics in India during 2005-09 leading to 30 to 60% losses in yield of both Bt and non-Bt cotton in various parts of the country (Dhawan *et al.,* 2007; Jhala *et al.*, 2008; Nagrare *et al.,* 2009). It was previously not reported to occur in India (Varshney, 1985), and thus supposed to be an invasive pest (Fand and Suroshe, 2015). Since its first occurrence in 2005 in North-West Gujarat State (Jhala *et al.*, 2008), it is now found throughout the cotton areas of India (Nagrare *et al.,* 2009). *P. solenopsis* is widespread in almost 24 countries in the world and infests over 200 plant species which includes both cultivated and wild flora (Fand and Suroshe, 2015).

Presently, *P. solenopsis* is no more a serious problem in India, however its infestation is confined to an endemic form in almost all the areas where it was earlier reported to cause havoc. A reasonably good blend of natural enemies both predators and parasitoids (Fand *et al.*, 2010a, b; 2011; Fand and Suroshe, 2015) have been reported to regulate the natural populations of *P. solenopsis*. Despite this, one cannot overlook the lessons learnt from the past episode of *P. solenopsis* outbreak making deranged the entire cotton economy of country. Looking at the history of pest problems and their management in India or elsewhere, it has apparently been found that majority of pest problems are being addressed only when the insects attain pest status over large areas and assumes an epidemic form. This further resulted in lack of preparedness to combat the emerging pest problems timely. Literature reports on *P. solenopsis* occurrence held mostly from tropical and subtropical cropping areas of the world, where the warmer conditions and year round availability of food plants favour its spread and abundance (Fand and Suroshe, 2015). According to the report of Intergovernmental Panel on Climate change (IPCC, 2013), tropical and subtropical areas are more likely to be hotter due to future climate change. Considering its highly polyphagous nature, invasiveness and rapid spread across vast geographical areas within a short period of time, one cannot circumvent the possibility that *P. solenopsis* may assume an epidemic form in future due to predicted global warming and changed cropping environments.

The vast majority of empirical studies have been conducted to understand the bioecology and population dynamics of *P. solenopsis* under varied environmental conditions

(Dhawan *et al.,* 2007; Vennila *et al.,* 2010; Nagrare *et al.,* 2011; Prasad *et al.,* 2012; Fand *et al.,* 2014a,b,c), and to evolve technological alternatives for its management (Fand *et al.,* 2010a,b; 2011; 2012; Nagrare *et al.,* 2011; Suroshe *et al.,* 2014). Based on comprehensive temperature-dependent phenology model employed in a geographic information system, Fand *et al.,* (2014a,b) provided a detailed analysis of climate change impact on the future distribution and damage potential of *P. solenopsis* in cotton growing areas of India and also the world at large. However, the socio-economic studies that focus on understanding the vulnerability, knowledge level, behavior and adaptive capacities of cotton farmers to cope with emerging and re-emerging pest problems under changing cropping environment and climatic scenarios are practically nil. While conducting empirical population studies on *P. solenopsis* in the context of looming climate change, the authors strongly felt a need for understanding the farmers' perception of climate change and changing agricultural pest scenario in order to improve their decision making ability and adaptive capacity to cope with changed situations. The adverse consequences of climate change may have direct bearing on the livelihood of the rural poor as their survival is directly linked to outcomes from food production systems. The coping and adaptation strategies of the farmers are largely linked with their perception on climate change and its impacts. Therefore, the farmers need to recognize the changes in climate already taking place in their areas and undertake appropriate measures towards adaptation.

The present study was undertaken to assess the vulnerability, knowledge level and adaptation behavior of farmers to the insect-pest infestations under changing climatic conditions. The implications of the present work are multifaceted and include an assumption that climate change driven changes in populations of insect-pests and resultant crop losses will have serious socio-economic impacts on rural farmers whose livelihoods depend directly on the agriculture. The outcome of the present study will assist researchers and policy makers to identify the extension gap and to develop and communicate reliable technologies to overcome future losses due to insect pests in general and *P. solenopsis* in particular. Our approach can be readily applied to other insect pests and cropping systems, to assess the farmers' adaptive capacities and to devise adaptive strategies to cope with the impact of climate change on future pest incidence.

