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Effect of colony strength on colony build up and foraging activity of *Apis mellifera* L.

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Abstract
The studies were carried out in Division of Entomology, SKUAST-Jammu to assess the effect of varied colony strength (6, 8 and 10 frames hive) on colony performance parameters viz. brood development, pollen and honey stores by *Apis mellifera* from June, 2013 to May, 2014 under Jammu conditions. The colony parameters in respect of brood, pollen and honey area fluctuated in all the test colonies with varied bee strength. The maximum brood development was recorded from October to June month with highest in 10-frame beehive. The maximum pollen area in all the three colonies was recorded from January to June month with maximum in 10-frame beehive. The maximum honey area in all the three colonies was recorded from March to August month. The brood development was positively correlated with maximum temperature negatively correlated with minimum temperature positive and significant for maximum relative humidity, negative and significant for minimum relative humidity and negative and significant for rainfall. The correlation coefficients between pollen area and weather parameters were found to be negative for maximum temperature, negative for minimum temperature negative for maximum relative humidity, negative for minimum relative humidity and negative and significant for rainfall. The honey reserves were found to be positive and highly significant for maximum temperature, positive for minimum temperature positive and highly significant for maximum relative humidity, negative and highly significant for minimum relative humidity and negative for rainfall. The foraging activity showed a rhythmic pattern depending upon the level of adaptation and colony strength. The incoming and outgoing bees at any point of time were not in equilibrium. The study clearly revealed that there should be adequate amounts of brood, pollen and honey reserves in the colonies initially for maximum honey production and the increase of colony strength.

Keywords: *Apis mellifera*, colony strength, brood, pollen, honey area, foraging activity

Introduction

The productive efficiency of bees in an area depends on the bee breed and bee forage, whereas the foraging index is the key factor, which determines the performance of a colony. Honey bees increase yields of cross pollinated crops, thus increasing farm incomes and provide employment to the landless and unemployed rural people [10]. The extent of honey production and pollination depends upon the foraging pattern of the colony. The foraging pattern in turn is influenced by the colony strength viz., number of workers, presence of brood, pollen and honey stores and also of artificial feeding. Brood rearing is an essential activity of bee colonies. This depends upon the availability of pollen and nectar, as also on climate factors prevailing in the locality. The colony strength influences the foraging pattern of bees. Population of the colony has a greater impact on the colony productivity and efficiency. Brood rearing and foraging are interrelated and so also the size of the colony. The amount of brood inside the colony depends on the number of bees. Likewise the amount of unsealed brood influences the pollen foraging by bees. Pollen and honey stores increase the foraging and amount of brood. The nectar and pollen stores and supplementary feeding to the colony have been found to influence the colony foraging activity. Besides these, the foraging activity of the colony is also influenced by the abiotic factors. The state of Jammu and Kashmir constitutes one of the most important bee-keeping zones in India. It offers great potentialities of bee-keeping due to its rich bee flora found in abundance. Jammu and Kashmir State constitutes one of the most important beekeeping areas of India [3]. *Apis mellifera* is well distributed in plains and hilly areas of Jammu region and is commercially managed for honey production and pollination. One of the problems faced by beekeepers in this region is the lack of standardized practice of management of *Apis mellifera* under Jammu region.

The present knowledge of colony strength and its influence on honey production in Jammu region is incomplete with only fragmentary reports being available. Scientific beekeeping with *Apis mellifera* and its commercial exploitation has now become widespread in J&K due to the prevalence of salubrious climate and abundant bee pasturage. Knowledge of colony developmental characteristics of bee species in particular agro climatic conditions can help the beekeepers to exploit the bees for better pollination services and honey production. The studies on its performance in Jammu region are limited.

Materials and Methods

The studies were carried out from June 2013 to May, 2014 in the University Apiary, Division of Entomology, Faculty of Agriculture, SKUAST - Jammu. The experiment was conducted to study the influence of colony strength in the brood area (cm^2), pollen (cm^2) and honey reserves (cm^2) in *A. mellifera* hives during June, 2013 to May, 2014. For this study, three colonies of *A. mellifera* in single walled Langstroth hives were selected, which were placed facing north and the hives were kept at shady places. The 6- frame, 8- frame and 10- frame were placed from right to left with a dummy board after the 4th, 6th and 8th frame, respectively, in first three colonies, to separate the colony from the empty space of the hive. The position of frames marked number 1, 2 and 3 for the purpose of identification and observations were recorded accordingly. In all these hives, the observations were recorded in each of the selected frames at weekly interval. The brood, pollen and honey area were measured by means of grid method at fortnightly intervals after the bees were gently brushed off from the comb surface of the frame. The total brood area was computed and doubled to get total brood area per comb.

