THE INFLUENCE OF COLONY POPULATIONS ON HONEY PRODUCTION[1]

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INTRODUCTION

Two ultimate objectives form the basis of the beekeeper's business, namely, the production of a crop and the conversion of that crop into money. The amount of honey produced per colony has an even greater significance in determining profits than the market price received for the honey.[3] [4]

Many factors affect the yield of colonies and yet very few usable data have been collected upon which an accurate analysis of the significance of any one factor can be based. The intensity and length of the honey flows are of first importance in characterizing differences between seasons, localities, regions, etc. Populations, races or strains of bees, and management contribute to individual variations between colonies and apiaries under the same honey flow. Individual colonies often produce yields many times the average for an apiary. In a broad sense, variations in yield due to differences in population and management are greater under present conditions than those due to the nature of the honey flow. The average beekeeper is not obtaining the maximum production per colony for any particular season or locality.

The purpose of this paper is to outline a method for making an analysis of the influence of colony populations on production, and to give the preliminary results of studies of this relationship carried on by the Intermountain States Bee Culture Field Laboratory.[5]

METHOD OF OBTAINING DATA

Data were collected on the seasonal changes in colony characteristics of colonies individually isolated to prevent drifting. Records of population and production obtained generally at 12-day intervals were used in this analysis. The populations were determined by obtaining the gross weight of the colony and subtracting the weight of the equipment after the bees had been removed. The bees became thoroughly mixed during the manipulation and a sample of 500 to 800 bees was taken from the cluster, weighed, and counted to obtain the average weight per bee in milligrams. This weight was used to convert the total weight of bees into the total number of bees. The usually

1 Received for publication Jan. 4, 1937; issued July 1937.

2 Forrest R. Hall, associate professor of commerce, University of Wyoming, has kindly given constructive criticism on the various phases of the statistical procedure employed.

3 Sechrist, E. L., and Kifer, R. S. PRELIMINARY REPORT ON APIARY ORGANIZATION AND HONEY PRODUCTION IN THE INTERMOUNTAIN STATES IN 1928. BASED ON STUDIES OF THE BUREAU OF ENTOMOLOGY AND THE BUREAU OF AGRICULTURAL ECONOMICS OF THE UNITED STATES DEPARTMENT OF AGRICULTURE. U. S. Dept. Agr. Rept., 18 pp. 1928. [Mimeographed.]

4 Burrier, A. S., Todd, F. E., and Scullen, H. A. COST OF PRODUCING HONEY IN OREGON FOR THE YEAR 1931. Oreg. Agr. Expt. Sta., Circ. 83, 13 pp. 1932.

5 Located at Laramie, Wyo., and maintained cooperatively by the University of Wyoming and the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture.

accepted number of 5,000 bees per pound is unreliable for estimating colony populations since the average for different colonies or for the same colony at different times may range between 2,800 and 4,800 per pound with the majority approximating 3,500. The record of production gives the net increase in honey for the period intervening between the date of the previous observation and that on which the population was determined.

Colony populations tend continuously to change. They either increase or decrease, although normal colonies are capable of maintaining a maximum population of about 60,000 bees during the active season. All normal colonies respond in a similar manner to their environment. It is well known that the intensity of the honey flow varies greatly according to locality, time of season, and weather. Since the required data can be obtained on only a few colonies in one locality at any time (from 6 to 10 per day), it is both desirable and necessary in analyzing the production-population relationship to standardize the production records to a common honey-flow level from which variations induced by locality and time have been eliminated. If this is possible, then production-population data representing a group of colonies taken for any locality, period, or season can be analyzed statistically and readily compared with any other similar data.