Materials and Methods

Survey design and study area

A cross sectional household survey was carried out using a standard (pre-tested) structured questionnaire applying qualitative methods of data collection and analysis. The questionnaire assessed demographic characteristics, farmers' perceptions of changes in climatic conditions as observed in the form of rise in temperature, changes in rainfall pattern and changing scenario of occurrence of pest outbreaks in crops, how these changes have affected their farming activities and what are the adaptive measures they have applied to cope with the changed situations during last 10 years. Farmers' interviews were conducted in four cotton growing districts distributed among two agro-ecological zones of Maharashtra state of India (Table 1). District selection was based on a representation of the major cotton growing area of Maharashtra state where significant losses in cotton yield occurred due to *P. solenopsis* infestation. A multi-stage, stratified random sampling method was used to select the districts and the villages, which was guided by knowledge of local leaders and ease of accessibility. One respondent per household was considered for the study. A total of 160 farmer households were interviewed individually between August and October 2014. A total of 160 respondents were distributed in 16 villages and four districts. Present study was based on qualitative variables of cotton farmers. Hence, size of different category respondents was selected based on their population involved in agriculture *i.e.* share in operational holding. Sixty-four farmers each from marginal and small category and 16 farmers each from medium and large category were interviewed.

Empirical model of farmers' perception

The summary statistics of explanatory variables used in mealybug perception model are presented in Table 2.

Question to be answered

What important factors affect farmers' perception of changing mealybug infestation due to climatic changes?

All the potential predictors were entered simultaneously into a multiple regression analysis (Cohen *et al.*, 2003) to see the variables those produce unique effect upon the dependent variable. The set of potential predictor variables specified to formulate a model were as below:

$$Y' = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 + e \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where, Y' is predicted value of Y; a is intercept of Y; the parameters $b_1, b_2, b_3, b_4, b_5, b_6, b_7$ and b_8 are the estimates of predictors $X_1, X_2, X_3, X_4, X_5, X_6, X_7$ and X_8, respectively; e is the error

The model assumed non existence of multicollinearity among independent variables (collinearity exists when Tolerance < 0.1; VIF > 10.0) (Germa and Marc, 2000). However, it was assumed that positive relationship exists between each predictor and dependent variable.

Henry Garrett ranking technique

Henry Garrett ranking technique (Garett and Woodworth, 1969) was used to evaluate the constraints faced by the cotton farmers. The farmers were asked to rank the given problems according to the magnitude of problem. The order of merit given by the respondents was converted into ranks by using the following formula.

$$\text{Percentage position} = \frac{[(R_{ij} - 0.5)100]}{N_j} \quad \ldots\ldots(2)$$

Where, R_{ij} is rank given for i^{th} item by j^{th} individual; and N_j is number of items ranked by j^{th} individual.

The percentage position of each rank thus obtained was converted into scores by referring to the table given by Garett and Woodworth (1969). Then for each factor the scores of individual respondents were added together and divided by the total number of respondents for whom the scores were added. These mean scores for all the factors were arranged in the order of their ranks and inferences were drawn.

Statistical analysis

Data was analyzed using Statistical Package for the Social Sciences (SPSS), version 15.0. Frequencies and means were compared to enable the description of farmers' perceptions about changes in climatic variables and plant health/pest incidence as well as the coping strategies being practiced to mitigate the adverse effects. Correlation, regression and Garrets ranking technique were used for data analysis and interpretation. T-statistic was used for explanation of statistical significance of variables. F-statistic was applied to find out overall strength of model.

Results and Discussion

Knowledge level of farmers about cotton mealybug

The results of the present study revealed that majority of the farmers from the study area were able to identify the major insect pests of cotton however, the proportion of farmers adopting appropriate and timely measures against their management was very low. Based on the responses of the farmers interviewed, it was observed that 73.5% of the respondents could identify the pest problems in cotton, however only 27.5% of them could adopt the appropriate management strategies. About 86.3% of the respondents were able to identify mealybug infestations in cotton however, only 35.0% could follow appropriate strategies for its management (Figure 1). Among the farmers those perceived mealybug infestation, 95.7 per cent recognized mealybugs even at less than 10 per cent infestation level (Figure 2). At present situations, 98.6% farmers observed that mealybug could account for only low to medium (5-15%) losses in cotton yield. This indicates that presently the mealybug infestations in cotton are relatively at moderate levels (Figure 3).