Bee strength of experimental colonies		
6 bee - frame	8 bee - frame	10 bee - frame
No. of colonies to be examined = 9 (3 each in 6, 8 and 10 bee-frame bee strength)		

The colony parameters viz. bee strength, brood, pollen and honey area (cm^2) was recorded at fortnightly intervals. Number of pollen foragers at the hive entrance was counted for five minutes in each bee colony at weekly intervals. The weather parameters were recorded to determine their impact on foraging.

Results and Discussion

Effect of colony bee strength on colony performance:

Brood development

The data on the effect of colony strength on colony build up (brood, pollen and honey stores) in 6, 8 and 10-frame colonies are presented in Table 1. These tables depict the colony build up i.e., build up of colony strength viz. brood, pollen reserves and honey reserves. Colony strength and brood, pollen and honey reserves showed a gradual increase with time. However, build pattern of other parameters was highly variable. Continuous brood rearing was observed throughout the year with fluctuations. Brood rearing activity in the colony having 6 frames increased gradually from September-October and peaked during April. The maximum (1171.92cm^2) and minimum brood area (567.00 cm^2) was observed in April (second fortnight) and second fortnight of August, respectively. There was a significant difference in the brood area in the colony having strength of 8 bee frame; highest brood area of 1299.90 cm^2 was recorded by the end of April. The minimum brood area (601.92 cm^2) was observed in the second fortnight of September, respectively. March and May also experienced good brood area i.e. 1087.90 (First fortnight) and 1091.94 cm^2 (second fortnight) which was at par with that of April but significantly different from rest of the treatments. The brood area started declining from May (second fortnight) till September, and lowest brood area (601.92 cm^2) was recorded during September (second fortnight) and it remained low during the entire rainy season. From September onwards, it started increasing. The brood, pollen and honey reserves of ten frame bee colonies shows fluctuations during the study period. In February, the brood area was 995.88 cm^2, which increased to 1193.94, 1541.94 and 1357.92 cm^2 in March, April and May, respectively. Brood area decreased after that and remained at low level up to August (633.90 cm^2) and again picked up in September (641.16 cm^2). Under Jammu conditions, summer and rainy season are identified as dearth season with respect to the availability of pollen and nectar. In tropical and sub-tropical areas, summer and rainy seasons are very harsh for bees. Generally no floral sources are available to bees from June to September [12]. Winter and spring season found to be most excellent time for brood production due to presence of optimum weather conditions and bee flora compared to rainy or autumn season. Food shortage causes quick dwindling and even death of bee colonies. Therefore, the brood development in a bee colony may vary according to different seasons and availability of bee forage, which plays a very important role in the production of brood and bees. The present finding are in agreement with those of Bisht [4] who also reported that highest brood area was during February (late winter season) and March (early spring season) and in April (late spring season). May and June (summer season) it started declining to some extent in case of *Apis cerana indica*. He further reported that after June (late summer season), the brood area considerably decreased and this condition continued with minute fluctuations up to January (early winter season) and August (mid rainy season) proved to be more unfavourable period. Brar *et al.* [5] also reported that brood rearing continues throughout the year in *Apis mellifera* with a major peak in March (early spring season) to May (early summer season) and a smaller peak in November (mid autumn season), especially in the toria growing area. It was also reported by Rizk and Atallah [16], that area of sealed brood was highest in January and February (winter season) and during this period, significant variability in mean day temperature, maximum temperature and mean relative humidity might have affected brood rearing. Das and Rahman [6] also observed that the maximum brood area was recorded in February (late winter season) and minimum in August (mid rainy season), similarly the highest brood population of *A. cerana indi*ca workers exhibited a significant negative and linear correlation with minimum and maximum temperature, relative humidity and rainfall; however, a positive correlation was observed with bright sunshine hour. Varshneya *et al.* [19] also reported that development of brood area was negatively correlated with temperatures (both maximum and minimum), relative humidity (both maximum and minimum) and rainfall during both the years. Significant positive correlations subsisted with bright sunshine hours. Devi *et al.* [7] reported April-May as favourable moths for the brood rearing activity of *A. mellifera*. Shahi *et al.* [17] reported a steep increase in frame strength from November (5.0) to March (10.0) and declined in the month of April (8.5) and concluded that the colony development was directly related to the availability of suitable flora and favourable weather conditions for bees.