DEVELOPMENT OF STATISTICAL METHODS

A graphic comparison of such data in 1932, represented by seasonal segments for 12 colonies individually isolated to prevent drifting and as nearly equivalent in breeding and management as possible, indicated that there is a straight-line relationship between the population of a colony and its production. The production levels for the various seasonal segments differed considerably whereas the slopes of the regression lines indicating the effect of population on production were fairly similar for all segments. Further study of this relationship has resulted in the development of the following statistical method, in some phases unique: The actual production levels of seasonal segments are standardized to a common honey flow of arbitrary intensity for the purpose of determining a significant correlation coefficient and the mean relative production of colonies varying over the normal population range, i. e., 15,000 to 60,000.

The line of regression is determined by the equation

$$Y=r\frac{\sigma_y}{\sigma_x}[X-M_x]+M_y$$

for each seasonal segment of one of more series of colonies. The values of Y (i. e., the production) for the corresponding values of X (e. g., 15,000 and 30,000 bees) for all seasonal segments are averaged to obtain the mean production level for all segments. This mean regression line is all raised (or lowered) proportionally to an arbitrary production level of 15 pounds for 15,000 bees to give the line of standardization. The actual production data for each seasonal segment are standardized by multiplying each by a factor. These factors are obtained by dividing the production indicated on the line of standardization for the mean population of each seasonal segment by the corresponding actual mean production. The correlation coefficient and regression equation are then computed by the usual methods, using the standardized production data and actual populations for the composite group. When the regression line is determined for the composite standardized data it will fall on the line of standardization (except for negligible differences due to decimals being dropped), giving a check against the computations.

In like manner these standardized regression lines, representing any number of seasons or localities, can be averaged until sufficient data are included to give a better average relationship between colony populations and production. The arbitrary production level of 15 pounds for 15,000 bees used for standardization is entirely within the limits of possible production, although any other level would be equally good in making statistical analyses. It was selected because 15,000 bees is approximately the minimum population for producing colonies. Since the relationship may be better expressed as the "production factor per thousand bees" by dividing any production indicated on the regression line by the corresponding population, the selected standard gives a convenient production factor of unity for producing colonies of minimum population.

APPLICATION OF STATISTICAL METHOD TO DATA

Table 1 summarizes the statistical data obtained from 16 seasonal segments, and the combined standardized data representing a composite of 133 observations, made in 1932 and 1933 on two series of colonies. Table 3 gives the actual population-production data and standardized production data used in determining these constants. The segments are numbered 1 to 16 for the purpose of identifying the actual and standardized regression lines limited by their respective minimum and maximum populations as drawn in figure 1. The high correlation coefficients for most segments indicate a close association between the two factors in question. When the differences in honey flows are eliminated by standardization, the high correlation coefficient of 0.9292 ± 0.0080 is obtained for the composite data. Here the number of cases is sufficiently large to make the coefficient reasonably significant.

Table 2 gives the production factors per thousand bees based on the regression equations given in table 1, the lines of which are drawn in figure 1. When these production factors are averaged for all 16 segments, they may be standardized by dividing each by the average factor for 15,000 bees, to reduce that factor to unity. It will be seen that when these average production factors are standardized, they are equivalent to the production factors obtained from the regression line of the composite standardized data. This duplication of results gives proof that the method presented for standardizing actual productions to a common honey flow does not distort the relationship between the two factors and that the correlation coefficient (r) of 0.9292 ± 0.0080 obtained from the standardized composite data is really significant.

TABLE 1.—*Summary of statistical data obtained in 1932 and 1933 from 16 seasonal segments and combined standardized data showing the population relationship for colonies of bees of three series*