Farmers' perception about impact of climatic factors on mealybug incidence

The farmers' knowledge and understanding of pest behavior under projected climatic changes are crucial in framing and implementing appropriate pest management strategies. Hence, knowledge of cotton growers about changing mealybug incidence in relation to climatic factors was evaluated. About 28.8% respondents perceived positive correlation between temperature and mealybug population, whereas 31.2% and 3.8% farmers perceived negative relationship with rainfall and relative humidity, respectively (Table 3). The correlations between farmers' knowledge on pest-weather relationship and adoption of appropriate strategies were worked out. The result indicated significant positive correlation between farmers' knowledge on temperature-mealybug relationships and adoption of appropriate strategies. Non-significant correlation between farmers' knowledge on rainfall/humidity-mealybug relationships and adoption of appropriate strategies was observed (Table 4). It means that farmers having knowledge of the influence of climatic factors on mealybug incidence were only proficient in adopting accurate management strategies at right time and vice versa. It was also evident from the farmers' statements while interviewing that they augment monitoring of their cotton fields during periods of high temperature when there is increased risk of mealybug infestation.

The temperature had been reported as one of the major climatic factor affecting incidence of mealybug (Prasad *et al.,* 2012; Fand *et al.,* 2014a). Such types of farmers were also more cautious in promptly initiating measures like pruning and destroying of mealybug infested plants or plant parts at the early stage of infestation, and undertaking timely control measures as soon as possible to prevent further spread of the pest. However, this proportion of knowledgeable farmers is very low (≤30%) and hence, there is an urgent need to sensitize the farmers about the climate change associated changes in incidence of insect pests of major crops in their regions and the different adaptation strategies to cope with the situation. Here, the role of technology transfer is crucial in disseminating the scientific knowledge to the farmers.

Factors that affect perception of mealybug

The mealybug perception model summary is shown in Table 5. The results indicated that the explanatory variables could explain 44.0% variability in mealybug perception by the farmers (R^2=0.44). The fit of the model as tested by F-test was good (F=14.66). The estimated parameters and statistically significant variables explaining perception about mealybug are presented in Table 6. The results indicated that multicollinearity does not exist among the explanatory variables (Tolerance > 0.1; VIF <10). T-test statistics revealed that four of the test variables viz., education, farming experience, localite sources and mass media are statistically significant at 1% level. These four variables had a significant positive relationship with perceiving ability of cotton farmers and undertaking timely management strategies. Thus, more attention of extension agencies is required towards these sources of information to enhance knowledge of farmers about climate change associated changes in incidence of insect pests. Education develops knowledge, skills, beliefs and habits towards perceiving ability of farmers. The longer farming experience of cotton farmers were positively attributed with mealybug perception. However its impact was very less (0.5 %). Similarly Tin and Cheng, 1997 reported that farm efficiency depends primarily on farmers' education rather than experience. The education level of the farm family head had been reported as important factor in determining the ability with which farmers are adopting coping strategies against the climate change (Okonya *et al.,* 2013). Therefore education level of farmers needs to be improved to enhance perception level. Further localite source of information (progressive farmers, neighbours, relatives, friends and family members) was found largest source (92.5%) of information to cotton growers with significant impact (20.7%) on their adoption behaviour. However influence of this is entirely dependent on societal interactions of individual farmers and thus may vary from case to case, the extension agencies have limited role to play here. Byg and Salick (2009) reported that local knowledge and experience help to advance the farmers' understanding of climate change and its impacts on agriculture and thereby improves their decision making ability towards adoption of appropriate measures. In our study, the mass media was observed to have significantly greater influence (34.2%) on farmers' perceptions of cotton mealybug. According to Devaraj and Ravichandran (2014), mass media plays an important role in bringing change in behaviour of farmers by putting across the useful information, which leads to decision making for adoption of appropriate strategies. Therefore highest priority should be given to mass communication media like television, newspaper, etc. to sensitize cotton farmers about climate-insect pest relationships and their management. During survey, the mobile based advisory service was found large but less effective source of information to the farmers. The most of the mobile based advisory services provides text information to the farmers. Hence it needs to be improved with inclusion of pest images in advisory note for easy identification of problem. Majority of farmers (95.7%) perceived mealybug at less than 10% infestation levels, hence only visual images/pictures are adequate to augment farmers' perception and decision making ability.

Extent of adoption of package of practices for mealybug management

Adoption level of farmers, according to scientific package of practices suggested by ICAR-Central Institute of Cotton Research, Nagpur, Maharashtra, India for managing mealybugs on cotton (Kranthi, 2014) is presented in Table 7.