Mohapatra and Satapathy [13] also reported that the brood area, number of frames with eggs and pollen store were maximum during December and were positively correlated. Similarly maximum bee population was recorded during May coinciding with maximum honey store showing a positive correlation. Nectar gatherers and pollen gatherers were maximum in January and February, respectively. Dearth period was observed to be during August and September.

Pollen Reserves

The data on the effect of colony strength of pollen reserves in 6, 8 and 10-frame bee colonies is presented in Table 1. The data revealed that colony strength and honey reserves showed a gradual increase with time. However, build pattern of other parameters was highly variable. The colonies with 6 frames, pollen reserves of the colonies increased and decreased during the period of observation. The highest pollen area 321.90cm² was recorded in first forth night of April which declined to 71.88cm² in second forth night of November, thereafter, an increasing trend was observed up to April (First fortnight). The pollen area in 8 frame bee colonies declined a minimum of 43.92cm² during August (First fortnight). From September to March, pollen reserves registered an increasing trend peaking to 431.94cm² in March (second fortnight). Continuous pollen harvesting by foragers was observed throughout the year with fluctuations. The 10 frame bee colonies collected pollen throughout the study period showing variations with a maximum pollen store (445.92 cm^2) in March and a minimum pollen store (133.92cm^2) in August and December (115.92cm^2). Neupane and Thapa [15] reported that autumn, winter and summer seasons were normal for pollen collection and brood production, while starvation and nutritional deficiencies due to the acute shortage of pollen in the rainy season was the major reason to decline or collapse the bee population before the honey flow season. Therefore, feeding the bees with adequate amount of nutritionally rich pollen during rainy season is essential to maintain a healthy and strong bee colony for the production of higher honey and other hive products. Mohapatra *et al.* [14] reported that pollen store has a significant impact on brood development and can be taken as a criterion for judging healthy colonies. Shahi *et al.* [17] reported a steep increase in frame strength from November (5.0) to March (10.0) and declined in the month of April (8.5). It is evident from the data that the colony development was directly related to the availability of suitable flora and favourable weather conditions for bees. Mohapatra and Satapathy [13] reported that the brood area, number of frames with eggs and pollen store were maximum during December and were positively correlated. Similarly maximum bee population was recorded during May coinciding with maximum honey store showing a positive correlation. Nectar gatherers and pollen gatherers were maximum in January and February, respectively. Dearth period was observed to be during August and September.

Honey Reserves

The data on the effect of colony strength in honey stores in colonies having differential bee strength is presented in the given Table 1. These tables depict the colony build up i.e., build up of colony strength viz. brood, pollen reserves and honey reserves. Colony strength and honey reserves showed a gradual increase with time. However, build pattern of other parameters was highly variable. Continuous honey harvesting was observed throughout the year with fluctuations. Nectar collecting activity in the colony having 6 frames increased gradually from November and peaked during May. The maximum (1557.90cm^2) and minimum honey area (219.90 cm^2) was observed in May (second fortnight) and the first fortnight of November, respectively. There was a significant difference in the honey area in the colony having strength of 8 bee frame; highest honey store of 1411.92 cm^2 was recorded by the end of May. The minimum honey area of 405 cm^2, 469.92 cm^2 and 449.88 cm^2 was observed in February (First fortnight), June (First fortnight) and the first fortnight of July, respectively. March and April also experienced good honey collection by bees i.e. 619.92 cm^2 (First fortnight) and 819.96 cm^2 (first fortnight) which were significantly different from rest of the observations. The honey reserves started declining from June (first fortnight) till September, and lowest honey area (603.90 cm^2) was recorded during September (second fortnight) and it remained low during the entire rainy season. From September onwards, it started increasing. The honey reserves of the ten frame bee colonies show fluctuations during the study period. The minimum honey area of 469.92 cm^2 was observed in February (First fortnight). The honey collection starts increasing gradually. March and April also experienced good honey collection by bees i.e. 539.88 cm^2 (First fortnight) and 691.92 cm^2 (first fortnight) which were significantly different from rest of the observations. The honey reserves started declining from June (first fortnight) till February, and lowest honey area of 469.92 cm^2 was recorded during February and it remained low during the entire rainy season. From March onwards, it started increasing. Continuous honey harvesting was observed throughout the year with fluctuations. Under normal weather conditions and ensured consistent food supply, colonies should increase [18].

