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Full Length Research Paper

Studies on some economic traits and biological characters of regular and reciprocal cross between a multivoltine and bivoltine race of the silkworm *Bombyx mori*

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In order to understand the genetics of cross breeding system between multivoltine and bivoltine race, a hybridization experiment was conducted by crossing females of multivoltine Pure Mysore race (PM) with males of a bivoltine race C_{108} and its reciprocals. The F_1 and F_2 progenies of the above crosses were derived in order to study the economic traits and biological characters. The results of the analysis of the thirteen economic traits in the F_1 progeny between the regular and reciprocal crosses clearly indicated that wherever PM is participated as female partner the values of the economic traits are on the higher side than the reciprocals. In regard to the studies on the biological characters, the F_1 progeny of a cross of females of PM with males of C_{108} produced non-diapause eggs exhibiting 23 - 24 days of larval duration and spinning light green cocoons. On the other hand a cross between females of C_{108} with males of PM produced only diapause type of eggs having larval duration of 22 days which is shorter by 1 - 1.5 days compared to regular cross. The F_2 progenies involving both the crosses produced 3:1 ratio diapause: non-diapause eggs and green: white cocoons indicating Mendelian pattern of inheritance for voltinism and cocoon colour. The authors in the present investigation discussed the importance of hemizygous and heterozygous individuals of F_1 progeny and its utility in genetics and breeding of silkworm *Bombyx mori*.

Key words: Regular and reciprocal crosses, *Bombyx mori,* Economic traits, biological characters.

INTRODUCTION

The sericultural industry involved in the production of silk occupies an important place in the Indian economy and provides gainful occupation to lakhs of people. Even though India is one of the oldest silk producing countries, majority of the silk produced is by multivoltine × bivoltine hybrids. It is estimated that nearly 80% of the silk in India is produced by multivoltine × bivoltine hybrids where multivoltine races are used as female parent. The above combinations of hybrids have performed uniformly in the rearer's house exhibiting moderate productivity. The average yield is now estimated as 50 Kg/100 disease free layings from multi- bi hybrids. Contrary to this, in the sericultural states of India the hybrids of bivoltine females with males of multivoltines are not commercially exploit-ted. The main reason attributed is that the contributions of bivoltines by virtue of its maternal inheritance may result in regular crop losses. As a result, fifty percent of male population of multivoltines and other fifty percent of female population of bivoltines are not properly utilized resulting in the revenue loss running to several corers of rupees. Thus, the genetic potentialities of the silkworm breeds are not fully exploited for silk production in our country. Understanding the genetic capabilities of multivoltine × bivoltine hybrids as well bivoltine × multivoltine hybrids is of utmost practical importance and it is worthwhile to examine the prospects of developing a thorough knowledge of the above crossing system in the

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light of the basic principles of genetics and understanding of basic biological characters. In the present paper the results of such differences for some economic traits and biological characters are discussed.

MATERIALS AND METHODS

The pure races of Mulberry Silkworm *Bombyx mori Viz*., multivoltine Pure Mysore (PM), bivoltine race C_{108} formed the materials for the present investigations. These races were drawn from the germ-plasm bank maintained in the Department of Studies in Sericultural Science, University of Mysore, Mysore, India. Parental seed cocoons of the above said two races were collected and layings of the pure races were prepared adopting the method described by Tazima (1962). After incubation of eggs at 25 ± 1°C and relative humidity of 80 ± 5%, two layings of each of the two pure races were selected. The larvae hatched from each layings were reared separately under uniform laboratory conditions as described by Narasimhanna and Krishnaswamy (1972). The larvae were fed with M_5 variety of mulberry (*Morus indica*) leaves.

For assessing the comparative performance of the pure races, thirteen economic characters namely Fecundity, Hatching percent-tage, Weight of fifth instar larvae, Larval duration, Yield/10000 larvae brushed by number and weight, Cocoon weight, Shell weight, Shell percentage, Filament length, Denier, Renditta and Pupation rate were analysed in three different seasons of the year. The parental seed cocoons of the above races, after the analysis were utilized in the preparation of the hybrid layings by crossing females of Pure Mysore with males of bivoltines and their reciprocals. The Duncan system of statistical model for one- way classification was employed following the method of Snedecor and Cochran (1967) for the data obtained during of course hybridization programme.

