Estimation of breeding values of sires in Crossbred Jersy cattle

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Abstract

Sire evaluation is one of the most important aspects of breed improvement programs which involve the estimation of breeding value of the bulls on the basis of their daughter's first lactation 305-day milk yield. Hence, the present research work was planned to estimate breeding value of Jersey crossbred sires on the basis of their daughter's first lactation 305-day milk yield, which are under Progeny testing programme, Andhra Pradesh Livestock Development Agency in Chittoor district of Andhra Pradesh. A total of 1200 progeny records belonging to 20 Jersey crossbred sires were utilized to estimate breeding values of sires for first lactation milk yield traits by using three different methods of sire evaluation viz., least squares method (LSM), best linear unbiased prediction (BLUP) and restricted maximum likelihood (REML) methods. The average breeding values for age at first calving, first lactation length, first service period and first dry period were 1045.14, 293.55, 149.40 and 113.83 days by LSM metho d and 1045.52, 294.54, 145.04 and 107.50 days by BLUP method and 1043.88, 295.86, 157.83 and 123.36 days by REML method for the respective traits. The error variance for REML method was lowest 18817.10 day^2 for age at first calving, 377.45 day^2 for first lactation length and 2720.81 day^2 for first dry period, whereas for first service period BLUP method had lower error variance of 6689.49 day^2. The highest coefficient of determination values for age at first calving (11.40%) and first dry period (37.60%) were noticed in REML method, whereas for the first lactation length (5.60%) and first service period (14.90%) highest R^2 value was observed in LSM method. The coefficient of variation values for most the first lactation milk yield traits were found to be almost similar by LSM and BLUP methods; for age at first calving (13.76%), for first service period (52.18% & 51.82%) and for first dry period (51.15% & 50.95%). The rank correlations and product moment correlations for FLMY traits estimated by three sire evaluation methods were found to be highly significant ($P \leq 0.01$). Rank correlations values ranged from 0.693 (LSM with REML) to 1.000 (BLUP with REML), whereas product moment correlations values ranged from 0.772 (LSM with REML) to 1.000 (BLUP with REML). REML was found to be most effective method of sire evaluation compared to other methods for the present set of data.

Key words: Age at first calving, Breeding value, Correlations, Jersy crossbred cattle, Progeny and Traits.

Introduction

Genetic improvement for growth and milk yield in crossbred cattle is of great importance in country like India, since crossbreds contribute more than 26.47% of milk production in our country. Indian crossbred cattle population produce 74.4 million tonnes of milk, out of which 15.4 million tonnes contributed from Andhra Pradesh (BAHS, 2024). The net returns from milk production calculated based on ₹ per day per cow significantly differ between crossbred cows and local cows (Shashikant *et al.,* 2024) therefore rural folks are adopting crossbred cows for dairy purpose. Selection of superior sires is the quickest path to genetic improvement, as sires are easily and rapidly disseminated in various herds under Progeny Testing Programme (Kumar *et al.,* 2017). Hence, the present research work was undertaken to estimate breeding value of Jersey crossbred sires on the basis of their daughter's first lactation 305-day milk yield, which are under Progeny testing programme, Andhra Pradesh Livestock Development Agency in Chittoor district of Andhra Pradesh.

There are several methods of sire evaluation *viz.,* Simple daughters average index, Least squares method (LSM), Simple regressed least squares (SRLS), Best linear unbiased prediction (BLUP), Derivative free restricted maximum likelihood (DFREML) and Restricted maximum likelihood (REML) for single as well as multiple traits models, which were studied and compared by different researchers (Banik and Gandhi, 2010; Dongre and Gandhi, 2014; Bajetha *et al.,* 2015a and Lodhi *et al.,* 2016a). Least squares method (LSM), Best linear unbiased prediction (BLUP) and Restricted maximum likelihood (REML) methods are used for sire evaluation in the present study. These methods will be compared to assess accuracy, stability and efficacy by utilizing standard error of the estimates, coefficient of variation and coefficient of determination. Spearman's rank correlation among ranks and product moment correlation among estimates of sire merit were used to judge the relative efficiency of different methods of sire evaluation. Therefore, the present investigation was carried out to find effective sire evaluation method for first lactation reproductive traits in Jersy crossbred cattle.

