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Correlation between production and biometric parameters in colonies of *Melipona scutellaris* Latreille, 1811 (Hymenoptera: Apidae)

R. M. O. Alves[1], D. R. Santos[2], A. S. Nascimento[2], G. S. Sodré[2], C. A. L. Carvalho[2]

[1] Instituto Federal de Educação, Ciência e Tecnologia Baiano, Catu
[2] Universidade Federal do Recôncavo da Bahia, Cruz das Almas

Author for correspondence: eiratama@gmail.com

Abstract. Abstract. The basis of all breeding is the selection of desired features that can be sustained when the crosses are made. By identifying these parameters starts a process of linking these with the object of improvement and also between them. The aim of this study was to identify the correlation between yield and biometric of *Melipona scutellaris* colonies. A total of 165 colonies from consecutive generations of a crossbreeding project conducted at UFRB had the variables: number of honey pots (NPM), number of pollen pots (NPP), size of honey pots (TPM), size of pollen pots (TPP), honey production (SMEs), pollen production (PPO), colony population (POP), weight of the queen (PRE), weight of the colony (PCO), size of the combs (ACF), number of combs (NFV), glossae size (GLO) and corbicula area (COR) evaluated. The values were entered into the SAS program and calculated the Pearson's correlations. Only four interactions presented positive values greater than 0.800: NPP x PPO (r= 0.923), TPP x PPP (r= 0.830), PM x NPM (r= 0.958) and TPM x MPV (r= 0.896). The correlations between production parameters and biometric in colonies of *M. scutellaris* show great variation and can be used in projects to species improve.
Keywords: meliponiculture, stingless bees, genetic improvement

Introduction

The basis of genetic improvement is the selection of desirable traits that can be maintained after cross-breeding. Thus, through the genetic evaluation of the studied populations, the best animals are selected, which will result in increased productivity (Gui & Zhu, 2012; Page Jr et al., 2012).

The rational production of bees has as main target their honey production. Honey is the best known and consumed product of the beehive, however other bees products can be exploited for economic purposes (Tsutsumi & Oishi, 2010; Alves et al., 2012). Thus, it is necessary to estimate genetic and phenotypic parameters, for use of genetic improvement and increase of productive potential.

It is believed that there are innumerable genes that control the productive characteristics in bees (Faquinello et al., 2013). The main characteristics used are those of phenotypic character such as: pollen basket size, pupa weight, colony weight, gloss size, honey and pollen production. Faquinello et al. (2013) reported in *Melipona* colonies, these characteristics may be associated with the productivity characteristics of the species. Souza et al. (2002) stated that the economically valuable characteristics in bees can be measured in the colonies, being extremely influenced by the environment.

Several authors have obtained estimates of genetic correlation between bee characteristics (Milne & Pries, 1984; Harbo, 1986; Milne et al., 1986; Souza et al., 2002). For stingless bees, many papers correlated the characteristics associated with the production of honey (Silva Barros, 2006; Aidar et al., 2008ab; Alves et al., 2012; Brito et al., 2013; Faquinello et al., 2013; Oliveira et al., 2015). However, these parameters may differ because of species diversity or heterogeneity of samples.

In this sense, the correlation study provides a better understanding of the relationship between variables, making it possible to perform selection with greater efficiency. Cruz (2001) emphasized that evaluating the correlation between two characteristics can achieve higher gains in the selection process.

The present work aimed to know the correlation between productive and biometric characteristics in colonies of *Melipona scutellaris*, aiming at estimating breeding techniques that increase productive potential.

Methods

The work was developed in the meliponary and laboratory of the Insecta Research Group of the CCAAB / UFRB in Cruz das Almas - BA (12º 39' 20'' W and 39º 07' 23'' S, altitude 220 m). The area is characterized by intense antropic activity, with orchards, diverse plantations and pasture.

