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Path Analysis of Honey Yield Components Using Different Correlation Coefficients in Caucasian Honey Bee

M. Topal, B. Emsen and A. Dodologlu
Department of Animal Science, Ataturk University, 25240, Erzurum, Turkey

Abstract: An experiment was conducted, using coefficients of Pearson correlation (r), Spearman's rho (r_s) and Kendall's tau (τ) to invastigate direct and indirect effects among honey yield and brood area, number of frames covered with bees, weight gain during nectar flow period, sealed queen cell height, emergence weight and pre-oviposition period in Caucasian honey bees. Correlation coefficients between honey yield and weight gain during nectar flow period were found positive and higher than that of other correlations in Caucasian honey bee. Number of frames covered with bees had significant positive relationship with honey yield and weight gain during nectar flow period according to r, r_s and τ in Caucasian. Results derivatives exhibited with respect to the 3 relation measures similarity. The direct effect of WGN and BA on honey yield and indirect effect of NFB on honey yield via WGN were found high and positive in respect of r, r_s and τ.

Key words: Caucasian honey bee, path analysis, spearman's rho, Kendall's tau

INTRODUCTION

The one of the most popular honey, bee races in modern beekeeping is Caucasian honey bee. The Caucasian bees are ardent brood production-raising strong colonies, colonies reach full strength in mid-summer, which is good for areas where the highest nectar flow is in mid-summer, very great user of propolis and in its native area a better honey producer than the *Apis mellifera*.

Beekeepers have long known that different genetic stocks have distinctive characteristics, so they have utilized different strains to suit their particular purpose, whether it is pollination, a honey crop, or bee production. Honey yields depend on many factors such as a succession of flowering plants to provide a regular supply of pollen and nectar over the season, a population of bees to harvest and process the pollen and nectar, the weather and the quality of care bees receive (Holmes, 2000).

Increased honey, wax, propolis, pollen, venom as well as, crop productivity through crop pollination, the prime objective of beekeeping industry, can be achieved by increasing bee strength (Kumar and Singh, 2000). Higher colony population and quality production is possible with improved colony management techniques.

The purpose of this investigation is to study direct and indirect effects of honey yield components on honey yield in Caucasian honey bee. Pearson correlation coefficient was used to path analysis generally but direct and indirect effects were estimated with Kendall's tau and Spearman's rho in this research. Direct and indirect effects determined with respect to three relation measures were compared.

MATERIALS AND METHODS

The experiment was conducted, in a total of 10 Caucasian honey bee colonies. Data on honey yield (kg), brood area (cm^2), number of frames of bees, weight gain during nectar flow period (kg), sealed queen cell height (cm), emergence weight (mg) and pre-oviposition period (day) were evaluated in this study.

The distributional properties of the honey yield and yield components were investigated with Kolmogorov-Smirnov test for normality. This test showed that honey yield and yield components values were normally distributed ($p>0.05$). Although, data showed normal distribution, Kendall's tau and Spearman's rho coefficients was used beside Pearson correlation coefficients to estimate Path coefficients.

Direct and indirect effects of brood area (X_1), number of frames of bees (X_2), weight gain during nectar flow period (X_3), sealed queen cell height (X_4), emergence weight (X_5) and pre-oviposition period (X_6) on honey yield (Y) were investigated using path analysis. Each, predictor variable has one direct effect and one indirect

Corresponding Author: Berna Emsen, Department of Animal Science, Ataturk University, 25240, Erzurum, Turkey

effect for each of the other predictor variables connected with the predictor variable. The total Spearman rank correlations between honey yield and yield components were partitioned direct and indirect effects by following equations:

$$
\begin{aligned}
r_{sY1} &= P_{Y1} + r_{s12}P_{Y2} + r_{s13}P_{Y3} + r_{s14}P_{Y4} + r_{s15}P_{Y5} + r_{s16}P_{Y6} \\
r_{sY2} &= r_{s12}P_{Y1} + P_{Y2} + r_{s23}P_{Y3} + r_{s24}P_{Y4} + r_{s25}P_{Y5} + r_{s26}P_{Y6} \\
r_{sY3} &= r_{s13}P_{Y1} + r_{s23}P_{Y2} + P_{Y3} + r_{s34}P_{Y4} + r_{s35}P_{Y5} + r_{s36}P_{Y6} \\
r_{sY4} &= r_{s14}P_{Y1} + r_{s24}P_{Y2} + r_{s34}P_{Y3} + P_{Y4} + r_{s45}P_{Y5} + r_{s46}P_{Y6} \\
r_{sY5} &= r_{s15}P_{Y1} + r_{s25}P_{Y2} + r_{s35}P_{Y3} + r_{s45}P_{Y4} + P_{Y5} + r_{s56}P_{Y6} \\
r_{sY6} &= r_{s16}P_{Y1} + r_{s26}P_{Y2} + r_{s36}P_{Y3} + r_{s46}P_{Y4} + r_{s56}P_{Y5} + P_{Y6}
\end{aligned} \quad (1)
$$

Path coefficients can be easily calculated with the following solution of matrix system:

$$
\begin{bmatrix} P_{Y1} \\ P_{Y2} \\ P_{Y3} \\ P_{Y4} \\ P_{Y5} \\ P_{Y6} \end{bmatrix} = \begin{bmatrix} r_{s11} & r_{s12} & r_{s13} & r_{s14} & r_{s15} & r_{s16} \\ r_{s21} & r_{s22} & r_{s23} & r_{s24} & r_{s25} & r_{s26} \\ r_{s31} & r_{s32} & r_{s33} & r_{s34} & r_{s35} & r_{s36} \\ r_{s41} & r_{s42} & r_{s43} & r_{s44} & r_{s45} & r_{s46} \\ r_{s51} & r_{s52} & r_{s53} & r_{s54} & r_{s55} & r_{s56} \\ r_{s61} & r_{s62} & r_{s63} & r_{s64} & r_{s65} & r_{s66} \end{bmatrix}^{-1} \times \begin{bmatrix} r_{sY1} \\ r_{sY2} \\ r_{sY3} \\ r_{sY4} \\ r_{sY5} \\ r_{sY6} \end{bmatrix}
$$

In the Eq. (1), coefficients given by P_{yi} were path coefficients (direct effects) between predictor variable i and responsible variable Y and $r_{sij}P_{YY}$ represented indirect effects of independent variable ith on responsible variable via independent variable jth, r_{sij} represented rank correlation coefficients between ith and jth traits. The sum of cdirect and indirect effects gave coefficient of correlation between Y and X_i. Each linear equation consisted of one direct effect and five indirect effects, which number of predictor variables minus one (Topal and Esenbuga, 2001). The determination coefficient (R^2) and residual effect (P_{YU}) were calculated with the following equation (Kang, 1992):

$$
\begin{aligned}
R^2 = (&P_{Y1}^2 + P_{Y2}^2 + P_{Y3}^2 + P_{Y4}^2 + P_{Y5}^2 + P_{Y6}^2 + \\
&2r_{12}P_{Y1}P_{Y2} + 2r_{13}P_{Y1}P_{Y3} + 2r_{14}P_{Y1}P_{Y4} \\
&+ 2r_{15}P_{Y1}P_{Y5} + 2r_{16}P_{Y1}P_{Y6} + 2r_{23}P_{Y2}P_{Y3} + \\
&2r_{24}P_{Y2}P_{Y4} + 2r_{25}P_{Y2}P_{Y5} + 2r_{26}P_{Y2}P_{Y6} + \\
&r_{34}P_{Y3}P_{Y4} + 2r_{35}P_{Y3}P_{Y5} + 2r_{36}P_{Y3}P_{Y6} 2r_{45} \\
&P_{Y4}P_{Y5} + 2r_{46}P_{Y4}P_{Y5} 2r_{56}P_{Y5}P_{Y6})
\end{aligned}
$$

The residual effect was,

$$
P_{YU} = \sqrt{1 - R^2}
$$

We calculated correlation and path coefficients in the MATLAB 7.0 program (MATLAB, 2004).

