

Impact of weather on brood area, pollen area and nectar area of artificially and naturally inseminated colonies of *Apis mellifera* L. and *Apis cerana indica* F.

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Comment [PM2]: Impact of weather parameters on foraging area of artificially and naturally inseminated colonies of *Apis mellifera* L. and *Apis cerana indica* F.

ABSTRACT

Experiment conducted to study the impact of weather parameters during April'16 to March'18 on brood area, pollen area and nectar area of artificially inseminated and naturally inseminated colonies of *Apis mellifera* L. and *Apis cerana indica* F. during April'16 to March'18. Investigation revealed that there was significant negative correlation of brood area ($r = -0.57$ in both AI and NI colonies) of *A. mellifera* L., during the year 2016-17 and nectar area ($r = -0.71$ in AI and $r = -0.70$ in NI colonies) with maximum temperature and maximum relative humidity, respectively. Whereas, pollen area was found to have having significant positive correlation with bright sunshine hours (0.83 in AI and 0.84 in NI colonies) and significant negative correlation with maximum temperature ($r = -0.89$ in AI and $r = -0.88$ in NI colonies) and total rainfall ($r = -0.57$ in AI and $r = -0.60$ in NI colonies). Again in During 2017-18, pollen area showed positive significant correlation with maximum relative humidity ($r = 0.57$ in AI and $r = 0.60$ in NI colonies) and negatively significant correlation with maximum temperature ($r = -0.87$ in AI and $r = -0.90$ in NI colonies) and total rainfall ($r = -0.74$ in AI and $r = -0.76$ in NI colonies). Nectar area was found to have having negatively significant correlation with maximum relative humidity ($r = -0.74$ in AI and $r = -0.77$ in NI colonies). The correlation study of However, *A. c. indica* F. was with weather parameters in the year 2017-18, revealed significant negative correlation of brood area ($r = -0.58$ in AI and $r = -0.60$ in NI colonies) and nectar area ($r = -0.66$ in AI and $r = -0.70$ in NI colonies) with maximum relative humidity during 2017-18.

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Key words: Correlation, Weather, *A. mellifera* L., *A. c. indica* F., brood area, pollen area, nectar area, temperature, relative humidity and rainfall

INTRODUCTION

Weather influences the growth and development of honeybees. The weather parameters like temperature, relative humidity, rain fall, number of rainy days and sunshine hours might have positive or negative influence on developmental parameters of

honeybees. The important developmental parameters of honeybees are brood rearing activity, pollen and nectar store. Weather conditions affect influences forage availability and thereby directly and indirectly influence honey bee health. Weather factor conditions can affect the onset and decline of specific foraging resources, lengthen or shorten the time in which resources are available for bees, change the quality of these resources, and alter the span during which bees can actively forage (Calovi *et al.* 2021). Reddy (1979) reported that relative humidity and rainfall showed a positive relationship with the pollen gathering activity by the bees. Verma (1983) noticed the increase in the pollen foraging activity with rise in the relative humidity, but not so affected by temperature. Mahrotra and Bisht (1984) found significant correlation of foraging activity for pollen and nectar foragers with day temperature and humidity. Abrol and Bhat (1987) reported that the foraging activity of *A. cerana* was significant and positive with temperature and non significant with relative humidity. The relationship correlation between weather parameters and honeybees are critically important. Therefore the present investigation was aimed to study impact of weather on brood area, pollen area and nectar area of artificially and naturally inseminated colonies of *Apis mellifera* L. and *Apis cerana indica* F.

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MATERIALS AND METHODS

During the experiment An investigational with all data on meteorological parameters viz., maximum temperature, relative humidity, total rainfall and bright sunshine hours were recorded for during the entire period of study from Department of Agro meteorology, AAU, Jorhat to determine their the influence of weather parameters on brood area, pollen area and nectar area of artificially and naturally inseminated colonies of *Apis mellifera* L. and *Apis cerana indica* F.