A total of 165 colonies from the division of 60 parental colonies obtaining two F1 and F2 generations from a project to select colonies of *Melipona scutellaris* developed at the Federal University of Bahia Recôncavo were used to evaluate the parameters: number of honey pots (NPM), number of pollen pots (NPP), size of the honey pots (cm^2) (TPM), size of the pollen pots (cm^2) (TPP), honey production (mL) (PME), production of pollen (g) (PPO), estimate of the population of the colony (number of individuals (POP), weight of the queen (g) (PRA), net weight of the colony (kg) (PCO), comb size (cm^2) (FAV) and number of combs (NFV). To determine each parameter, 15 samples (n = 15) were used per colony. Twenty workers were collected from each colony and evaluated for characteristics: size of glossae (mm) (GLO) and corbicula area (mm^2) (COR).

The production of honey (PME) was estimated by the relation between the number of pots (NPM) multiplied by the average volume of the honey pots (VPM). Pollen production (PPO) was calculated by the relationship between the number of pollen pots (NPP) multiplied by the average weight of pollen pots (PPP) according to Brito et al. (2013) and Faquinello et al. (2013). The population estimate (POP) of each colony was obtained from the mean number of rearing cells per cm of honeycomb as described in Alves et al. (2012). The data were analyzed by S.A.S. (Statistical Analysis System, SAS Institute Inc.,1982). The design was completely randomized. Pearson's correlation coefficient was used for the correlation calculations.

Results and discussion

The correlation estimates of the characteristics analyzed in the 165 colonies and the significance of the correlations are presented in Table 1.

Correlations between the evaluated parameters presented positive values greater than 0.800 for only 4 interactions: NPP x PPO (r= 0.923), TPP x PPP (r= 0.830), PME x NPM (r= 0.958) and TPM x VPM (r= 0.896). Most of the interactions presented values considered low, but the correlation was positive. The glossae presented only a positive correlation (GLO x MPV) and the other correlations of this parameter were negative. According to Souza et al. (2002) negative correlations are the result of the conception in the elaboration of the statistical model.

Honey production

The correlations between the characteristics and the honey production of the parental colonies and in the F1 and F2 generations showed positive and negative variations. Sousa et al. (2002) reported that in *Apis mellifera* the correlation of honey production with pupal weight, glossae length, corbicula area and tibia length obtained low and positive values.

The number of pots of honey and the size of the pots were the characteristics most correlated with honey production (Table 1) and highly significant. The production of honey is a result of the number of pots of honey multiplied by the average volume of the pots, which shows the relationship between these characteristics and the production of honey. Therefore, larger pots in large quantities are directly related to increased production.

Faquinello et al. (2013) suggested that near the flowering period the bees increase the area of the pots by increasing the storage capacity of the food, being verified in their study with *M. quadrifasciata anthidioides* that the production of honey was related to the number of honey pots of the hive. These results are similar to those recorded in this study with *M. scutellaris*.

The correlation between the volume of the honey pot (VPM) and the honey production (PME) was r= 0.259 and between the volume of the pot and its size was significant (r= 0.896) (Table 1). Larger pots allow greater accumulation of honey by reducing the space occupied, besides allowing lower consumption of honey by the workers in the production of wax, resulting in an increase in the volume of honey accumulated and increase in the final production. However, some factors may influence these characteristics (VPM and PME) as the availability of resources from blossoms, excess or shortage of rainfall and population density of hives (Brito et al., 2013).

The correlations with honey production that presented negative and non - significant values were TPP (r= -0.005) and PPP (r= -0.004). However, NPP (r= 0.142) and PPO (r= 0.155) were positive but not significant, according to Milne & Pries (1984) who stated that pollen production provides an indirect effect on honey production, as increased pollen intake allows an increase in the number of workers collectors and the population in time of abundant flowering. The sudden entrance of pollen during large flowering can induce storage in the mellows between the pots of honey due to the lack of space which causes decrease of the honey production.