Series and segment no.	Date	Colonies in seasonal segment	Average population (X)	Average production (Y)	Standard deviations		Correlation coefficient (r)	Regression equation	Standardized production for average population	Standardization factor
					σ_x	σ_y				
		Number	*1,000 bees*	*Pounds*	*1,000 bees*	*Pounds*			*Pounds*	
Isolated series for 1932:										
1	July 21	12	22.1	14.4	4.818	6.837	0.8403	$1.1925X-11.95$	27.2	1.889
2	July 27	5	24.3	10.3	5.972	4.116	.6129	$.4224X+.04$	31.0	3.010
3	Aug. 8	5	32.7	27.5	6.117	9.330	.9863	$1.5044X-21.69$	45.4	1.651
4	Aug. 20	6	32.4	40.3	6.237	13.019	.9690	$2.0227X-25.24$	44.9	1.114
5	Sept. 1	6	37.2	10.7	7.107	3.850	.7760	$.4204X-4.94$	53.2	4.972
6	Aug. 2	6	31.2	13.6	6.191	4.948	.8429	$.6736X-7.42$	42.9	3.154
7	Aug. 14	6	37.6	54.0	5.237	11.104	.7214	$1.5296X-3.51$	53.9	.998
8	Aug. 26	6	38.5	41.0	4.493	4.540	.7722	$.7803X+11.00$	55.4	1.351
Isolated series for 1933:										
9	July 20–21	12	20.4	22.2	6.271	9.679	.7264	$1.1212X-.67$	24.3	1.095
10	Aug. 1–2	12	28.8	32.8	7.471	12.798	.8995	$1.5408X-11.58$	38.7	1.180
11	Aug. 13–14	12	36.9	53.8	8.134	16.571	.9198	$1.8739X-15.34$	52.7	.980
Pollen series for 1933:										
12	July 10	9	32.9	18.8	10.229	8.021	.7685	$.6026X-1.03$	45.8	2.436
13	July 23	9	40.8	31.9	10.543	9.097	.8680	$.7489X+1.35$	59.4	1.862
14	Aug. 3	9	44.4	47.8	6.463	13.776	.7537	$1.6065X-23.53$	65.6	1.372
15	Aug. 15	9	47.5	54.3	5.734	9.543	.4445	$.7398X+19.16$	70.9	1.306
16	Aug. 29	9	51.9	51.7	7.086	12.614	.7495	$1.3342X-17.54$	78.5	1.518
Total or average		133						$1.1321X-7.1$		1.515
Line of standardization		133						$1.7200X-10.8$		
Production standardized		133	34.6	48.7	11.5474	21.2769	$0.9292\pm.0080$	$1.7121X-10.54$		