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Statistical analysis

The data was analysed statistically using Randomised Block Design and correlation study was made on of the meteorological parameters was investigated affecting for their influence on brood area, pollen area and nectar area with independent variables to find out the influence of meteorological parameters. The statistical analysis was as follows:

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Simple correlation studies

To calculate the correlation co-efficient(r), the following standard statistical formula by Karl Pearson was adopted (Panse and Sukhatme, 1985).

$$r = \frac{\sum xy - \frac{\sum x \cdot \sum y}{N}}{\sqrt{\left(\sum x^2 - \frac{(\sum x)^2}{N}\right) \left(\sum y^2 - \frac{(\sum y)^2}{N}\right)}}$$

Where, r = Correlation co-efficient

n = Number of observation

x = Independent variables

y = Dependent variables

Then the Correlation co-efficient(r) was tested for significant or non significant by Fisher 't' test, which is defined as follows :

$$t = \frac{r}{\sqrt{(1-r^2)}} \times \sqrt{n-2} \text{ with } n-2 \text{ degrees of freedom}$$

For correlation studies, monthly average values of the environmental factors were taken into consideration to know the influence of meteorological parameters on brood area, pollen area and nectar area during the present investigation.

Simple regression analysis

Simple regression line was fitted to know the impact of independent variables on the dependent variables.

The regression line was given by the equation:

$$Y = a + bx$$

Where, for each unit increase in 'x' variable, the 'Y' variable increases by 'b' unit.

Y= Dependent variables

x = Independent variables

a =Intercept

RESULT AND DISCUSSION

The effect influence of various meteorological factors, such as viz; maximum temperature, maximum relative humidity, total rainfall and bright sunshine hours on brood area, pollen area and nectar area of *A. mellifera* L. and *A. c. indica* were worked

out through simple correlation method. Those However, Karl Pearson's correlation coefficient(r) which were found to be significant after being tested by Fisher's 't' were further studied through regression equation and illustrated graphically as follows:

1. Correlation of meteorological parameters with brood area, pollen area and nectar area of *A. mellifera* L.

Correlation studies of meteorological parameters with brood area, pollen area and nectar area were carried out in *A. mellifera* L. during April'16 to March'17 and the results have been discussed below (Table 1).

Relationship of brood area with maximum temperature: From the investigation, it was revealed that the relationship between average maximum temperature and brood area of *A. mellifera* L. was found to be significant, negative and linear in with artificially inseminated colonies ($r = -0.57$, $P < 0.05$). The data indicated revealed 32.9 per cent variation in brood area, which was observed to be controlled by maximum temperature ($R^2 = 0.329$). The regression of brood area on maximum temperature could be expressed by the equation $Y = -144.18X + 7390.1$ (Fig. 1A). Similarly, a significant, negative and linear relationship ($r = -0.57$, $P < 0.05$) was existed reported between average maximum temperature and brood area of naturally inseminated colonies of *A. mellifera* L.. The data indicated that 32.4 per cent variation in brood area which was controlled by maximum temperature ($R^2 = 0.324$). The regression of brood area on maximum temperature could be expressed by the equation $Y = -147.94X + 7316.1$ (Fig. 1B). The result was in conformity with the observations of Rahman (1992).

Relationship of pollen area with maximum temperature: An investigation revealed that the relationship between average maximum temperature and pollen area was found to be negatively significant and linear in artificially inseminated colonies of *A. mellifera* L. ($r = -0.89$, $P < 0.05$). The data indicated that 80.07 per cent variation in pollen area was controlled by maximum temperature ($R^2 = 0.8007$). The regression of pollen area on maximum temperature could be expressed by the equation $Y = -108.66X + 3926.8$ (Fig. 1C). The relationship between average maximum temperature and pollen area of naturally inseminated colonies of *A. mellifera* L. was found to be significant, negative and linear ($r = -0.88$, $P < 0.05$). The data indicated 78.4 per cent variation in brood area was observed to be controlled by maximum temperature ($R^2 = 0.784$). The equation $Y = -103.99X + 3680.1$ indicated the magnitude of this association (Fig. 1D). Such relationship has been observed by Zapart *et al.* (2018).

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Relationship of pollen area with total rainfall: A significant, negative and linear relationship was **existed** **revealed** between total rainfall and pollen area of artificially inseminated colonies of *A. mellifera* L. ($r = -0.57$, $P < 0.05$). The data indicated that 32.0 per cent variation in pollen area was controlled by total rainfall ($R^2 = 0.320$). The regression of pollen area on total rainfall could be expressed by the equation $Y = -1.1638X + 940.36$ (Fig. 1E). **It was found that** **However**, rainfall **has** **showed** significant, negative and linear effect on pollen area of naturally inseminated colonies of *A. mellifera* L. ($r = -0.60$, $P < 0.05$). However, 37 per cent variation in pollen area was regulated by total rainfall ($R^2 = 0.370$) and the regression of pollen area on total rainfall could be expressed by the equation $Y = -1.2093X + 839.17$ (Fig. 1F). Contrary to the present findings Nag (2016) documented positive impact of total rainfall on pollen area.