RESULTS AND DISCUSSION

The mean values of the economic traits of two parents viz; Pure Mysore and C_{108} and their F_1 hybrids along with statistical data for three seasons of the year are presented in Tables 1 - 3. Based on the results it is clear that the two races revealed differential performances in three seasons. The multivoltine Pure Mysore exhibited longest larval duration of 661 h in Post-monsoon season compared to 570 h in C_{108} . In addition quantitative traits like cocoon weight, shell weight and shell ratio are significantly higher ($P < 0.05$) in the bivoltine C_{108} compared to multivoltine race. This could be ascribed to the differences in the voltinism and racial specificity as pointed out by Murakami (1989a and b). Based on the findings on the performance of the F_1 hybrids in three different seasons of the year, it is obvious that F_1 hybrids of reciprocal crosses also spun cocoons of tightly formed shells, uniform growth and uniform crop performance compared to popular crosses where multivoltine Pure Mysore is used as female parent. In all the three seasons (Tables 1 - 3) analysis of the various economic traits in the regular and reciprocal crosses of F_1 hybrids revealed significant differences ($P < 0.05$) for eleven out of thirteen economic traits analysed. Based on the results it is obvious that Pure Mysore wherever participated as female partner with bivoltines, the value of economic traits are on the higher side than the reciprocals. The above findings tally with the findings of Benchamin et al. (1983) and Tazima (1988) who have observed similar results in their studies on multivoltine × bivoltine and bivoltine × multivoltine hybrids. It is also important that several multivoltine x bivoltine hybrids are commercially exploited in addition to the F_1 hybrids derived from a cross between Pure Mysore females with bivoltine males (Radhakrishna et al., 2001; Ravindra Singh et al., 2005; Umadevi et al., 2005). In the present study the F_1 hybrids of multivoltine × bivoltine analysed in three seasons clearly indicated uniform larval growth period from I-V instars while, in the reciprocal crosses the larval growth period is normal from I-IV instars and V instar larval period is reduced by 25 - 28 h. Similar results were recorded by Tazima (1988) utilizing multivoltine × bivoltine hybrid and he opined that such differences in larval duration are due to Lm^e genes. On the other hand Murakami (1994) opined that a reduction in the larval duration in reciprocal crosses in a multivoltine × bivoltine hybrid is due to the role played by X chromosome. Analysis of the genetic characteristics for voltinism and cocoon colour during F_1 and F_2 generation in both the crosses revealed interesting results (Table 4, Figures 1 and 2). In the crosses wherever Pure Mysore female is utilized with bivoltine race the F_1 eggs are non-diapause and F_2 eggs are diapause type, but the eggs laid by the F_2 moths revealed a typical Mendelian pattern of inheritance exhibiting 3:1 diapause to non-diapause type pattern. In the reciprocal crosses the F_1 progenies are diapause type and F_2 progenies are non-diapause type and F_2 moths laid 3:1 diapause to non-diapause eggs (Figure 1). Tazima (1988) while reporting on the improvement of multivoltine Pure Mysore race revealed that dormancy is always dominant over non- dormancy. Similar result was observed by Murakami (1989 a) utilizing Cambodge as a female parent. The results of the authors in the present investigation supports the findings of Tazima (1964) and Murakami (1989 a). Based on the data on cocoon colours (Figure 2) it is clear that the F_2 progenies also revealed 3:1 segregation in a typical Mendelian pattern (three green and one white) and is in conformity with the findings of Murakami (1988 and 1994). Schematic representations of the two different crosses are shown in Figure 3. Based on the segregation of the characters it is important that breeders should take cognescence of hemizygous and heterozygous popula-tions to understand the viability features of F_1 hybrids. The above results are in conformity with findings of Subramanya and Murakami (1994) who have proposed that hemizygous and heterozygous population play an important role in the expression of quantitative and qualitative traits and also basic biological characters such as voltinism and moultinism, larval growth, cocoon colour and shape of the cocoons.