The correlation between colony weight and honey production was low and positive (0.058), but not significant. Silva Barros (2006) positively correlated this characteristic with honey production in colonies of *M. scutellaris*. In spite of presenting a positive correlation, the colony weight should not be used as a single criterion in the selection of stingless bee's colonies. It is necessary to evaluate the weight of the selection object (pollen, honey, geopropolis) and not only the colony. Considering that this parameter has been used as a selection criterion in genetic improvement programs (Oliveira et al., 2015).

Table 1. Correlation between parameters: number of pollen pots (NPP), size of the pollen pots (cm^2) (TPP), weight of pollen pots (g) (PPP), production of pollen (g) (PPO), size of the honey pots (cm^2) (TPM), volume of honey pots (mL) (VPM), number of honey pots (NPM), honey production (mL) (PME), colony weight (kg) (PCO), glossae size (mm) (GLO), comb size (cm^2) (FAV), number of combs (NFV), population (number of individuals) (POP), weight of the queen (g) (PRA), corbicula area (mm^2) (COR) from 165 colonies of *Melipona scutellaris*

	NPP	**TPP**	**PPP**	**PPO**	**TPM**	**VPM**	**NPM**	**PCO**	**GLO**	**FAV**	**NFV**	**POP**	**PRA**	**COR**
PME	0.142	- 0.005	- 0.004	0.155	0.323**	0.259**	0.958**	0.058	- 0.151	0.149	0.167*	- 0.103	- 0.030	- 0.095
NPP	.	0.004**	- 0.111*	0.923**	0.078	0.044	0.130	0.141	- 0.054	- 0.088	- 0. 086	- 0.151	- 0.09	- 0.163**
TPP	.	.	0.830**	0.240**	0.403*	0.394**	- 0.11	0.085	- 0.239	0.008	0.085	0.006	- 0.069	0.131
PPP	.	.	.	0.160**	0.460	0.440	- 0.114	0.048	- 0.26*	0.024	0.065	0.012	- 0.125	0.048
PPO	.	.	.	.	0.217**	0.171*	0.100	0.157*	- 0.065	- 0.09	- 0.080	- 0.171*	- 0.099	- 0.157
TPM	.	.	.	.	.	0.896**	0.085*	0.021	- 0.122	0.194*	0.002	0.067	0.133	- 0.075
VPM	.	.	.	.	.	.	0.005	0.038	0.015	0.158*	0.003	0.056	0.098	0.043
NPM	.	.	.	.	.	.	.	0.032	-0.163*	0.110	- 0.167*	- 0.127	- 0.062	- 0.101
PCO	.	.	.	.	.	.	.	.	- 0.038	0.218**	0.078	0.095	- 0.100	0.017
GLO	.	.	.	.	.	.	.	.	.	0.065	- 0.037	0.092	0.191**	- 0.033
FAV	.	.	.	.	.	.	.	.	.	.	- 0.021	0.403**	0.025	- 0.123
NFV	.	.	.	.	.	.	.	.	.	.	.	0.711**	0.021	0.082
POP	.	.	.	.	.	.	.	.	.	.	.	.	0.041	0.002
PRA	.	.	.	.	.	.	.	.	.	.	.	.	.	0.120

** e * - significance 1% and 5% respectively according to the t test.

However, Aidar (1996) and Aidar et al. (2008b) reported that the use of the colony's gross weight may lead to erroneous calculations when estimating honey production and that the parameter (weight) was not significant for increasing the productivity of *M. seminigra* hives in the Amazon.

This criterion of selection requires caution, since there are other factors that may influence the gross weight of the colony, for example for bees of the genus *Melipona* the presence in hives of large geopropolis, as well as population density (Faquinello et al., 2013).

The weight of the queen (PRA) presented a positive (0.030) but low correlation with PME. Aidar et al. (2008a) showed that although the general average showed a high and positive correlation (0.759) between PRA and colony productivity in the *M. seminigra* species in Amazonia, the mean per colony presented a low correlation. Aidar et al. (2008b) obtained in *M. compressipes manaosensis* a low correlation between PRA and PME and verified that the weight of the fertilized queen is not directly correlated with the number of individuals in the colony.