RESULTS

Correlation coefficients among honey yield, brood area, number of frames of bees, weight gain during nectar flow period, sealed queen cell height, emergence weight and pre-oviposition period were presented in Table 1.

Correlation matrix in each one of three coefficient measure (r, r_s, τ) (Table 1) clearly showed that the correlation between honey yield and weight gain during nectar flow period was found positive and higher than the other correlations. Number of frames of bees had a significant positive relationship among honey yield and weight gain during nectar flow period according to r, r_s and τ in Caucasian. This means that weight gain during nectar flow period and number of frames of bees has linear positive relationship with honey yield. It was observed that, the when the number of frames increased there was also, an increment at weight gain during nectar flow period and the increment in both character provided an increment on honey yield with the direct effects. According to three relationship coefficients, a positive but insignificant relationship was found between honey yield and BA, SQH, EW and POP.

Path coefficients and indirect effects of brood area, number of frames of bees, weight gain during nectar flow period, sealed queen cell height, emergence weight and pre-oviposition period on honey yield calculated according to Pearson correlation (r), Spearman's rho (r_s) and Kendall's tau (τ) were presented in Table 2.

Table 1: Parson correlation (r), spearman's rho (r_s) and Kendall's tau (τ) for honey yield and honey yield components in Caucasian honey bee

Correlation measures		HY	BA	NFB	WGN	SQH	EW
r	BA	0.164					
	NFB	0.641*	0.058				
	WGN	0.834**	0.022	0.719*			
	SQH	0.185	-0.429	0.116	0.008		
	EW	0.028	0.634*	0.372	0.198	-0.287	
	POP	0.424	-0.261	-0.171	0.142	0.525	-0.302
r_s	BA	0.334					
	NFB	0.685*	0.283				
	WGN	0.911**	0.085	0.734*			
	SQH	0.168	-0.310	0.084	0.083		
	EW	0.064	0.669*	0.370	0.095	-0.235	
	POP	0.385	-0.220	-0.153	0.326	0.520	-0.316
τ	BA	0.270					
	NFB	0.494	0.256				
	WGN	0.782**	0.068	0.548*			
	SQH	0.126	-0.199	0.052	0.051		
	EW	0.114	0.494*	0.330	0.092	-0.201	
	POP	0.297	-0.172	-0.128	0.226	0.411	-0.322

*: Significant at the 0.05 probability level, **: Significant at the 0.01 probability level; HY: Honey Yield, BA: Brood Area, NFB: Number of Frames of Bees, WGN: Weight Gain During nectar flow period, SQH: Sealed Queen cell Height, EW: Emergence Weight, POP: Pre-Oviposition Period

Table 2: Direct and indirect effects for analysis honey yield components using Parson correlation (r), spearman's rho (r_s) and Kendall's tau (τ) in caucasian honey bees

Direct	Indirect	Correlation coefficients		
		P_r	P_{rs}	P_τ
BA		0.524	0.539	0.264
	NFB	0.031	0.004	0.021
	WGN	0.010	0.074	0.046
	SQH	0.012	-0.052	-0.013
	EW	-0.294	-0.224	-0.021
	POP	-0.120	-0.007	-0.027
NFB		0.526	0.014	0.083
	BA	0.030	0.153	0.068
	WGN	0.339	0.633	0.375
	SQH	-0.003	0.014	0.003
	EW	-0.172	-0.124	-0.014
	POP	-0.078	-0.005	-0.021
WGN		0.471	0.862	0.684
	BA	0.013	0.046	0.018
	NFB	0.378	0.010	0.045
	SQH	-0.001	0.014	0.003
	EW	-0.092	-0.032	-0.004
	POP	0.065	0.011	0.036
SQH		-0.029	0.167	0.066
	BA	-0.225	-0.168	-0.053
	NFB	0.061	0.001	0.004
	WGN	0.004	0.072	0.035
	EW	0.133	0.079	0.009
	POP	0.241	0.017	0.065
EW		-0.463	-0.335	-0.042
	BA	0.332	0.361	0.130
	NFB	0.196	0.005	0.027
	WGN	0.094	0.082	0.063
	SQH	0.008	-0.039	-0.013
	POP	-0.139	-0.010	-0.051
POP		0.459	0.032	0.158
	BA	-0.137	-0.119	-0.045
	NFB	-0.090	-0.002	-0.011
	WGN	0.067	0.281	0.154
	SQH	-0.015	0.087	0.027
	EW	0.140	0.106	0.014
P_{YU}		0.100	0.090	0.540
R^2		0.990	0.990	0.710