Thus, based on the overall performance of economically important parameters multivoltine female × bivoltine male

Table 1. Mean values of the thirteen economic traits of two parental races and their F_1 hybrids in Pre-monsoon season

Traits / Races	Fecundity	Hatching %	Larval duration (h)	Larval Wt (gm)	Yield / 10000 No	Yield / 10000 Wt in Kg	Cocoon Wt (gm)	Shell Wt (gm)	Shell %	Filament length (m)	Denier	Renditta	Pupation Rate
PM	444.33 ± 20.21^{c}	91.42± 2.51^{b}	648 ± 13.85^{a}	19.78 ± 0.319^{d}	8947 ± 61.61^{a}	9.730 ± 0.026^{d}	1.115 ± 0.020^{d}	0.160 ± 0.018^{d}	14.35 ± 1.34^{b}	382 ±1069^{d}	1.91 ± 0.040^{b}	11.20 ± 0.134^{a}	90.80 ± 0.333^{a}
C108	545.66 ± 3.48^{b}	95.41 ± 0. 344^{ab}	535 ±2.51^{b}	42.16 ± 0.272^{a}	8052.66 ± 34.70^{c}	16.430 ± 0.017^{a}	2.076 ± 0.031^{a}	0.383 ± 0.002^{a}	18.48 ± 0.140^{a}	1032 ±2.64^{a}	2.256 ± 0.032^{a}	7.95 ± 0.017^{c}	92.10 ± 0.387^{a}
PM × C108	530.33 ± 1.45^{b}	96.47 ± 0.315^{a}	525 ± 13.98^{b}	34.03 ± 0.442^{b}	8066 ± 33.32^{c}	13.920 ± 0.057^{b}	1.739 ± 0.033^{b}	0.315 ± 0.004^{b}	18.11 ± 0.292^{a}	728.33 ± 9.70^{b}	2.06 ± 0.017^{b}	10.25 ± 0.053^{b}	92.15 ± 0.713^{a}
C108 × PM	592 ±5.19^{a}	93.190 ± 0.213^{ab}	513 ± 13.74^{b}	30.60 ± 0.303^{c}	8254 ± 28.82^{b}	11.236 ± 0.014^{c}	1.405 ± 0.026^{c}	0.241 ± 0.008^{c}	17.14 ± 0.504^{a}	590.66 ± 7.68^{c}	2.16 ± 0.061^{a}	10.44 ± 0.057^{b}	90.97 ± 0.260^{a}
F-value	33.818	3.098 NS	26.752	741.153	102.385	7715.44	215.07	84.79	6.45	1082.87	14.120	321.40	2.47NS

Note: The values are derived from three replicates ± SE. The values with the same letters are not statistical significant (P > 0.05) when subjected to DMRT (Duncan's Multiple Range Test).

Table 2. Mean values of the thirteen economic traits of two parental races and their F_1 hybrids in Monsoon season.

Traits / Races	Fecundity	Hatching %	Larval Duration (h)	Larval Wt (gm)	Yield / 10000 No	Yield / 10000 Wt in Kg	Cocoon Wt (gm)	Shell Wt (gm)	Shell %	Filament Length (m)	Denier	Renditta	Pupation Rate
PM	452 ±7.02^{c}	96.51 ± 0.545^{a}	657 ±16.29^{a}	28.27 ± 0.433^{d}	9182.66 ± 50.42^{a}	9.756 ± 0.040^{d}	1.088 ± 0.008^{d}	0.153 ± 0.008^{c}	14.01 ± 0.592^{b}	351 ±19.35^{c}	2.08 ± 0.084^{b}	11.68 ± 0.268^{a}	93.14 ± 0.531^{a}
C108	538.33 ± 2.33^{b}	96.52 ± 0.439^{a}	577.33 ± 2.03^{b}	46.29 ± 0.260^{a}	8118.33 ± 57.85^{b}	15.92 ± 0.072^{a}	2.008 ± 0.038^{a}	0.368 ± 0.014^{a}	18.29 ± 0.365^{a}	1025.33 ± 8.37^{a}	2.35 ± 0.044^{a}	8.20 ± 0.052^{c}	92.25 ± 0.465^{ab}
PM × C108	533.33 ± 5.78^{b}	96.81 ± 0.833^{a}	555.66 ± 7.51^{bc}	34.91 ± 0.167^{b}	8432.66 ± 216.20^{b}	13.59 ± 0.551^{b}	1.640 ± 0.056^{b}	0.285 ± 0.012^{b}	17.36 ± 0.176^{a}	684 ± 13.08^{b}	2.11 ± 0.064^{b}	10.34 ± 0.104^{b}	92.19 ± 0.366^{b}
C108 × PM	586.33 ± 8.51^{a}	94.75 ± 0.847^{a}	534.66 ± 2.73^{c}	31.10 ± 0.261^{c}	8351 ±56.65^{b}	12.35 ± 0.068^{c}	1.505 ± 0.009^{c}	0.271 ± 0.007^{b}	18 ±0.463^{a}	671.33 ± 7.31^{b}	2.17 ± 0.060^{ab}	10.45 ± 0.038^{b}	90.92 ± 0.336^{b}
F-value	77.29	1.86NS	34.31	711.13	15.20	83.44	122.60	67.52	21.31	453.59	3.307NS	96.29	4.45