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Relationship of pollen area with bright sunshine hours: From the investigation, it was **found** **revealed** that bright sunshine hours has positive and linear ($r = 0.83$, $P < 0.05$) effect on pollen area of artificially inseminated colonies of *A. mellifera* L.. The data indicated **that** 68.9 per cent variation in pollen area was controlled by bright sunshine hours ($R^2 = 0.689$) and the regression of pollen area on bright sunshine hours could be expressed by the equation $Y = 177.34X + 98.326$ (Fig. 1G). Similarly, the relationship between bright sunshine hours and pollen area of *A. mellifera* L. was found to be significant, positive, and linear **in with** naturally inseminated colonies ($r = 0.84$, $P < 0.05$). **The data indicated** **From the data it was revealed** that 71.2 per cent variation in pollen area was **found to be** regulated by bright sunshine hours ($R^2 = 0.712$). The regression of pollen area on bright sunshine hours could be expressed by the equation $Y = 174.25X + 193.17$ (Fig. 1H). This was in conformity with the observations of Nag (2016).

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Relationship of nectar area with maximum relative humidity: A significant, negative and linear relationship ($r = -0.71$, $P < 0.05$) was **existed** **came into light** between maximum relative humidity and nectar area of artificially inseminated colonies of *A. mellifera* L. The data indicated **that** 51 per cent variation in nectar area was found to be controlled by maximum relative humidity ($R^2 = 0.51$) where the equation $Y = -420.99X + 41875$ indicated the magnitude of the association (Fig. 1I). Similarly, the relationship between maximum relative humidity and nectar area of naturally inseminated colonies of *A. mellifera* L. was found to be negatively significant and linear ($r = -0.70$, $P < 0.05$). The data indicated that 49.1 per cent variation in nectar area was regulated by maximum relative humidity ($R^2 = 0.491$). The regression of nectar area on maximum relative humidity could be expressed by the equation

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$Y = -398.47X + 39515$ (Fig. 1J). Nag (2016) also made similar observations of negative and significant impact of maximum relative humidity on nectar area.

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2. Correlation of brood area, pollen area and nectar area with different meteorological parameters of *A. mellifera* L.

During April'17 to March'18, correlation studies of brood area, pollen area and nectar area were again carried out with meteorological parameters in *A. mellifera* L. and the results are discussed as below (Table 2).

Relationship of pollen area with maximum temperature: The relationship between maximum temperature and pollen area of *A. mellifera* L. was found to be significant, negative and linear in with artificially inseminated colonies ($r = -0.87$, $P < 0.05$) where 76.9 per cent variation in pollen area was observed to be controlled by maximum temperature ($R^2 = 0.769$). The regression equation $Y = -91.56X + 3443.8$ indicated the magnitude of this association (Fig. 2A). Similarly, the relationship between maximum temperature and pollen area of *A. mellifera* L. was found to be significant, negative and linear in naturally inseminated colonies ($r = -0.90$, $P < 0.05$) where 82.1 per cent variation in pollen area was observed to be controlled by maximum temperature ($R^2 = 0.821$). The regression of pollen area on maximum temperature could be expressed by the equation $Y = -91.254X + 3314.4$ (Fig. 2B). Similar results were also obtained by Chaand *et al.* (2017) in *A. mellifera* L.

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Relationship of pollen area with maximum relative humidity: The relationship between maximum relative humidity and pollen area of *A. mellifera* L. was found to be significant, positive and linear in with artificially inseminated colonies ($r = 0.57$, $P < 0.05$). The data indicated that 31.8 per cent variation in pollen area was found to be regulated by maximum relative humidity ($R^2 = 0.318$). The equation $Y = 84.73X + 7288.3$ indicated the magnitude of this association (Fig. 2C). Similarly, a significant, positive and linear relationship was existed between maximum relative humidity and pollen area of naturally inseminated colonies of *A. mellifera* L. ($r = 0.60$, $P < 0.05$). The data indicated 36.5 per cent variation in pollen area was observed to be controlled by maximum relative humidity ($R^2 = 0.365$). The regression of pollen area on maximum relative humidity could be expressed by the equation $Y = 87.607X + 7682$ (Fig. 2D). Gebremedhn *et al.* (2014) also reported such observations in *A. mellifera* L. colonies.