Table.1 Characteristics of the agro-ecological zones (AEZ) selected for study

Agro-ecological zone	Districts	Characteristics of AEZ	Cropping pattern
Central Maharashtra Plateau Zone/ Zone of Assured Rainfall	Amravati Jalgaon, Aurangabad	Rainfall 700 - 900 mm, 75 % rains received in all districts of the zone, black coloured soils derived from basalt rock, major soil types are: vertisols, entisols and inceptisols, Max. temperature 41^{o}C, Min. temperature 21^{o}C	Sorghum and cotton are the predominant crops occupying 33% and 22.55% of gross cropped area, respectively. Other crops include oilseeds, pulses
Western Maharashtra Scarcity Zone	Whole Ahmednagar, parts of Jalgaon and Aurangabad districts	<750 mm rainfall with uncertainty and ill distribution, Bimodal rainfall pattern with two peaks: June-July and September-October, Occurrence of cyclic drought once in every 3-5 years, delayed onset and early cessation of monsoon, major soil type: vertisols, Max. temperature 40^{o}C, Min. temperature 15^{o}C	Rain fed agriculture with cropping pattern based on cereals, oilseeds, pulses, cotton, two main cropping seasons viz., *kharif* and *rabi* due to bimodal rainfall pattern, moderate livestock rearing

Source: http://www.mahaagri.gov.in/CropWeather/AgroClimaticZone.html#sz, Accessed online 21/05/2015

Table.2 Summary statistics of explanatory variables for perception model

Variables	Denotations	Explanation	Mean	Std. dev.
Dependent				
Mealybug perception	Y	Farmer perceive mealybug (if yes 1, otherwise 0)	0.86	0.35
Independent (Sources of knowledge/ information)				
Education	X_1	Education level of farmer (if above A level 1, otherwise 0)	0.69	0.46
Experience	X_2	Farming experience (years; continues)	22.96	14.18
Localite sources	X_3	Progressive farmers/family members/ neighbours/friends/ relatives (if yes 1, otherwise 0)	0.93	0.26
HRD programmes	X_4	Training, workshop, seminar, exhibition, study tour, field day, meeting, etc. (if yes 1, otherwise 0)	0.40	0.49
Mobile advisory services	X_5	Mobile phone SMS, voices and videos based agri. information and advisory services (if yes 1, otherwise 0)	0.66	0.47
Government sources	X_6	Government extension agencies like state agriculture department, KVKs, etc. (if yes 1, otherwise 0)	0.26	0.44
Private sources	X_7	Private extension agencies like Krishi seva kendra, Agri-clinic, private consultants, etc. (if yes 1, otherwise 0)	0.55	0.50
Mass media	X_8	Television, newspaper, radio, etc. (if yes 1, otherwise 0)	0.88	0.33

Table.3 Farmer's perception about mealybug incidence in relation to climatic factors

(Per cent)

Relationship	Temperature	Rainfall	Humidity
Positive	**28.8**	2.5	15.0
Negative	3.8	**31.2**	**3.8**
Don't change	1.2	3.8	8.7
Don't know	66.2	62.5	72.5
Total	**100**	**100**	**100**

Table.4 Correlations between adoption of appropriate strategies and knowledge (n=160)

		Identified and adopt appropriate strategies
Knows perfect relationship between temperature-mealybug	Pearson Correlation coefficient	0.229(**)
	Sig. (2-tailed)	0.004
Knows perfect relationship between rainfall-mealybug	Pearson Correlation coefficient	0.05
	Sig. (2-tailed)	0.527
Knows perfect relationship between humidity-mealybug	Pearson Correlation coefficient	-0.088
	Sig. (2-tailed)	0.268

**Correlation is significant at the 0.01 level (2-tailed)

Table.5 Summary of mealybug perception model

Model	df	R Square	F	Sig.
1	(8, 151)	0.44	14.66	0.00

Table.6 Estimated parameters of mealybug perception model

Variables	Coefficients		t	Sig.	Collinearity Statistics	
	B	Std. Error	B	Std. Error	Tolerance	VIF
Constant	-0.010	0.106	-0.093	0.926		
X_1	**0.238**	0.053	4.528	**0.000**	0.743	1.347
X_2	**0.005**	0.002	3.465	**0.001**	0.918	1.089
X_3	**0.207**	0.084	2.467	**0.015**	0.904	1.106
X_4	0.081	0.056	1.436	0.153	0.584	1.712
X_5	0.053	0.051	1.048	0.296	0.770	1.298
X_6	0.021	0.057	0.365	0.716	0.709	1.411
X_7	0.038	0.049	0.783	0.435	0.740	1.351
X_8	**0.342**	0.073	4.709	**0.000**	0.765	1.307

Table.7 Extent of adoption of package of practices for mealybug management (n=160)