Materials and Methods

Data for the present investigation were collected from history cum pedigree sheet of 1200 Jersey crossbred cattle over a period of 5 years (2013-2018) sired by 20 Jersey crossbred sires maintained under field conditions by selected farmers under progeny testing programme in Chittoor district Andhra Pradesh. Cows with abnormal and incomplete records were excluded from the study. Only the sires having records on at least 5 daughters were included in the present study. The records of only those animals with known pedigree and normal lactation were considered. The lactation records of less than 100 days were considered as abnormal and were not included in the analysis. The total duration of the present study was divided into 3 periods. Each year was divided into three seasons namely winter (November-February), summer (March-June) and Rainy (July-October). The traits considered in the present study were age at first calving (the age of a female animal at the time she gives birth to her first calf), first lactation length (the total number of days a cow produces milk after giving birth for first time, until she dries off), first service period (age at which a heifer is first inseminated or naturally mated with the intention of becoming pregnant) and first dry period (interval between the end of the first lactation and the birth of the second calf, during which the cow is not milked).

Statistical analysis: Jersey crossbred sires were evaluated on the basis of first lactation 305 days milk yield using three methods of sire evaluation, viz. Least Squares Method (LSM Harvey,1987), Best Linear Unbiased Prediction (BLUP Henderson,1973) and Restricted Maximum Likelihood Method (REML Meyer, 2007). The effectiveness of different sire evaluation methods was judged by using the various criteria like error variance, coefficient of determination (R^2), coefficient of variation (CV %), rank correlation and product moment correlation. The sire evaluation method with lowest error variance was considered the most efficient method. The spearman's rank correlations and product moment correlations between the breeding values of sires derived from by various for the traits used to judge the effectiveness of the methods

Statistical Model

Least-squares method (LSM)

Sire was treated as random effect and other non-genetic factors (season, period and herd) were taken as fixed effects in statistical model is $Y_{ij} = \mu + S_i + e_{ij}$., ($Y_{ij} = j^{th}$ dependent single trait of daughter of i^{th} sire., μ = Population means., S_i = Effect of i^{th} sire and e_{ij} = Random error assumed to be distributed normally and independently with mean zero and constant variance i.e. NID (0, σ^2_e).

Best Linear Unbiased Prediction (BLUP) method

In the present study the BLUP evaluations were obtained by using Harvey software under Univariate animal model and the matrix notation of the model is Y = Xb + Za +e., (Y = Observational matrix of traits., b = Vector of

fixed effects., a = Vector of random sire effects., X and Z= Design matrices for fixed and random effects, respectively and e = Vector of random residual effects).

Restricted Maximum Likelihood method (REML)

In the matrix notation, the mathematical model of REML can be written as: $Y_{ijk} = X_{bi} + Z_{ui} + e_{ijk}$., ($Y_{ijk} = k^{th}$ observation of j^{th} random effect of i^{th} fixed effect., b_i = Vector of observation of fixed effect i.e. Season, Period., u_i = Vector of additive genetic effect (Random effect/Sire effect)., X = Design matrix/Incident matrix of fixed effect., Z = Design matrix/Incident matrix of random effect and e_{ijk} = Vector of residual errors).

Results and Discussion

The breeding value of 20 Jersey crossbred sires were computed using least squares method (LSM), best linear unbiased prediction (BLUP) and restricted maximum likelihood (REML) methods for different reproductive traits. The above methods were compared to assess accuracy and efficiency by applying the error variance, coefficient of determination (R^2), coefficient of variation (CV %), rank correlation and product moment correlation.

Age at first calving

The average breeding value of Jersey crossbred sires for age at first calving estimated by different methods was found to be 1045.14 days (LSM), 1045.52 days (BLUP) and 1043.88 days (REML). The minimum and maximum breeding values under different methods varied from 989.25 to 1093.21 days (LSM), 1011.16 to 1077.50 days (BLUP) and 975.94 to 1107.79 days (REML), with a difference of 103.96, 66.34 and 131.85 days, respectively (Table 1). These values were almost comparable with the reported values in literature by Divya (2012) in Karan Fries (1015 days) by REML method and Kumar et al. (2017a) in Holstein Friesian crossbred cattle (1092 days) by LSM. However, Bjetha et al. (2015a) in Sahiwal cattle (1177.65 days) by LSM method, Lodhi et al. (2015) in Cross bred cattle (1198.42 days) by BLUP method and Singh and Singh (2016b) in Cross bred cattle (1359.95) by BLUP method was higher than the present study.