Relationship of pollen area with total rainfall: The relationship between total rainfall and pollen area of *A. mellifera* L. was found to be significant, negative and linear in

with artificially inseminated colonies ($r = -0.74$, $P < 0.05$). The data indicated 55.1 per cent variation in pollen area was observed to be controlled by total rainfall ($R^2 = 0.551$). The regression of pollen area on total rainfall could be expressed by the equation $Y = -1.841X + 1056$ (Fig. 2E). Similarly, the relationship between total rainfall and pollen area of *A. mellifera* L. was found to be significant, negative and linear in with naturally inseminated colonies ($r = -0.76$, $P < 0.05$). The data indicated revealed that 58.5 per cent variation in pollen area was regulated by total rainfall ($R^2 = 0.585$). The equation $Y = -1.829X + 933.58$ indicated the magnitude of this association (Fig. 2F). Such observations were in conformity with the results obtained by Chaand *et al.* (2017).

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Relationship of nectar area with maximum relative humidity: A significant, negative and linear relationship was existed between maximum relative humidity and nectar area of artificially inseminated colonies of *A. mellifera* L. ($r = -0.74$, $P < 0.05$). The data indicated 55.7 per cent variation in nectar area was observed to be controlled by maximum relative humidity ($R^2 = 0.557$). The regression of nectar area on rainfall could be expressed by the equation $Y = -343.63X + 34290$ (Fig. 2G). Similarly, the relationship between maximum relative humidity and nectar area of *A. mellifera* L. was found to be significant, negative and linear relationship in with naturally inseminated colonies ($r = -0.77$, $P < 0.05$). The data indicated 59.8 per cent variation in nectar area was observed to be controlled by maximum relative humidity ($R^2 = 0.598$). The regression of nectar area on maximum relative humidity could be expressed by the equation $Y = -338.9X + 33634$ (Fig. 2H). The results were in agreement with the findings of Gebremedhn *et al.* (2014).

3. Correlation of meteorological parameters with brood area, pollen area and nectar area of *Apis cerana indica* F.

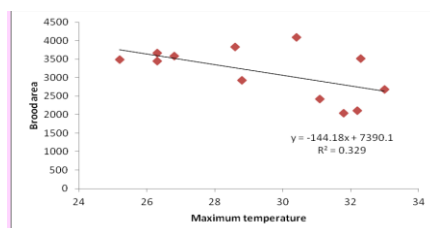
Correlation studies were also carried out in *A. c. indica* between meteorological factors and brood area, pollen area and nectar area during April'17 to March'18 and the results are discussed below (Table 3).

Relationship of brood area with maximum relative humidity: In *A. c. indica*, it was found that relative humidity has significant effect on brood area and has adverse and linear effect in with artificially inseminated colonies ($r = -0.58$, $P < 0.05$) where, 34.2 per cent variation in brood area was observed to be controlled by maximum relative humidity ($R^2 = 0.342$). As shown in figure 12A, the regression of brood area on maximum relative humidity could be expressed by the equation $Y = -248.82X + 25463$ (Fig. 3A). Similarly, the relationship between maximum relative humidity and brood

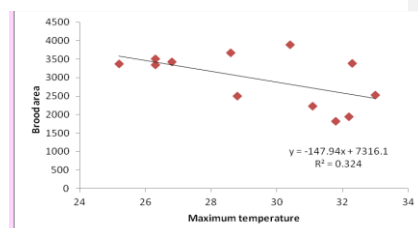
area of *A. c. indica* was found to be significant, negative and linear in with naturally inseminated colonies ($r = -0.60$, $P < 0.05$) where, 36.3 per cent variation in brood area was observed to be regulated by maximum relative humidity ($R^2 = 0.363$). The regression of brood area on maximum relative humidity could be expressed by the equation $Y = -258.18X + 26175$ (Fig. 3B). Similar results were also obtained by Pastagia and Patel (2014) and Painkra *et al.* (2017).

Relationship of nectar area with maximum relative humidity: Relative humidity has revealed significant, negative and linear relationship on with nectar area of artificially inseminated colonies of *A. c. indica* ($r = -0.66$, $P < 0.05$). The data indicated 44 per cent variation in nectar area was observed to be controlled by maximum relative humidity ($R^2 = 0.440$). The regression of nectar area on maximum relative humidity could be expressed by the equation $Y = -122.31X + 12277$ (Fig. 3C). Similarly, the relationship between maximum relative humidity and nectar area of *A. c. indica* was found to be significant, negative and linear in with naturally inseminated colonies ($r = -0.70$, $P < 0.05$). The data indicated 50.2 per cent variation in nectar area was observed to be controlled by maximum relative humidity ($R^2 = 0.502$). The regression of nectar area on maximum relative humidity could be expressed by the equation $Y = -130.22X + 12901$ (Fig. 3D). Contrary to the present finding Painkra (2017) documented positive significant correlation of maximum relative humidity with nectar area.