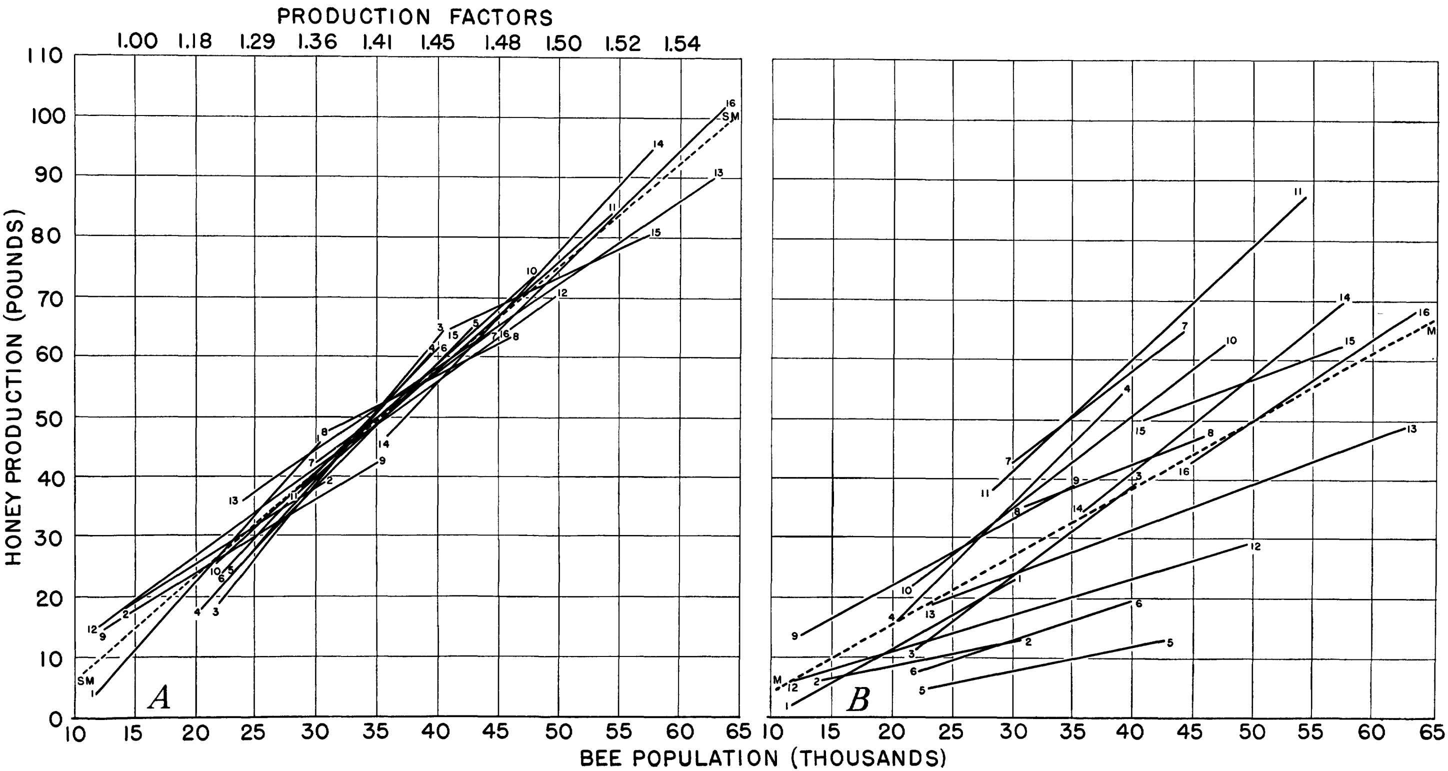

FIGURE 1.—Influence of colony population on production as indicated by statistical data obtained from 16 seasonal segments and two series of colonies, 1932 and 1933: *A*, Standardized mean (*SM*) of seasonal segments—standardized segments (1–16, see tables 1–3) of population ranges; *B*, actual regression lines of seasonal segments (1–16) of population ranges—actual mean (*M*) of seasonal segments.

TABLE 2.—*Production factors per thousand bees based upon seasonal regression lines for actual production and upon standardized regression lines*

Series and segment no.	Date	Production factor per 1,000 bees for colonies of—									
		15,000	20,000	25,000	30,000	35,000	40,000	45,000	50,000	55,000	60,000
Isolated series for 1932:											
1	July 21	0.393	0.595	0.716	0.793	0.851	0.895	0.927	0.954	0.975	0.993
2	July 27	.423	.423	.424	.424	.423	.423	.423	.423	.423	.423
3	Aug. 8	.060	.420	.636	.780	.886	.963	1.022	1.070	1.111	1.143
4	Aug. 20	.340	.760	1.012	1.180	1.303	1.393	1.462	1.518	1.564	1.602
5	Sept. 1	.093	.175	.224	.257	.280	.298	.311	.322	.331	.338
6	Aug. 2	.180	.305	.376	.427	.463	.490	.509	.526	.538	.550
7	Aug. 14	1.293	1.355	1.388	1.413	1.429	1.443	1.451	1.460	1.465	1.472
8	Aug. 26	1.513	1.330	1.220	1.147	1.094	1.055	1.024	1.000	.980	.963
Isolated series for 1933:											
9	July 20–21	1.080	1.090	1.096	1.100	1.103	1.105	1.107	1.108	1.109	1.110
10	Aug. 1–2	.767	.960	1.076	1.153	1.209	1.253	1.284	1.310	1.331	1.348
11	Aug. 13–14	.853	1.105	1.260	1.363	1.434	1.490	1.533	1.568	1.595	1.618
Pollen series for 1933:											
12	July 10	.533	.550	.560	.567	.574	.578	.580	.582	.584	.585
13	July 23	.840	.815	.804	.793	.789	.783	.780	.776	.773	.772
14	Aug. 3	.040	.430	.664	.823	.934	1.013	1.084	1.136	1.178	1.215
15	Aug. 15	2.020	1.700	1.508	1.380	1.289	1.220	1.167	1.124	1.087	1.058
16	Aug. 29	.167	.455	.632	.750	.834	.895	.944	.985	1.015	1.042
Average		.6622	.7793	.8498	.8968	.9309	.9561	.9755	.9914	1.0037	1.0145
Average standardized		1.00	1.18	1.28	1.35	1.41	1.44	1.47	1.50	1.52	1.53
Line of standardization		1.00	1.18	1.29	1.36	1.41	1.45	1.48	1.50	1.52	1.54