Among 20 tested sires, sire no. 24 recorded the best breeding value (indicating early age at first calving) under all the three methods (975.94 days by REML: 989.25 days by LSM: 1011.16 days by BLUP), which indicates that all methods have higher degree of similarity in estimating breeding value of sires (Table 1).

First lactation length

The average breeding value for first lactation length estimated by different methods was found to be 293.55 days (LSM), 294.54 days (BLUP) and 295.86 days (REML). The minimum and maximum breeding values under different methods were 284.09 and 301.42 days (LSM), 294.03 and 295.41 days (BLUP) and 294.92 and 297.48 days (REML), with a difference of 17.33, 1.38 and 2.56 days, respectively (Table. 2), which was less than the value reported in literature by Dash et al. (2014).

Among the tested sires, the highest breeding value for first lactation length observed was 301.42 days (LSM) in sire no. 3611, followed by sire no. 283 as 297.48 days (REML) and 295.41 days (BLUP). The lowest breeding value observed was 284.09 days (LSM) in sire no. 140, followed by sire no. 4304 as 294.03 days (BLUP) and 294.92 days (REML) (Table 1).

First Service Period:

The results indicated that the better average breeding value for first service period (145.40 days) was observed by best linear unbiased prediction method (Table 1). However, this value was less than the reported values in literature by Lodhi et al. (2015). The better estimated breeding value was (119.73 days) recorded by least squares method, which has 19.66% genetic superiority over the average breeding value.

The highest difference between maximum and minimum breeding values was observed (63.54 days) by least squares method. These values are well within the range of results reported by Kishore (2012). Similar findings by LSM method were reported by Dahiya et al. (2005), Bajetha et al. (2015a), Lodhi et al. (2015) and Satish (2015). Among the 20 tested sires, for first service period sire no. 4304 recorded the best breeding value of 119.73 days by LSM method and 144.72 days by BLUP method. (Table 1)

First dry period

The average breeding value of Jersey crossbred sires for first dry period estimated by different methods was found to be 113.83 days (LSM), 107.50 days (BLUP) and 123.36 days (REML). The minimum and maximum breeding

values under different methods were 75.61 and 212.02 days (LSM), 88.39 and 136.82 days (BLUP) and 85.71 and 181.99 days (REML), with a difference of 136.42, 48.43 and 96.28 days, respectively (Table 2). The better estimated breeding value was (75.61 days) observed by least squares method which has 35.58% genetic superiority over the average breeding value as compared to other methods. These results are well within the range of values reported by Bajetha et al. (2015a) and Lodhi et al. (2015). Among the 20 tested sires, sire no. 13 recorded best breeding value for first dry period under all three methods (75.61 days by LSM: 85.71 days by REML: 88.39 days by BLUP) whereas, the sire no. 127 recorded the breeding value of 212.03 days by LSM method (Table 1)

Error variance

Table 3 revealed that on the basis of error variance of the estimates, restricted maximum likelihood method was the most efficient method with low error variance value for all first lactation milk yield traits, as 18817.10 day^2 for age at first calving, 377.45 day^2 for first lactation length and 2720.81 day^2 for first dry period except for first service period as 6689.49 day^2 by BLUP. Dash et al. (2014) also reported that REML method is the most efficient over the least squares and best linear unbiased prediction methods of sire evaluation. While Abbas et al. (2016) and Singh and Singh (2016) considered BLUP as most efficient method.

The findings of present study revealed that best linear unbiased prediction was found to be second efficient method for reproductive traits like age at first calving, first lactation length and first dry period.

Coefficient of determination (R^2%)

In the present study, the restricted maximum likelihood method showed highest R^2 value (%) for majority of the first lactation milk yield traits, as 11.40 (AFC) and 37.60 (FDP), followed by LSM method where R^2 values for the respective traits were 10.40 and 31.80. Similar to these findings, Dash et al. (2014) reported higher R^2 value for first lactation milk yield traits by REML method (Table 3)

For first lactation length and first service period the higher R^2 value (%) was found by least squares method (5.60 and 14.90), followed by restricted maximum likelihood (1.50) method for first lactation length and best linear unbiased prediction (11.20) method for first service period. These results are in agreement with the findings of Abbas et al. (2016) and Singh and Singh (2016).