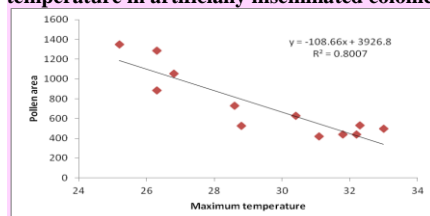
Fig. 1. Correlation of meteorological parameters with brood area, pollen area and nectar area of *Apis mellifera* L. (April'16 to March'17)



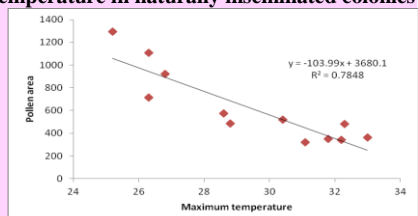
a) Relationship of brood area with maximum temperature in artificially inseminated colonies



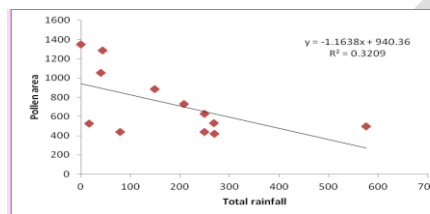
b) Relationship of brood area with maximum temperature in naturally inseminated colonies



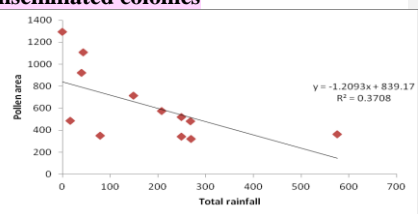
c) Relationship of pollen area with maximum temperature in artificially inseminated colonies



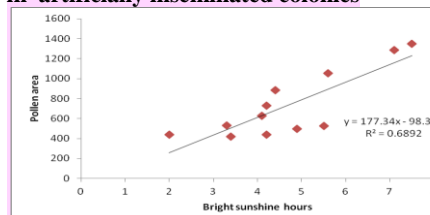
d) Relationship of pollen area with maximum temperature in naturally inseminated colonies



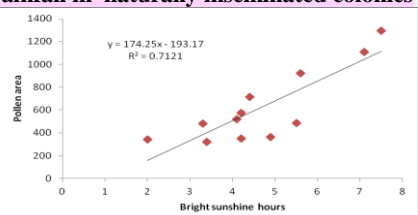
E. Relationship of pollen area with total rainfall in artificially inseminated colonies



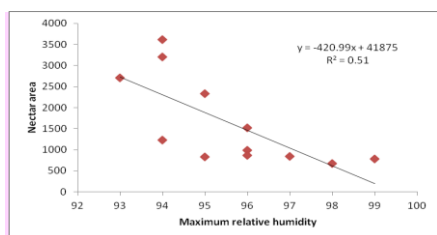
F. Relationship of pollen area with total rainfall in naturally inseminated colonies



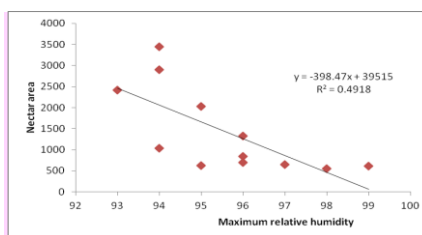
G. Relationship of pollen area with bright sunshine hours in artificially inseminated colonies