The validity of including segment 2 in the composite analysis might be questioned, since this segment covers a production period of only 6 days and all other segments represent practically 12-day periods (table 3). It should be recognized that the production period has no significance in determining the relative production between colonies so long as it is constant for the group. The available nectar varies from day to day, being determined by climatic and honey-plant conditions. Actual gains in honey may be made during only a small portion of the production period whether this covers 6, 10, 12, or even more days. The production periods in this type of analysis, however, should not be too long, since smaller colonies make larger proportional gains in population owing to more intensive brood rearing, [6] permitting these to raise their population-production level within the production period.

TABLE 3.—*Population-production data for colonies of bees in 16 seasonal segments, involving the isolated series for 1932 and the isolated and the pollen series for 1933*

ISOLATED SERIES FOR 1932

Segment and colony no.	Population	Production	Standardization factor	Standardized production
Segment 1 (July 21):	*Thousands*	*Pounds*		*Pounds*
1	21.0	12.1	1.889	22.9
2	24.4	11.6		21.9
3	11.6	3.7		7.0
4	18.1	11.4		21.5
5	21.2	17.7		33.4
6	25.4	21.9		41.4
7	22.4	14.4		27.2
8	16.5	5.9		11.1
9	27.9	15.2		28.7
10	23.3	15.0		28.3
11	22.7	13.1		24.7
12	30.3	31.2		58.9

[6] FARRAR, C. L. THE INFLUENCE OF THE COLONY'S STRENGTH ON BROOD REARING. Ontario Dept. Agr., Beekeepers' Assoc. Ann. Rept. 51–52: 126–130, illus. 1932.

TABLE 3.—*Population-production data for colonies of bees in 16 seasonal segments, involving the isolated series for 1932 and the isolated and the pollen series for 1933*—Continued