Foraging Activity

The foraging activity of *Apis mellifera* presented in Table 3 reveals that foraging activity varied with the strength of the bee colony. The foraging activity showed a rhythmic pattern depending upon the level of adaptation and colony strength. The incoming and outgoing bees at any point of time were not in equilibrium. *Apis mellifera* showed a distinct activity pattern. *Apis mellifera* showed a distinct activity pattern as the outgoing bees were maximum during 1200-1400 hours in all treatments. The pollen gathering activity was, however, variable in colonies having variable strength. The nectar collectors in 6 (10.56 ± 0.01), 8 (12.23 ± 0.01) and 10 (13.41 ± 0.02) bee frame colonies were maximum between 1200-1400 hours. Significant increase in foragers collecting pollen only and nectar only was related to the greater availability of pollen and nectar which was mainly due to the blooming of more plant species yielding both pollen and nectar. Honeybees depend upon flowering plants for nectar and pollen and in the process render valuable service of cross pollination resulting in the improvement and perpetuation of the plant species. Crops improve both qualitatively and quantitatively receiving the services of pollinators [8]. The foraging activity of *Apis mellifera* showed a rhythmic pattern for collection of nectar and pollen rewards. This behavior indicates their different intrinsic and extrinsic capabilities. This behavior pattern is very important for the pollination of the crops and rearing of these bees for honey production [8]. Foraging behavior is one of the distinctive behaviors of honey bees, *Apis mellifera*. This behavior is the link between the honey bee colony and the ambient environment. Therefore, various in-colony and out-colony factors have an impact on this behavior, and many studies have been employed to investigate these factors [1]. Higher foraging activity with less

pollen collection was found in colonies headed by virgin queens than colonies headed by mated queens while lower foraging activity and pollen collection were found in queenless colonies than in colonies with a mated or virgin queen [9]. Also, foraging activity is impacted by colony strength and brood rearing activity [2], and the degree of pollen need [20]. The infection of honey bee foragers with diseases and parasites such as *Nosema* sp. or *Varroa destructor* may result in the inability of foragers to return to their colonies or increased time to return [11].

Table 1: Effect of varied strength on brood, pollen, honey in *Apis mellifera*

Months	Duration (Fortnight)	Average brood area (cm^2)			Average pollen area (cm^2)			Average honey area (cm^2)		
		6 frame	8 frame	10 frame	6 frame	8 frame	10 frame	6 frame	8 frame	10 frame
June, 2013	1	738.00	799.92	789.96	101.94	63.90	277.92	697.92	469.92	703.92
	2	784.80	781.92	639.90	103.92	71.94	295.92	717.90	513.90	721.98
July	1	645.90	759.90	679.92	101.94	59.94	191.88	557.88	449.88	633.96
	2	655.92	765.90	687.90	123.96	59.94	195.90	561.90	477.90	615.90
August	1	589.38	695.88	637.92	113.94	43.92	141.90	469.92	505.92	591.96
	2	567.00	631.92	633.90	108.00	39.96	133.92	453.90	483.90	577.92
September	1	571.74	605.94	641.16	81.90	85.92	161.94	487.92	597.90	721.92
	2	601.92	601.92	635.88	83.94	91.92	171.96	453.90	603.90	723.90
October	1	645.90	645.90	647.94	87.96	135.90	171.90	403.92	755.88	763.92
	2	663.90	663.90	663.90	97.92	147.90	187.92	341.88	757.92	767.94
November	1	699.96	699.96	675.96	81.90	177.90	181.92	219.90	621.90	649.92
	2	725.58	665.94	673.98	71.88	131.94	155.94	229.92	635.94	661.92
December	1	711.90	711.90	677.94	71.94	103.92	115.92	269.94	471.90	567.96
	2	713.94	689.94	675.96	79.92	167.94	211.92	287.88	473.88	587.94
Jan., 2014	1	717.96	705.96	711.90	67.98	407.94	429.90	505.92	615.90	497.88
	2	725.88	745.92	761.88	109.92	415.92	445.92	517.92	615.96	517.98
February	1	743.94	743.94	995.88	213.96	377.88	275.94	456.36	405.90	489.90
	2	777.90	953.94	1029.96	245.94	399.96	291.90	475.92	475.92	469.92
March	1	871.92	1087.92	1193.94	289.92	415.92	433.92	519.90	619.92	539.88
	2	953.94	1091.94	1219.92	313.92	431.94	445.92	519.90	621.90	545.94
April	1	1119.90	1261.92	1541.94	321.90	333.90	379.88	521.88	819.96	691.92
	2	1171.92	1299.90	1587.96	189.90	267.90	375.92	799.92	845.88	787.92
May	1	1061.88	1249.92	1357.92	161.88	161.88	257.92	1125.90	995.94	1067.94
	2	875.94	1021.98	907.92	139.92	67.92	285.88	1557.90	1411.92	1615.92
C.D(P=0.05)		81.90	37.36	30.26	13.25	20.15	19.48	25.65	31.38	22.37
S.Em(±)		28.67	13.08	10.59	4.64	7.05	6.82	8.98	10.99	7.83