H. Relationship of pollen area with bright sunshine hours in naturally inseminated colonies

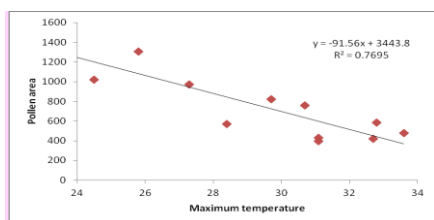


I. Relationship of nectar area with maximum relative humidity in artificially inseminated colonies

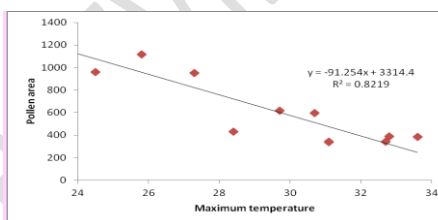


J. Relationship of nectar area with maximum relative humidity in naturally inseminated colonies

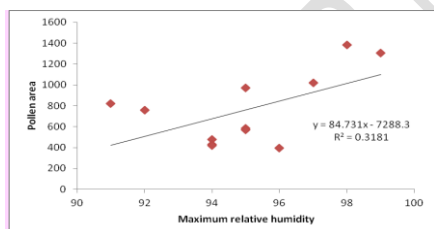
Fig. 2. Correlation of brood area, pollen area and nectar area with different meteorological parameters of *Apis mellifera* L. (April'17 to March'18)



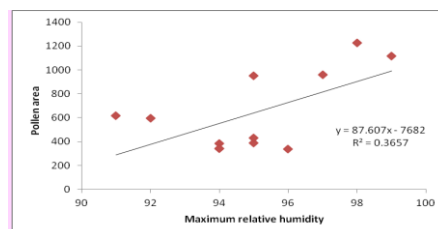
A) Relationship of pollen area with maximum temperature in artificially inseminated colonies



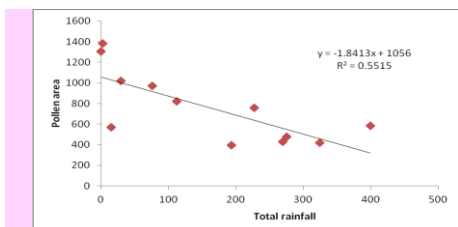
B) Relationship of pollen area with maximum temperature in naturally inseminated colonies



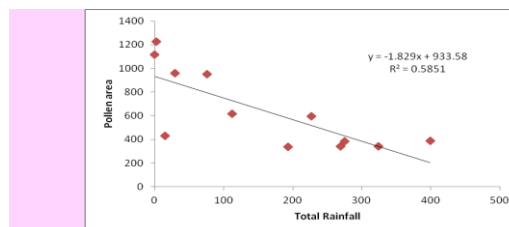
C) Relationship of pollen area with maximum relative humidity in artificially inseminated colonies



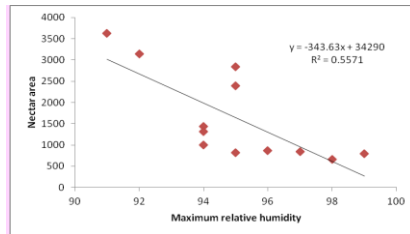
D) Relationship of pollen area with maximum relative humidity in naturally inseminated colonies



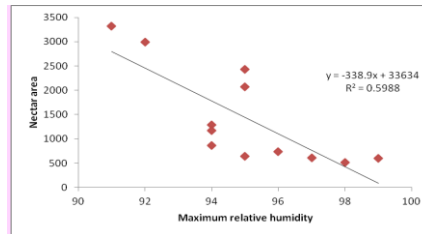
E) Relationship of pollen area with total rainfall in artificially inseminated colonies



F) Relationship of pollen area with total rainfall in naturally inseminated colonies

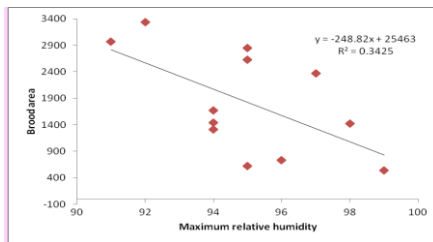


G) Relationship of nectar area with maximum relative humidity in artificially inseminated colonies

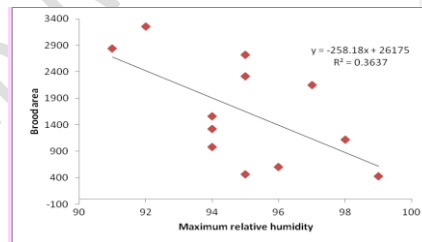


H) Relationship of nectar area with maximum relative humidity in naturally inseminated colonies

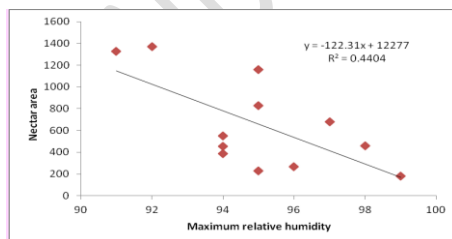
Fig. 3. Correlation of meteorological parameters with brood area, pollen area and nectar area of *Apis cerana indica* F. (April'17 to March'18)