Based on R^2 values as criterion to judge the accuracy of sire evaluation methods, REML was founded to be fittest over LSM and BLUP methods for majority of first lactation milk yield traits, whereas for first lactation length and first service period LSM was found to be the most accurate method.

Coefficient of variation (CV %**)**

The contents of Table 2 revealed that least squares and best linear unbiased prediction methods were found to be with similar lower coefficient of variation values for majority of first lactation reproductive traits. While Abbas et al. (2016) and Singh and Singh (2016) considered BLUP as most efficient method over LSM method.

Rank correlations and product moment correlations among different sire evaluation methods for first lactation reproductive traits.

The Spearman's rank correlations among sire ranks and simple product moment correlations between estimated breeding values of sires were also used to judge the effectiveness of different sire evaluation methods.

Rank correlations

The rank correlation coefficient between sires evaluated by various methods of sire evaluation for all first lactation milk yield traits were found to be highly significant ($P \leq 0.01$) (Table 3; above diagonal) and ranged from 0.897 (LSM x REML) to 0.986 (LSM x BLUP) for first lactation length and 0.972 (LSM x REML) to 0.998 (BLUP x REML) for first dry period, whereas for age at first calving the value was found to be unity (1.00) by all three methods.

The higher (near to unity) rank correlations amongst sires from different sire evaluation methods have higher degree of similarity of ranking. Ranking of sires by using anyone of these methods could result in similar ranking of sires ranging from 89% to 98 % for first lactation length, 100% for age at first calving and 97% to 99% for first dry period. The present findings confirmed with the results of Bajetha et al. (2015) who also reported highly significant rank correlations (0.90 to 0.99) for first lactation reproductive traits. For first service period, rank correlations among breeding values of sires were found to be moderate (0.693; LSM with REML) to high (0.950; LSM with BLUP) indicating that these methods could result in similar ranking of sires ranging from 69 to 95%.

The present study revealed that BLUP with REML method are equally effective and could be better option for estimating breeding values for age at first calving and first dry period traits, whereas for first lactation length and first service period, LSM with BLUP method could be better option for estimating breeding values of sires than other methods. Similar findings were also reported by Bajetha et al. (2005), Singh and Singh (2016) for majority of the first lactation reproductive traits.

Table 1. Breeding value estimates for Age at first calving, first lactation length, first service period and first dry period using different sire evaluation methods in Jersey crossbred sires.

Sire Id	Age At First Calving			First Lactation Length			First Service Period			First Dry Period		
	LSM (days)	BLUP (days)	REML (days)	LSM (days)	BLUP (days)	REML (days)	LSM (days)	BLUP (days)	REML (days)	LSM (days)	BLUP (days)	REML (days)
4	1008.95	1025.86	1005.16	295.18	294.66	296.08	160.34	145.40	157.99	116.47	109.39	127.38
13	994.12	1014.26	982.06	293.64	294.58	296.56	134.12	144.89	157.48	**75.61**	**88.39**	**85.71**
24	**989.25**	**1011.16**	**975.94**	291.20	294.33	295.47	158.05	145.43	158.03	160.74	136.82	181.99
26	1089.44	1072.51	1097.77	297.40	294.73	296.21	136.66	145.06	157.65	150.78	118.71	145.65
127	1089.03	1071.47	1095.66	291.81	294.44	295.67	132.52	144.97	157.56	212.03	131.60	171.24
140	1057.60	1052.66	1058.33	**284.09**	294.06	294.97	143.92	145.19	157.38	120.61	109.37	127.18
141	1058.56	1054.70	1062.46	294.91	294.63	296.02	163.01	145.58	158.18	107.93	106.65	121.91
142	1051.57	1049.04	1051.14	293.08	294.51	295.31	183.27	145.59	158.19	140.48	115.91	140.22
144	1076.12	1065.55	1083.99	294.09	294.57	296.41	181.97	145.87	158.47	135.70	117.29	143.04
208	1034.22	1038.34	1029.89	288.16	294.07	294.99	145.69	145.17	157.16	85.51	98.06	104.88
279	1061.95	1055.52	1064.04	295.92	294.65	296.06	132.55	144.99	157.59	80.27	97.63	104.03
281	1022.49	1031.13	1015.61	298.93	294.92	296.58	145.61	145.20	157.44	80.38	91.30	91.55
283	1033.65	1036.63	1026.54	300.96	**295.41**	**297.48**	157.60	145.55	158.15	88.93	102.35	113.27
3606	1052.51	1049.93	1052.92	287.57	294.14	295.11	144.18	145.14	**156.90**	83.75	98.67	106.15
3610	1068.23	1059.34	1071.62	293.73	294.53	295.67	145.70	145.21	157.55	139.31	113.99	136.37
3611	1056.00	1051.53	1056.10	**301.42**	294.93	296.59	164.98	145.37	157.96	101.17	103.94	116.59
3612	**1093.21**	**1077.50**	**1107.79**	293.06	294.47	295.70	133.71	145.01	157.60	105.30	106.32	126.45
4302	997.10	1014.61	985.36	291.87	294.36	295.71	127.92	144.85	157.54	86.79	95.34	99.45
4303	1039.94	1042.33	1037.82	296.99	294.77	296.30	169.25	145.54	158.13	96.61	101.05	110.88
4304	1028.92	1036.36	1025.98	287.06	**294.03**	**294.92**	**119.73**	**144.72**	157.31			