Package of practices	Frequency	Percentage
Cultural practices (Mean)	**66.00**	**41.25**
Early crop termination	26	16.25
Destruction of cotton stalks	140	87.50
Clean cultivation	124	77.50
Border crop	14	08.75
Regular monitoring of the pest	26	16.25
Biological practices (Mean)	**3.33**	**02.08**
Conservation of natural enemies	0	00.00
Releases of predatory lady bird beetles	0	00.00
Releases of parasitoid *Aenasius bambawalei*	0	00.00
Neem extract	20	12.50
Fish oil resin soap	0	00.00
Verticillium lecanii	0	00.00
Chemical practices (Mean)	**70.67**	**44.17**
Less hazardous insecticides	92	57.50
Moderately hazardous insecticides	58	36.25
Highly hazardous insecticides	62	38.75

Table.8 Constraints faced in mealybug management

Constraints	Total Score	Mean Score	Rank
Cultural practices			
Lack of knowledge about importance of border crops	9292	58.08	I
Non-availability of labour on peak season	8254	51.59	II
Lack of knowledge about importance of early crop termination, cotton stalk destructions and clean cultivation	6824	42.65	III
High wages of labour	4966	31.04	IV
More laborious and time consuming	4460	27.88	V
Biological practices			
Lack of knowledge about bio-control agents	8798	54.99	I
Often slow speed of action compared to chemical control	7004	43.78	II
Poor recovery by biological methods	5322	33.26	III
Non-availability of bio-control agents	3662	22.89	IV
Require additional control measures	2654	16.59	V
Require an exact identification of the pest/pathogen	0806	05.04	VI
Selection of pesticides			
High pesticide prices	8362	52.26	I
Incorrect chemical pesticide selection	5498	34.36	II
Non-availability of pesticides at right time	5304	33.15	III
Incorrect pest diagnosis	3206	20.04	IV
Poor market accessibility	2450	15.31	V
Supply of adulterated/low quality products	2192	13.70	VI
Other/Socioeconomic constraints			
Non availability of labours	8260	51.63	I
Weather uncertainties	6314	39.46	II
Lack of skilled labour	5280	33.00	III
High cost of cultivation	4342	27.14	IV
Lack of community based management	2996	18.73	V
Fragmented land holdings	1072	06.70	VI