Table 2: Correlation of brood, pollen and honey with abiotic factors

Parameters	Average brood area (cm^2)			Average pollen area (cm^2)			Average honey area (cm^2)		
	6 Frame	8 Frame	10 Frame	6 Frame	8 Frame	10 Frame	6 Frame	8 Frame	10 Frame
Maximum temperature	0.028	0.109	0.028	0.175	0.713**	-0.312	0.527**	0.336	0.578**
Minimum temperature	-0.208	-0.078	-0.189	-0.187	-0.724**	-0.389	0.386	0.121	0.393
Maximum relative humidity	0.477*	0.513*	0.365	0.135	0.332	-0.136	0.837**	0.576**	0.739**
Minimum relative humidity	-0.613**	-0.498*	-0.408*	-0.051	-0.023	-0.212	-0.429*	0.627**	-0.577**
Rainfall	-0.441*	-0.271	-0.292	-0.132	-0.423*	-0.320	-0.075	-0.349	-0.203

Significant at 5% level of significance*
Significant at 1% level of significance**

Table 3: Influence of colony strength on foraging activity of *Apis mellifera* L. at different time intervals

Time (h)	6 frame bee colony			8 frame bee colony			10 frame bee colony		
	Outgoing bees/5min	Incoming bees/5min		Outgoing bees/5min	Incoming bees/5min		Outgoing bees/5min	Incoming bees/5min	
		Pollen	Nectar		Pollen	Nectar		Pollen	Nectar
	Mean± S. E	Mean± S. E	Mean± S. E	Mean± S. E	Mean± S. E	Mean± S. E	Mean± S. E	Mean± S. E	Mean± S. E
10.00 -12.00	9.29±0.01	6.60±0.02	5.88±0.02	11.74±0.02	8.48±0.03	6.75±0.02	12.19±0.01	10.31±0.01	6.29±0.02
12.00-14.00	11.59±0.01	8.26±0.02	10.56±0.01	12.35±0.01	7.63±0.02	12.23±0.01	14.51±0.01	11.57±0.00	13.41±0.02
14.00-16.00	6.42±0.02	6.60±0.02	6.78±0.04	5.56±0.05	7.07±0.04	7.63±0.02	8.08±0.02	9.34±0.01	7.85±0.02
C.D(P=0.05)	0.08	0.09	0.14	0.13	0.16	0.10	0.07	0.04	0.10
S.Em(±)	0.02	0.02	0.03	0.03	0.04	0.02	0.01	0.01	0.02

Conclusion

From the study, it can be concluded that the influence of food reserves resulted in the increase of pollen reserves of the colonies the nectar foraging of the colonies increased, and pollen foraging decreased significantly. Similarly, when the amounts of honey reserves in the colonies were increased, the nectar foraging decreased while the pollen foraging increased significantly. Colony strength and brood, pollen and honey reserves showed a gradual increase with time. However, build pattern of other parameters was highly variable. The foraging activity showed a rhythmic pattern depending upon the level of adaptation and colony strength. Significant increase in foragers collecting pollen only and nectar only was related to the greater availability of pollen and nectar which was mainly due to the blooming of more plant species yielding both pollen and nectar.

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