Brito et al. (2013) did not find differences between fecundated queens of *M. quadrifasciata anthidioides* in the F1 and F2 generations and report that the queen's weight was not influenced by environmental conditions such as availability of food in the field, number of individuals in the colony among other factors. The area of the pollen basket (COR) presented a non-significant and low correlation (r= 0.095) with PME, differing from the findings for Apis published by Milne & Pries (1984) and Milne et al. (1986). The area of the pollen basket is influenced by the size of the individual. Bees with larger pollen baskets carry higher pollen load, which will influence the increase in the honey collector population (Milne & Pires, 1984; Milne et al., 1986; Costa-Pereira, 2014), this characteristic being desirable for colony selection to increase hive productivity. Souza et al. (2002) found a high coefficient (r= 0.578) concluding that honey production can be improved through the indirect selection of these characteristics.

The size of the glossae (GLO) presented negative correlations with honey production (PME). According to Sousa et al. (2002) the size of the tongue presented low correlation with the honey production in *A. mellifera* and negative values. Kerr (1969) related the GLO to the production of honey in *A. mellifera carnica*, reporting the possibility of bees with larger glosses to explore flowers with tube of the deep corolla. Ramalho (2004) reported that in the high arboreal strata of the forest many trees have small flowers, but with dense inflorescences being visited by stingless bees. The species *M. scutellaris* inhabits forest regions and explores floral resources of trees and shrubs with large numbers of flowers and shallow corolla tube.

Velthuis et al. (1997) cited that bees do not specialize in visits to flowers based only on glossae length and body size. This statement suggests that honey production may be related to the size of the tongue, but the use of this information as a selection criterion should be careful, since other factors that may attract bees to collect floral resources, such as odor, flower coloration and abundance of the plant species, as well as the health conditions of the colony (Rech et al., 2014, Witter et al., 2014, Pires et al., 2016).

The correlation between the size of the tongue (GLO x PPO) and the queen's weight (PRA x PPO) was negative and not significant (Table 1), showing that these characters have little weight in selection projects for pollen production for the species studied. Souza et al. (2002) estimated that there is influence of the environment on the production of honey, pollen and propolis by bees

The honeycomb size had positive correlation and low values with honey production (Table 1). This correlation is possibly influenced by the high number of workers needed to collect nectar and also the ones that transform the nectar into honey. This increase in population may also favor the collection of other products such as pollen and resin, as well as depending on environmental conditions (Pegoraro et al., 1999).

The number of combs presented negative value and low correlation with honey production (-0.103), being significant at 1%. This is a factor that can influence the production of honey indirectly through the association with the size of the combs implying an increase of the population and consequently a greater number of workers for the collection of resources.

Population (POP) presented a low correlation with PME, which differs from that found by Harbo (1986) and Szabo & Lefkovitch (1989). For these authors the population growth contributes to the greater storage of the honey when maintained a number between the maximum and minimum population in the colony. The characteristics size and number of combs are modulators of the POP parameter, which is directly linked to the PME by increasing the amount of individuals that are destined to the collection of resources.

Information regarding the population of the colony (POP) that reflects the number of individuals in it is important. Normally, colonies with higher population densities also have more bee-bees that can collect more during flowering periods, allowing the defense against enemies and maintenance of the thermal homeostasis of the hive (Brito et al., 2013).

The correlation between NFV and POP was high (0.711), showing that this is an important factor in increasing the number of workers required to produce honey, but if there are management problems and old queens, the combs may be smaller in size, which results in smaller number of collecting bees. At first, it could be estimated that when increasing the number of combs the population would grow in the same proportion, but this fact is true when associated to the size of the combs and not only to the increase of their number.