Fig.1 Knowledge of farmers about major cotton pests

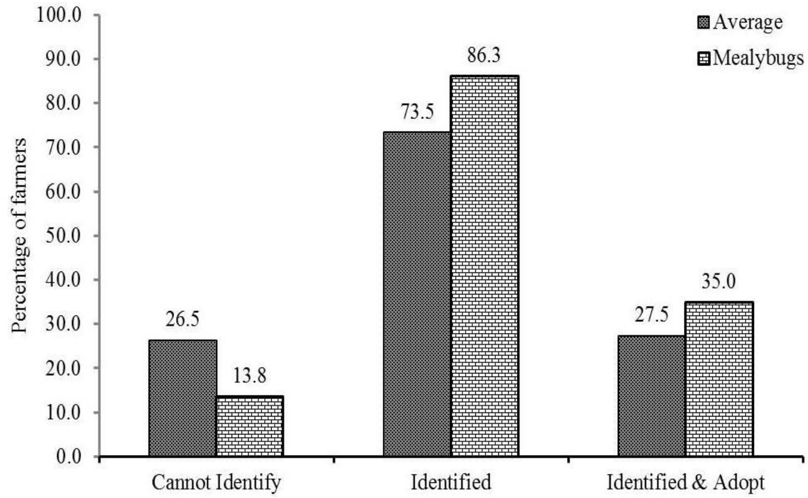


Fig.2 Farmers' recognition of mealybug at different levels of field infestations

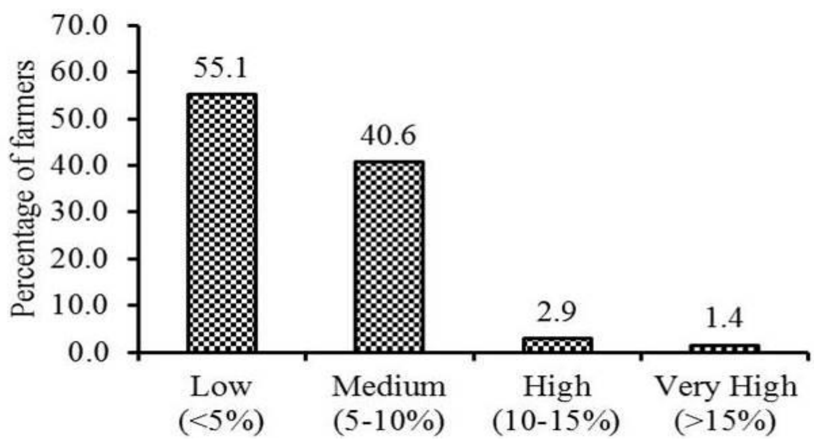
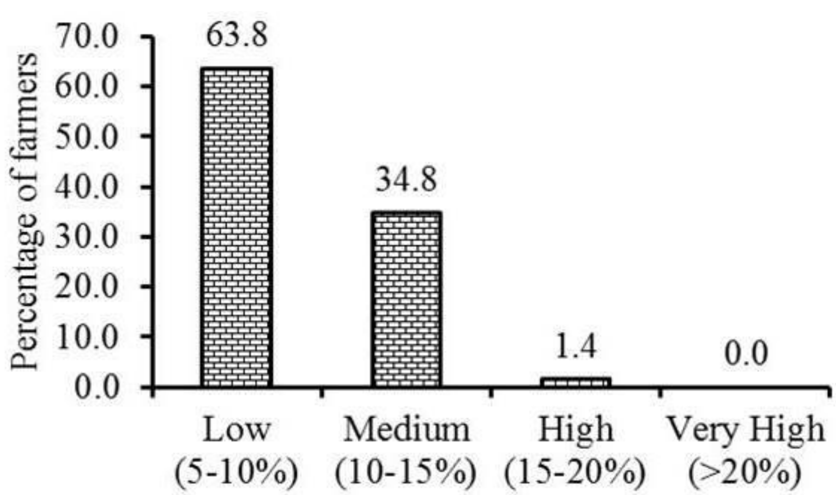


Fig.3 Farmers' perception of cotton yield losses due to mealybug infestation at current situations



Here, adoption means degree of actual use of any recommended package of practice for mealybug management. Chemical methods are the most adopted (44.17%) followed by cultural practices (41.25%), while biological methods are the least adopted one (2.08%). Among the cultural practices, destruction of cotton stalks (87.50%) and clean cultivation (77.50%) are the greatest adopted measures followed by early crop termination (16.25%), pest monitoring (16.25%) and growing of border crops (8.75%). Among biological methods, use of neem extract was found to be 12.50%. The use of other environmentally safe biopesticides and biological control agents like predators and parasitoids is limited only to scientific investigations in laboratory and is field application was found practically nil because of lack of knowledge and awareness among the farmers.

Constraints faced while adoption of package of practices

It could be seen from Table 8 that respondents are facing number of constraints that restricted their action towards adoption of recommended package of practices for mealybug management. Lack of knowledge about importance of border crops that prevented farmers from being adopted ranked first among cultural practices (58.08 garret points). Non-availability of labour during peak season was second cause (51.59 garret points). Lack of knowledge about significance of cultural practices like early crop termination, destruction of cotton stalks and clean cultivation was next in the order (42.65 garret points) followed by high labour wages (31.04 garret points) and more laborious cultural practices (27.88 garret points). The major constraints in adoption of biological practices were observed to be lack of knowledge about bio-control agents (54.99 garret points) followed by often slow speed of action compared to chemical methods (43.78 garret points), poor recovery by biological methods (33.26 garret points), non-availability of bio-control agents at local markets (22.89 garret points), requirement of additional control measures (16.59 garret points) and exact identification of pests (5.04 garret points). High pesticide price (52.26 garret points), incorrect selection (34.36 garret points), timely unavailability (33.15 garret points), incorrect pest diagnosis (20.04 garret points), poor market accessibility (15.31 garret points) and supply of adulterated / low quality products (13.70 garret points) were the major constraints in adoption of appropriate chemical measures. Non availability of labors (51.63 garret points), weather uncertainties (39.46 garret points), lack of skilled labour (33.00 garret points), high cost of cultivation (27.14 garret points), lack of community based management (18.73 garret points) and fragmented land holdings (6.70 garret points) are additional constraints that hamper timely and effective pest management actions. The constraints identified in this study needs to be addressed for higher adoption of recommended package of practices for management of mealybug and other insect pests in cotton. Increased awareness among cotton farmers on use of integrated control measures like border crops, biopesticides, bio-control agents, etc. and use of less hazardous chemicals are vital to eco-friendly pest management.