Table 2. Average breeding value estimates for first lactation reproductive traits using different sire evaluation methods in Jersey crossbred sires.

Method	Average breeding value (ABV) (days)	Number of sires		Maximum breeding value (days)	Minimum breeding value (days)	Difference
		Above ABV	Below ABV			
Age at First Calving						
LSM	1045.14	11(55%)	9(45%)	1093.21(4.60%)	989.25(5.35%)	103.96
BLUP	1045.52	11(55%)	9(45%)	1077.50(3.05%)	1011.16(3.29)	66.34
REML	1043.88	11(55%)	9(45%)	1107.79(6.12%)	975.94(6.51%)	131.85
First Lactation Length						
LSM	293.55	11(55%)	9(45%)	301.42(2.68%)	284.09(3.22%)	17.33
BLUP	294.54	10(50%)	10(50%)	295.41(0.29%)	294.03(0.17%)	1.38
REML	295.86	10(50%)	10(50%)	297.48(0.55%)	294.92(0.32%)	2.56
First Service Period						
LSM	149.04	8(40%)	12(60%)	183.27(22.97%)	119.73(19.66%)	63.54
BLUP	145.40	7(35%)	13(65%)	145.87(0.32%)	144.72(0.47%)	1.15
REML	157.83	8(40%)	12(60%)	158.47(0.40%)	156.90(0.59%)	1.57
First Dry Period						
LSM	113.83	8(42.11%)	11(57.89%)	212.02(86.26%)	75.61(35.58%)	136.42
BLUP	107.50	8(42.11%)	11(57.89%)	136.82(27.27%)	88.39(17.78%)	48.43
REML	123.36	9(47.37%)	10(52.63%)	181.99(47.52%)	85.71(30.52%)	96.28

Table 3. Effectiveness of different sire evaluation methods for first lactation milk yield traits in Jersey crossbred sires.

Method	Error variance (kg^2)	Coefficient of determination (R^2 %)	Coefficient of variation (CV %)
Age at first calving			
LSM	20627.14	10.40	13.76
BLUP	20626.20	8.90	13.76
REML	**18817.10**	**11.40**	14.38
First lactation length			
LSM	383.20	**5.60**	6.62
BLUP	381.69	1.10	6.60
REML	**377.45**	1.50	6.59
First service period			
LSM	6782.73	**14.90**	52.18
BLUP	**6689.49**	11.20	51.82
REML	6694.56	00.50	54.61
First dry period			
LSM	3981.05	31.80	51.15
BLUP	3950.33	20.50	50.95
REML	**2720.81**	**37.60**	56.04

Table 4. Rank correlations (above diagonal) and product moment correlations (below diagonal) among different sire evaluation methods for first lactation milk yield traits.