ISOLATED SERIES FOR 1932—Continued

Segment and colony no.	Population	Production	Standardization factor	Standardized production
	Thousands	*Pounds*		*Pounds*
Segment 2 (July 27):			3.010	
1	24.3	11.0		33.1
3	14.1	3.3		9.9
4	22.5	15.0		45.2
5	29.9	8.8		26.5
6	30.6	13.6		40.9
Segment 3 (Aug. 8):			1.651	
1	33.7	30.5		50.4
3	21.9	10.9		18.0
4	31.8	24.5		40.4
5	36.0	34.4		56.8
6	40.3	37.2		61.4
Segment 4 (Aug. 20):			1.114	
1	36.9	51.5		57.4
2	20.4	17.3		19.3
3	28.7	28.0		31.2
4	34.6	49.4		55.0
5	34.5	44.8		49.9
6	39.2	50.7		56.5
Segment 5 (Sept. 1):			4.972	
1	41.9	13.3		66.1
2	23.0	5.4		26.8
3	33.5	9.3		46.2
4	39.7	6.5		32.3
5	42.6	14.7		73.1
6	42.7	15.0		74.6
Segment 6, (Aug. 2):			3.154	
7	30.9	13.9		43.8
8	22.1	8.1		25.5
9	38.2	16.7		52.7
10	27.7	14.8		46.7
11	28.3	6.8		21.4
12	40.0	21.3		67.2
Segment 7 (Aug. 14):			.998	
7	44.3	54.5		54.4
8	33.4	36.2		36.1
9	43.4	69.7		69.6
10	35.1	51.8		51.7
11	30.0	46.9		46.8
12	39.7	65.0		64.9
Segment 8 (Aug. 26):			1.351	
7	38.4	42.2		57.0
8	37.0	34.2		46.2
9	46.0	47.1		63.6
10	37.7	39.2		53.0
11	31.0	37.6		50.8
12	40.9	45.9		62.0
ISOLATED SERIES FOR 1933				
Segment 9 (July 20–21):			1.095	
1	16.3	15.4		16.9
2	19.6	17.6		19.3
3	18.5	24.4		26.7
4	19.2	32.6		35.7
5	23.4	30.2		33.1
6	16.6	27.0		29.6
7	12.3	14.4		15.8
8	15.5	11.1		12.2
9	31.0	25.8		28.3
10	19.1	13.1		14.3
11	17.9	11.1		12.2
12	35.1	43.5		47.6
Segment 10 (Aug. 1–2):			1.180	
1	24.8	31.4		37.1
2	28.9	25.2		29.7
3	22.2	21.5		25.4
4	27.5	38.6		45.5
5	28.3	28.5		33.6
6	24.8	34.9		41.2
7	23.7	24.0		28.3
8	21.6	14.0		16.5
9	40.7	54.3		64.1
10	29.3	27.1		32.0
11	25.4	33.6		39.6
2	47.8	61.0		72.0

TABLE 3.—*Population-production data for colonies of bees in 16 seasonal segments, involving the isolated series for 1932 and the isolated and the pollen series for 1933*—Continued

ISOLATED SERIES FOR 1933—Continued

Segment and colony no.	Population	Production	Standardization factor	Standardized production
Segment 11 (Aug. 13–14):	*Thousands*	*Pounds*		*Pounds*
1	31.8	41.0		40.2
2	28.4	45.0		44.1
3	32.0	33.7		33.0
4	38.3	59.1		57.9
5	38.0	55.0		53.9
6	32.6	48.0		47.0
7	33.1	54.5	0.980	53.4
8	29.8	34.6		33.9
9	53.4	75.8		74.3
10	36.9	61.9		60.7
11	34.3	43.8		42.9
12	54.4	93.4		91.5

POLLEN SERIES FOR 1933

Segment and colony no.	Population	Production	Standardization factor	Standardized production
Segment 12 (July 10):				
2	22.6	19.6		47.7
3	33.7	22.2		54.1
4	11.9	4.0		9.7
5	37.9	17.6		42.9
6	35.9	17.1	2.436	41.7
7	41.1	33.6		81.8
8	49.6	27.4		66.7
9	29.3	15.0		36.5
10	33.8	12.8		31.2
Segment 13 (July 23):				
2	30.6	30.0		55.9
3	42.9	29.0		54.0
4	23.3	10.5		19.6
5	37.7	32.4		60.3
6	45.8	35.1	1.862	65.4
7	48.1	34.4		64.1
8	62.7	47.2		87.9
9	36.7	32.0		59.6
10	39.6	36.8		68.5
Segment 14 (Aug. 3):				
2	38.6	32.6		44.7
3	48.5	51.8		71.1
4	35.8	21.5		29.5
5	42.2	54.8		75.2
6	46.1	63.6	1.372	87.3
7	50.2	66.0		90.6
8	57.6	56.0		76.9
9	41.1	41.0		56.3
10	39.4	42.7		58.6
Segment 15 (Aug. 15):				
2	40.8	51.7		67.5
3	57.6	72.0		94.0
4	43.4	66.5		86.8
5	46.0	50.4		65.8
6	43.8	56.1	1.306	73.3
7	48.9	44.7		58.4
8	57.4	57.7		75.4
9	44.5	49.4		64.5
10	44.8	40.0		52.2
Segment 16 (Aug. 29):				
2	44.8	50.0		75.9
3	60.5	65.4		99.3
4	63.6	73.9		112.2
5	46.8	50.4		76.5
6	48.4	58.7	1.518	89.1
7	60.9	55.2		83.8
8	46.9	31.7		48.1
9	45.6	41.4		62.8
10	49.3	38.3		58.1