The findings of the present study show that farmers' knowledge of past experiences matches closely the empirical observations on climate linked pest exacerbation. Therefore, this research has brought out the usefulness of perception studies in development of policies related to climate change adaptation in agroecosystems. As elsewhere in the world (Mertz *et al.,* 2009; Kusakari *et al.,* 2014), the majority of farmers in the study area also believe that the climate has changed considerably over past few decades and this had added owes to the uncertainty in the farm sustainability and profitability. The farmers from study area also expressed a serious concern that the emergence of severe pest problems such as mealybug and other sucking pests have become critical issues in cotton in recent years.

In our earlier studies on temperature-based phenology modeling (Fand *et al.*, 2014a) and climate change impact analyses (Fand *et al.*, 2014b), we have shown that temperatures throughout the tropics and subtropics where the world's cotton growing belt is concentrated, are highly congenial for the population built up and spread of cotton mealybug *P. solenopsis* and there is possibility that the temperature rise predicted under future climatic changes may exacerbate the damage by this pest. Presently, this pest is restricted to endemic form in cotton areas with low-moderate infestations, however considering its highly invasive and polyphagous nature (Fand and Suroshe, 2015), one cannot circumvent its unprecedented flare up as witnessed earlier due to certain changes in agroecosystem environment.

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References

Byg, A. and Salick, J. 2009. Local perspectives on a global phenomenon- climate change in eastern Tibetan villages. Global Environmental Change, 19(2): 156-166.

Cohen, J., Cohen, P., West, S.G. and Aiken, L.S. 2003. Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences. Lawrence Erlbaum Associates, London, 691p.

Devaraj and Ravichandran, P. 2014. A study on the role of information and mass media communication technology among farming community of Mandya district, Karnataka state. Journal of Advances in Library and Information Science, 3(1): 43-46.

Dhaliwal, G.S. and Koul, O. 2010. Quest for Pest Management: From Green Revolution to Gene Revolution. Kalyani, New Delhi, 386p.

Dhawan, A.K., Singh, K., Saini, S., Mohindru, B., Kaur, A., Singh, G. and Singh, S. 2007. Incidence and damage potential of mealybug *P. solenopsis* Tinsley on cotton in Punjab. Indian Journal of Ecology, 34: 110-116.

Estay, S.A., Lima, M. and Labra, F.A. 2009. Predicting insect pest status under climate change scenarios: combining experimental data and population dynamics modelling. Journal of Applied Entomology, 133(7): 491-499.

Fand, B.B., Gautam, R.D. and Suroshe, S.S. 2010a. Comparative biology of four coccinellid predators of solenopsis mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae). Journal of Biological Control, 24(1): 35-41.

Fand, B.B., Gautam, R.D. and Suroshe, S.S. 2010b. Effect of developmental stage and density of *Phenacoccus solenopsis* Tinsley (Homoptera: Pseudococcidae) on the predatory performance of four coccinellid predators. Journal of Biological Control, 24(2): 110-115.

Fand, B.B., Gautam, R.D. and Suroshe, S.S. 2011. Suitability of various stages of mealybug, *Phenacoccus solenopsis* (Homoptera: Pseudococcidae) for development and survival of the solitary endoparasitoid, *Aenasius bambawalei* (Hymenoptera: Encyrtidae). Biocontrol Science and Technology, 21(1): 51-55.

Fand, B.B., Kamble, A.L. and Kumar, M. 2012. Will climate change pose serious threat to crop pest management: A critical review?. International Journal of Scientific and Research Publications, 2(11): 2250-3153.

Fand, B.B., Tonnang, H.E.Z., Kumar, M., Kamble, A.L. and Bal, S.K. 2014a. A temperature-based phenology model for predicting development, survival and population growth potential of the mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae). Crop Protection, 55: 98-108.

Fand, B.B., Tonnang, H.E.Z., Kumar, M., Bal, S.K., Singh, N.P., Rao, D.V.K.N., Kamble, A.L., Nangare, D.D. and Minhas, P.S. 2014b. Predicting the impact of climate change on regional and seasonal abundance of the mealybug *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) using temperature-driven phenology model linked to GIS. Ecological Modelling, 288: 62-78.

Fand, B.B., Kumar, M. and Kamble, A.L. 2014c. Predicting the potential geographic distribution of cotton mealybug *Phenacoccus solenopsis* in India based on MAXENT ecological niche model. Journal of Environmental Biology, 35(5): 973-982.

Fand, B.B. and Suroshe, S.S. 2015. The invasive mealybug *Phenacoccus solenopsis* Tinsley, a threat to tropical and subtropical agricultural and horticultural production systems – A review. Crop Protection, 69:34-43.