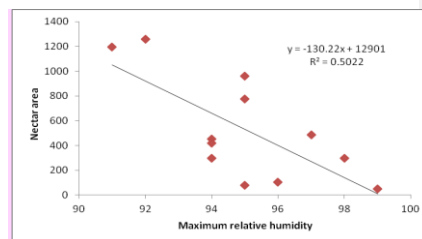
A) Relationship of brood area with maximum relative humidity in artificially inseminated colonies



B) Relationship of brood area with maximum relative humidity in naturally inseminated colonies



C) Relationship of nectar area with maximum relative humidity in artificially inseminated colonies



D) Relationship of nectar area with maximum relative humidity in naturally inseminated colonies

Table 1. Correlation of brood area, pollen area and nectar area of *A. mellifera* L. L. with different meteorological factors

Month of observ ation	Brood area		Pollen area		Nectar area		Maxim um tempera ture (°C)		Maximu m relative humidit y (%)		Total rainfall (mm)		Bright sunshine hours (hr)	
	AI	NI	AI	NI	AI	NI								
April'16	3829.8	3678.0	730.2	573.2	3619.8	3443.2	28.6	94	208.1	4.2				
May'16	4091.2	3882.4	629.8	519.4	3201.8	2903.4	30.4	94	249.7	4.1				
June'16	3517.8	3381.6	532.2	479.6	2333.8	2030.2	32.3	95	267.5	3.3				
July'16	2680.8	2524.6	497.4	362.2	1524.8	1323.8	33.0	96	576.0	4.9				
August'16	2427.2	2229.0	420.2	321.8	1233.6	1038.2	31.1	94	269.1	3.4				
Septem ber'16	2102.6	1946.2	436.8	342.6	992.2	847.8	32.2	96	249.2	2.0				
October '16	2039.2	1813.8	440.8	349.0	872.0	695.2	31.8	96	78.4	4.2				
Novem ber'16	2926.8	2507.0	527.8	486.4	845.0	654.4	28.8	97	16.5	5.5				
Decemb er'16	3449.8	3342.8	1287.4	1108.0	783.4	612.2	26.3	99	43.5	7.1				
January '17	3494.2	3368.4	1349.2	1295.2	671.8	556.0	25.2	98	0.1	7.5				
Februar y'17	3581.8	3423.6	1052.4	922.8	832.8	625.2	26.8	95	39.4	5.6				
March' 17	3672.6	3503.6	882.4	714.4	2712.6	2411.0	26.3	93	148.8	4.4				
							AI	NI	AI	NI	AI	NI	AI	NI
Correlation with brood area (r=)							-0.57*	-0.57*	0.20	0.19	-0.19	-0.15	0.38	0.37
Correlation with pollen area (r=)							-0.89*	-0.88*	0.45	0.49	-0.57*	-0.60*	0.83*	0.84*
Correlation with nectar area(r=)							0.10	0.09	-0.71*	-0.70*	0.36	0.35	-0.37	-0.36

*= Significant at 5% level of probability

Table 2. Correlation of brood area, pollen area and nectar area of *A. mellifera* L. L. with different meteorological factors

Month of observation	Brood area		Pollen area		Nectar area		Maximum temperature (°C)	Maximum relative humidity (%)	Total rainfall (mm)	Bright sunshine hours (hr)
	AI	NI	AI	NI	AI	NI				
April'17	388 8.6	374 4.2	823. 4	616. 6	362 0.8	332 1.2	29.7	91	111.8	4.5
May'17	420 3.8	383 6.8	758. 0	595. 2	314 5.0	298 9.8	30.7	92	226.9	4.2
June'17	367 4.8	342 1.4	581. 8	386. 8	239 1.2	207 1.6	32.8	95	399.2	3.7
July'17	284 2.6	256 4.0	478. 2	384. 6	143 8.6	128 6.4	33.6	94	275.1	4.0
August'17	237 6	212 3.4	427. 2	342. 6	131 0.2	117 2.2	31.1	94	269.1	3.4
September'17	211 3.6	197 4.6	419. 0	340. 4	100 6.0	865. 8	32.7	94	324.4	3.3
October'17	201 8.8	194 4.2	395. 4	337. 2	867. 8	742. 4	31.1	96	192.8	5.2
November'17	295 3.0	272 9.8	569. 8	428. 8	818. 0	640. 8	28.4	95	14.7	7.4
December'17	342 6.4	323 9.4	130 5.6	111 5.0	796. 0	605. 0	25.8	99	0.0	5.4
January'18	348 3.0	331 7.0	138 2.2	122 6.8	664. 4	510. 0	23.9	98	2.7	4.7
February'18	355 6.4	342 3.2	102 1.0	961. 6	848. 6	615. 0	24.5	97	29.1	3.4
March'18	358 3.6	346 3.0	971. 6	952. 4	283 5.8	243 6.0	27.3	95	76.0	4.0
							AI	NI	AI	NI
Correlation with brood area (r=)							-0.39	-0.45	-0.12	-0.08
Correlation with pollen area (r=)							-0.87*	-0.90*	-0.57*	-0.60*
Correlation with nectar area (r=)							-0.28	-0.31	-0.74*	-0.77*