Pollen production

Among the characteristics correlated with pollen production (PPO), the number of pollen pots (NPP) was high and positive. TPP presented low correlation, because the pot size varies mainly according to the local architecture, genetic effects may contribute to a lower percentage.

The correlation between PPO and PCO was low and positive, but not significant. This fact demonstrated that there is a correlation between weight and productivity. However, not being significant, it was demonstrated that in the evaluation of PCO, the values of all components in the colony must be observed; geopropolis, combos, wax and food pots and subtracting the result of the weight of the pollen to obtain the final production.

Among the correlations of pollen production with the other characteristics that most arouse attention is the low and negative value obtained between COR x PPO (Table 1). This fact diverged from the findings by Helmich et al. (1985), Milne et al. (1986) and Milne & Pries (1984) who demonstrated the relationship between the corbicula area and the pollen collection, that is, bees with larger corbicula area carry more pollen, resulting in a larger number of workers contributing to the production.

The proportion of collecting workers carrying pollen and the amount of pollen harvested increased according to the number of newborns present in the colony (Pegoraro et al., 1999). This study observed that the correlations between COR and PPO were low and not significant between generations and within generations. The relationship between the corbicula area and pollen production demonstrates a non-significant inverse relationship, decreasing COR and increasing PPO between generations (Table 2).

The correlation between PPO and POP was negative and low, but significant. The analysis by generation showed that there was a gradual reduction of the POP among the generations, being the parent that presented higher average contributing to increase of the general average, while the PPO presented growth of the parental generation for F2. Milne & Pries (1984) working with *A. mellifera* reported that the increase of the worker population was due to the greater collection of pollen, which provided a resource to expand the population of the colony. The fact that PPO growth and the reduction of POP and COR between generations is possibly due to the higher value of pollen production during the developmental stages of the F1 and F2 generations.

Gordon et al. (1995) after selection in *A. mellifera* strains found significant correlations among the variables: amount of adult bees and breeding in relation to stored pollen.

The relationship between NFV and PPO was significant at 1% and 5% in parental and F2 with higher parental value, in that generation the colonies were older (Table 3). The value of the mean NFV between the generations decreased, demonstrating that the colonies present NFV variation according to the environmental conditions.

The FAV presented negative variation in all generations and significance at 5% in F1 alone. Higher pollen production may influence honeycomb size, since pollen is stored near the nest, and lack of space can reduce honeycomb size when space is limited.

Table 2. Estimates of correlation, pollen production and corbicula area between and within three generations of the bee *Melipona scutellaris*

Generation	Parental	F1	F2	Generations
Correlation	- 0.001 ns	- 0.094 ns	0.036 ns	- 0. 0157 ns
Pollen production (g) (PPO)	110.36	161.43	204.27	156.39
Corbicula area (mm) (COR)	1.92	1.87	1.80	1.86

ns – not significant at 1%; 5% respectively according to the t test.

Table 3. Correlation coefficients (COR) and mean of pollen production (PPO), population (POP), number of combs (NFV) and honeycomb size (FAV) between and within generations (GER) of bee *Melipona scutellaris*

GER	PPO		POP		NFV		FAV	
	average	cor	average	cor	average	cor	average	cor
P	110.0	- 0.001ns	2485	0.15ns	6.81	0.304 *	8.93	- 0.04ns
F1	161.4	- 0.094ns	2238	- 0.27*	6.35	- 0.080 ns	8.59	- 0.35**
F2	204.2	0.036ns	2236	- 0.15ns	5.63	- 0.035 **	9.56	- 0.09ns
M	156.0	-0.157ns	2326	- 0.17*	6.29	0.080 ns	9.02	- 0.09ns

ns – not significant. ** e * significance at 1%; 5% respectively according to the t test.

Conclusion

The correlations found between the production and biometric parameters in colonies of *Melipona scutellaris* showed great variation and can be used in the genetic improvement of the species as selection criteria.

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