Method	**LSM**	**BLUP**	**REML**
Age at first calving			
LSM	-	1.000**	1.000**
BLUP	0.998**	-	1.000**
REML	0.998**	1.000**	-
First Lactation length			
LSM	-	0.986**	0.897**
BLUP	0.949**	-	0.917**
REML	0.894**	0.944**	-
First service period			
LSM	-	0.950**	0.693**
BLUP	0.960**	-	0.756**
REML	0.772**	0.796**	-
First dry period			
LSM	-	0.974**	0.972**
BLUP	0.934**	-	0.998**
REML	0.931**	0.999**	-
** Significant at $P \leq 0.01$			

Simple product moment correlations

The simple product moment correlations among the estimated of breeding values of sires by three different methods of sire evaluation are presented in Table 3 (below diagonal). It was observed that product moment correlations between estimated sire merits by different methods for all first lactation milk yield traits were highly significant ($P \leq 0.01$). The product moment correlations ranged from 0.998 (LSM with BLUP) to 1.00 (BLUP with REML) for age at first calving, 0.894 (LSM with REML) to 0.949 (LSM with BLUP) for first lactation length, 0.772 (LSM with REML) to 0.960 (BLUP with LSM) for first service period and 0.931 (LSM with REML) to 0.999 (REML with BLUP) for first dry period. Singh and Singh (2016) noticed higher simple correlations ranging from 0.99 to 1.00 (BLUP with LSM) for first lactation length and first service period respectively (Table 4).

Since rank correlations and product moment correlations by REML with BLUP method were highly correlated and revealed that REML and BLUP method can well be used for evaluation of sires under field conditions,

followed by LSM with BLUP method. While Bajetha et al. (2015) and Singh and Singh (2016) stated LSM with BLUP was best for sire evaluation

The estimated breeding values of sires had very high significant product moment and rank correlations among first lactation reproductive traits estimated by various methods, indicating that there was higher degree of similarity in ranking of sires by REML with BLUP method.

Sire ranking on the basis of estimated breeding value for first lactation milk yield traits by different sire evaluation methods

The result revealed that for age at first calving sire no. 24 had highest merit computed by three methods. It was found that ten sires out of top ten shared their ranks by being in top ten irrespective of methods employed for computation of breeding value.

Sire no. 3612 was found as lowest in merit by all the three methods. It was found that ten sires out of bottom ten shared their ranks by being in bottom position under three methods of sire evaluation.

For first lactation length, results revealed that sire no. 283 had highest genetic merit computed by BLUP and REML methods, whereas sire no. 3611 showed highest genetic merit computed by LSM method. It was found that nine sires out of top ten shared their ranks by being in top ten irrespective of methods employed for computation of breeding value.

Sire no. 4304 had lowest genetic merit computed by BLUP and REML methods, whereas sire no.140 by LSM method. It was found that nine sires out of bottom ten shared their ranks by being in bottom position under three methods of sire evaluation.

The results for first service period revealed that sire no. 4304 had highest genetic merit computed by LSM and BLUP methods, whereas sire no.3606 by REML method. It was found that seven sires out of top ten shared their ranks by being in top ten irrespective of methods employed for computation of breeding value.

Sire no. 144 had lowest genetic merit computed by BLUP and REML methods, whereas sire no.142 by LSM method. It was found that seven sires out of bottom ten shared their ranks by being in bottom position under three methods of sire evaluation.

The results for first dry period revealed that sire no. 13 had highest merit computed by all three methods. It was found that nine sires out of top ten, shared their ranks by being in top ten irrespective of methods employed for computation of breeding value.

Sire no. 24 had lowest genetic merit computed by BLUP and REML methods, whereas sire no.127 by LSM method. It was found that nine sires out of bottom ten shared their ranks by being in bottom position under three methods of sire evaluation.

The top ten sire ranks on the basis of first lactation milk yield trait revealed that all sires wouldn't rank similarly for all the traits. In general, however, the rank of sires by different sire evaluation methods showed that 4-5% top sires almost had similar rank for all the traits.

Conclusion

Based on error variance and coefficient of determination, REML was most efficient and accurate method of sire evaluation. Based on coefficient of variation values for comparison among methods for first lactation milk yield traits, LSM and BLUP were found to be most stable methods. Highly significant difference observed between simple product moment and rank correlations for first lactation milk yield traits revealed high degree of similarity by REML with BLUP method. Therefore, preference should be given to use REML, followed by LSM and BLUP methods for sire evaluation of Jersey crossbred cattle under field progeny testing programme.

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