*= Significant at 5% level of probability

Table 3. Correlation of brood area, pollen area and nectar area of *A. c. indica* with different meteorological factors

Month of observation	Brood area		Pollen area		Nectar area		Maximum temperature (°C)	Maximum relative humidity (%)		Total rainfall (mm)	Bright sunshine hours (hr)	
	AI	NI	AI	NI	AI	NI						
April'17	2971.8	2837.2	1055.2	834.0	1328.8	1194.8	29.7	91		111.8	4.5	
May'17	3337.0	3250.4	839.8	645.0	1370.2	1257.2	30.7	92		226.9	4.2	
June'17	2850.4	2717.4	774.4	571.4	829.4	773.2	32.8	95		399.2	3.7	
July'17	1671.6	1559.4	569.8	515.8	548.8	451.2	33.6	94		275.1	4.0	
August'17	1443.6	1324.2	529.4	472.6	455.8	418.0	31.1	94		269.1	3.4	
September'17	1309.0	983.2	522.6	452.8	388.2	295.2	32.7	94		324.4	3.3	
October'17	735.0	607.8	464.4	306.2	265.4	105.2	31.1	96		192.8	5.2	
November'17	622.8	466.8	285.6	254.8	228.4	79.8	28.4	95		14.7	7.4	
December'17	539.0	427.2	352.2	302.4	179.0	48.0	25.8	99		0.0	5.4	
January'18	1421.2	1122.8	827.4	593.2	461.2	299.0	23.9	98		2.7	4.7	
February'18	2368.2	2153.6	966.6	881.2	679.8	484.2	24.5	97		29.1	3.4	
March'18	2632.6	2319.2	1233.8	1099.2	1158.6	958.4	27.3	95		76.0	4.0	
							AI	NI	AI	NI	AI	NI
Correlation with brood area (r=)							0.13	0.16	0.58*	0.60*	0.27	0.29
Correlation with pollen area (r=)							0.25	0.27	0.27	0.25	0.09	0.13
Correlation with nectar area (r=)							0.09	0.17	0.66*	0.70*	0.13	0.23

*= Significant at 5% level of probability

CONCLUSION

The correlation study of *A. mellifera* during the year 2016-17 revealed significant negative correlation of brood area ($r = -0.57$ in both AI and NI colonies) and nectar area ($r = -0.71$ in AI and $r = -0.70$ in NI colonies) with maximum temperature and maximum relative humidity, respectively. Whereas, pollen area was found to have significant positive correlation with bright sunshine hours (0.83 in AI and 0.84 in NI colonies) and significant negative correlation with maximum temperature ($r = -0.89$ in AI and $r = -0.88$ in NI colonies) and total rainfall ($r = -0.57$ in AI and $r = -0.60$ in NI colonies). Again in 2017-18, pollen area showed positive significant correlation with maximum relative humidity ($r = 0.57$ in AI and $r = 0.60$ in NI colonies) and negatively significant correlation with maximum temperature ($r = -0.87$ in AI and $r = -0.90$ in NI colonies) and total rainfall ($r = -0.74$ in AI and $r = -0.76$ in NI colonies). Nectar area was found to have negatively significant correlation with maximum relative humidity ($r = -0.74$ in AI and $r = -0.77$ in NI colonies). *A. cerana indica* showed significant negative correlation of brood area ($r = -0.58$ in AI and $r = -0.60$ in NI colonies) and nectar area ($r = -0.66$ in AI and $r = -0.70$ in NI colonies) with maximum relative humidity during 2017-18.

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Comment [PM22]: Rearrange alphabetically. From A to Z and year in sequential manner.

Comment [PM23]: Overall, technically well investigated and written manuscript