Garett, H.E. and Woodworth, R.S. 1969. Statistics in Psychology and Education. Vakils, Feffer and Simons Ltd., Bombay, 491p.

Germa, C. and Marc, S. 2000. Collinearity, heteroscedasticity and outlier diagnostics in regression. Do they always offer what they claim? pp. 79-94. Ferligoj, A. and A. Marvar (eds.). New Approaches in Applied Statistics. MetodoloskiZvezki, Slovenia. 249p.

IPCC, 2013.in: Stocker, T.F., Qin, D., Plattner, G.K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V., Midgley, P.M. (Eds.), Climate Change-The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, United Kingdom and New York, pp. 1535.

Jhala, R.C., Bharpoda, T.M. and Patel, M.G. 2008. *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae), the mealybug species recorded first time on cotton and its alternate host plants in Gujarat, India. Uttar Pradesh Journal of Zoology, 28(3): 403-406.

Kranthi, K.R. 2013. Testing seed quality of Bt. cotton, Cotton Statistics & News, Cotton Association of India, No. 29, 15 October 2013.

Kranthi, K.R. 2014. Package of practices for managing mealybug on cotton. https://www.icac.org/tis/regional_networks/asian_network/meeting_5/documents/papers/papkranthikr.pdf/ (accessed 15.01.14).

Kranthi, K.R., Kranthi, S., Ramesh, K., Nagrare, V.S. and Barik, A. 2009. Advances in cotton IPM. http://www.cicr.org.in/research_notes/ip m1.pdf./ (accessed 06.08.16).

Kusakari, Y., Asubonteng, K.O., Jasaw, G.S., Dayour, F., Dzivenu, T., Lolig, V., Donkoh, S.A., Obeng, F.K., Gandaa, B. and Kranjac-Berisavljevic, G. 2014. Farmer-perceived effects of climate change on livelihoods in Wa West District, Upper West Region of Ghana. Journal of Disaster Research, 9(4): 516–528.

Mertz, O., Mbow, C., Reenberg, A. and Diouf, A. 2009. Farmers' perceptions of climate change and agricultural adaptation strategies in rural Sahel. Environmental Management, 43(5): 804–816.

Nagrare, V.S., Kranthi, S., Biradar, V.K., Zade, N.N., Sangode, V., Kakde, G., Shukla, R.M., Shirave, D., Khadi, B.M. and Kranthi, K.R. 2009. Widespread infestation of the exotic mealybug species, *Phenacoccus solenopsis* (Tinsley) (Hemiptera: Pseudococcidae), on cotton in India. Bulletin of Entomological Research, 99(5): 537-541.

Nagrare, V.S., Kranthi, S., Kumar, R., Jothi, B.D., Amutha, M., Deshmukh, A.J., Bisane, K.D. and Kranthi, K.R. 2011. Compendium of cotton mealybugs. Central Institute for Cotton Research. P. B. No 2, Shankar Nagar P. O., Nagpur - 440010.

Okonya, J.S., Syndikus, K. and Kroschel, J. 2013. Farmers' perception of and coping strategies to climate change: evidence from six agro-ecological zones of Uganda. Journal of Agricultural Science, 5(8): 252-263.

Prasad, Y.G., Prabhakar, M., Sreedevi, G., Rao, G.R. and Venkateswarlu, B. 2012. Effect of the temperature on development, survival and reproduction of the mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) on cotton. Crop Protection, 39: 81-88.

Suroshe, S.S., Gautam, R.D. and Fand, B.B. 2014. Safety evaluation of insecticides on adult Aenasiusbambawalei Hayat (Hymenoptera: Encyrtidae), a solitary endo-parasitoid of the mealybug, *Phenacoccus solenopsis* Tinsley. Indian Journal of Entomology, 76(3): 224-228.

Tin, N. and Cheng, E. 1997. Productivity gains from farmer education in China. Australian Journal of Agricultural and Resource Economics, 41(4): 471-497.

Varshney, R.K. 1985. A review of Indian Coccids (Homoptera: Coccoidea). Oriental Insects, 19(1): 1-101.

Vennila, S., Deshmukh, A.J., Pinjarkar, D., Agarwal, M., Ramamurthy, V.V., Joshi, S., Kranthi, K.R. and Bambawale, O.M. 2010. Biology of the mealybug, *Phenacoccus solenopsis* on cotton in the laboratory. Journal of Insect Science, 10: 1-9.

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