It was observed that, EW (-0.463) and SQH (-0.029) had negative effect, while the maximal positive direct effects on honey yield in Caucasian honey bee were found in NFB (0.526), BA (0.524), WGN (0.471) in path analysis composed according to Pearson correlation coefficients. Honey yield will present, a standart deviation as much the direct effect of independent variables as when there is one standart deviation in each dependent variable. Accordingly, the highest direct of the variable will also have the highest effect on honey yield.

In path analysis constituted according to Spearman and Kendall's tau coefficients, the direct effects of NFB, SQH and POP was positive but very small, negative and very small in EW, while the direct effects of WGN and BA was found positive and large. Besides, the direct effect of NFB on honey yield via WGN was found positive and large in every three relationship measures. In other words, if WGN is large, NFB will get increase depending on WGN and honey yield will get increase according as the increment of WGN and NFB.

It was observed that independent variables of BA, NFB, WGN, SQH, EW and POP could explain honey yield 99% with Path model adjusted according to Pearson correlation and Spearman rho coefficent and 71% with Path model adjusted according to Kendall's tau coefficent. Although, similar results were obtained in path analysis, which was adjusted according to three correlation coefficients, similar results in path analysis model adjusted according to Pearsons and Spearmans correlation coefficent were better than Kendall's tau coefficent. Because, the determination coefficients of path models composed according to r and r_s were found large and their residual effects were determined small as well.

Independent variables explained much better the dependent variable in the model that had a small residual effect. When the variables show normal distribution, direct and indirect effects obtained using Pearson correlation analysis can be used to explain dependent variable regardless of number (n) in the experiment.

DISCUSSION

Bhusal and Thapa (2006) found significantly positive correlation among brood rearing, colony strength, out going bees and honey yield in *Apis mellifera* L. Mostajeran *et al.* (2006) reported that there was a significant positive correlation between brood area and colony population but insignificant correlation between brood area and harvested honey.

Bhusal and Thapa (2006) reported that honey yield was dependent variable on initial bee population in and *Apis mellifera* L. The direct effect of EW was found negative, while its direct effect via BA was positive and large. EW showed positive effect via BA, while it had a negative effect on honey yield alone. There was a positive and significant correlation coefficents between EW and BA, while very small and insignificant correaltion coefficents was observed among EW and honey yield. In this way, when the effect of independent variable was exhibited alone or together it was observed that how dependent variables affected independent variables.

In various apicultural researches, Spearman correlation coefficient was used to investigate among traits (Rinderer *et al*., 2002; Scheiner *et al*., 2003; Erber *et al*., 2006; Seeley and Tarpy, 2007). Pearson and Spearman rank correlation were used to test relationships between colony size and traits (number of workers, sexual and number of the brood, ovarian development) by Strohm and Bordon-Hauser (2003).

In an early study, direct and indirect effects of environmental factors on flight activity of *Apis florae* F. were investigated by Sihag and Abrol (1986).

In the other study, Strohm and Bordon-Hauser (2003) calculated path coefficients the number of workers, sexual and number of the brood on total sexual productive.

CONCLUSION

Consequently, it was determined that the path coefficients obtained according to the different three relation measures showed the similar results in this study. However, it seemed that the relation measures (correlations) between honey yield and yield components were misleading as the path analysis was not taken into consideration. Because, when non-significant and negative correlations were taken into consideration together with the effects of other factors might be significant in path analysis. Owing to this trait, the path analysis is very important to investigate the factors that have an effect on yield. From the result, when the relation between honey yield and yield components were investigated, the path analysis revealed the more potent and real results than the coefficient measures (r, r_s, τ).

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