APPLICATION OF RESULTS

It will be seen in table 2 that the production per unit of bees substantially increases, on the average, as the population increases. This also holds true in 12 out of 16 segments. Segment 2 did not vary over the population range of 14,100 to 30,600; segments 8, 13, and 15 show decreases in production per unit of bees although all three represented comparatively narrow population ranges. The standardized production factors per unit of bees may be interpreted to mean that one colony with 60,000 bees will probably produce 1.54 times as much honey as four colonies each with 15,000 bees; one colony with 45,000 bees will probably produce 1.48 times as much honey as three colonies each with 15,000 bees; one colony with 30,000 bees will probably produce 1.36 times as much honey as two colonies each with 15,000 bees.

In localities where the honey flow is of short duration, ranging from 10 to 40 days, the significance of this marked advantage in strong colonies is readily apparent. In localities having an extended honey flow lasting from 60 to 90 days, as is characteristic of the intermountain region, the advantage of strong colonies at the beginning of the flow is still evident although to a less extent than where the flow is short. This situation results from the fact that smaller colonies rear more brood in proportion to their population than do large colonies [7] and are thus able to gain in strength more rapidly. The stronger colony actually rears more brood, other things being equal, than do smaller colonies and is thus able to maintain its advantage until a maximum strength of approximately 60,000 bees is reached for all colonies.

The same amount of honey can be produced from a small number of strong colonies at a greater saving in both labor and equipment than from a larger number of small colonies. This fact is particularly significant in determining profit or loss under low honey prices and it should be recognized as a sound business principle when dealing with a favorable market.

SUMMARY AND CONCLUSIONS

A high correlation and a linear relationship were found to exist between the populations of small groups of colonies and their respective productions during periods of less than 2 weeks when all colonies had access to the same source of nectar for the same period of time. The production level varied between seasonal or locality segmental groups of colonies owing to differences in the amount of nectar available, but the relative production slopes of 16 segments when reduced to standard production factors per unit of bees were found to be fairly similar.

A method was developed of standardizing segmental population-production data to a standard honey-flow level by averaging the actual regression lines of the segmental data. This average line is raised (or lowered), all points proportionally, to a selected standard where 15,000 bees produce 15 pounds of honey. A standardization factor is obtained for each segment by dividing the production indicated on the line of standardization for its mean population by its respective actual mean production. The actual production for each

[7] FARRAR, C. L. See footnote 6.

colony in a segment is then multiplied by the standardization factor representative of its segment to obtain the standardized production. When the standardized production for each of 133 cases representing 16 seasonal segments was correlated with the actual population, a correlation coefficient of 0.9292±0.008 was obtained. The resulting regression equation was determined and found practically to coincide with the line of standardization. When this line was reduced to factors representing the mean relative production per thousand bees over the normal colony population range it was found that bees in colonies with 30,000, 45,000, and 60,000 bees produced at a rate of 1.36, 1.48, and 1.54 times as much honey, respectively, as colonies with 15,000 bees.

The lines representing the slopes of the different seasonal segments and extending over the normal population range, i. e., 15,000 to 60,000 bees, were factored. These factors when averaged and reduced to the standard of unity of 15,000 bees, were the same as those derived from the regression line of the composite standardized data. This procedure demonstrates that the standardization method does not distort the relationship existing between the actual population and production data and indicates that the coefficient of correlation, 0.9292, thus obtained can be considered significant.

The conclusion may be drawn from the production factors derived that the production efficiency of colonies increases as the population increases throughout the normal population range of 15,000 to 60,000 bees.

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