Note: The values are derived from three replicates ± SE. The values with the same letters are not statistical significant (P > 0.05) when subjected to DMRT.

male represent good hybrid combinations, but bivoltine female × multivoltine male also could be exploited with more scientific care.

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Table 3. Mean values of the thirteen economic traits of two parental races and their F_1 hybrids in Post-monsoon season.

Traits / Races	Fecundity	Hatching %	Larval Duration (hrs)	Larval Wt (in gms)	Yield / 10000		Cocoon Wt (in gms)	Shell Wt (In gms)	Shell %	Filament Length (meters)	Denier	Renditta	Pupation Rate
					No	Wt in Kg							
PM	498.66 ± 14.11^{b}	97.77 ± 0.181^{a}	661 ±12.70^{a}	20.35 ± 0.115^{c}	9424.66 ± 46.08^{a}	11.13 ± 0.031^{c}	1.195 ± 0.005^{c}	0.165 ± 0.004^{c}	13.803 ± 0.329^{c}	394.33 ± 5.61^{c}	1.86 ± 0.037^{c}	10.99 ± 0.080^{a}	93.39 ± 0.394^{ab}
C108	567.66 ± 2.03^{a}	95.85 ± 0.228^{b}	570.33 ± 1.20^{b}	43.25 ± 0.431^{a}	9527.33 ± 32.57^{a}	18.45 ± 0.934^{a}	2.06 ± 0.025^{a}	0.388 ± 0.004^{a}	18.84 ± 0.232^{a}	1018.66 ± 6.49^{a}	2.5 ± 0.046^{a}	8.20 ± 0.028^{c}	93.32 ± 0.497^{ab}
PM × C108	562 ±7^{a}	97.75 ± 0.383^{a}	555.66 ± 6.12^{bc}	32.21 ± 0.535^{b}	9295 ±68.55^{a}	16.91 ± 0.229^{ab}	1.84 ± 0.032^{b}	0.323 ± 0.010^{b}	17.56 ± 0.284^{b}	693.33 ± 12.99^{b}	2.123 ± 0.048^{b}	10.28 ± 0.129^{b}	93.63 ± 0.268^{a}
C108 × PM	576 ±3.21^{a}	96.68 ± 0.263^{b}	528.66 ± 10.52^{c}	31.48 ± .583^{b}	9314.33 ± 146.99^{a}	16.30 ± 0.318^{b}	1.77 ± 0.020^{b}	0.304 ± 0.004^{b}	17.16 ± 0.297^{b}	688.66 ± 8.21^{b}	2.153 ± 0.032^{b}	10.33 ± 0.075^{b}	92.08 ± 0.509^{b}
F-value	19.107	11.46	42.34	424.26	1.57NS	39.26	247.17	198.45	55.67	839.94	39.67	197.79	2.64NS

Note: The values are derived from three replicates ± SE. The values with the same letters are not statistical significant (P > 0.05) when subjected to DMRT.

Table 4. Segregation of egg colour, cocoon colour in the F_2 progenies of regular hybrids and its reciprocals.

Hybrids ↓	Types of eggs (in numbers)			Cocoon colours (in numbers)		
	Diapause	Non-diapause	Total	Green	White	Total
PM × C_{108}	68370 74.70%	23151 25.30%	91521	3332 73.02%	1231 26.98%	4563
F_2moths	3	1		3	1	
C_{108} ↓ × PM	69819 73.39%	25317 26.61%	95136	3543 73.35%	1287 26.65%	4830
F_2moths	3	1		3	1	

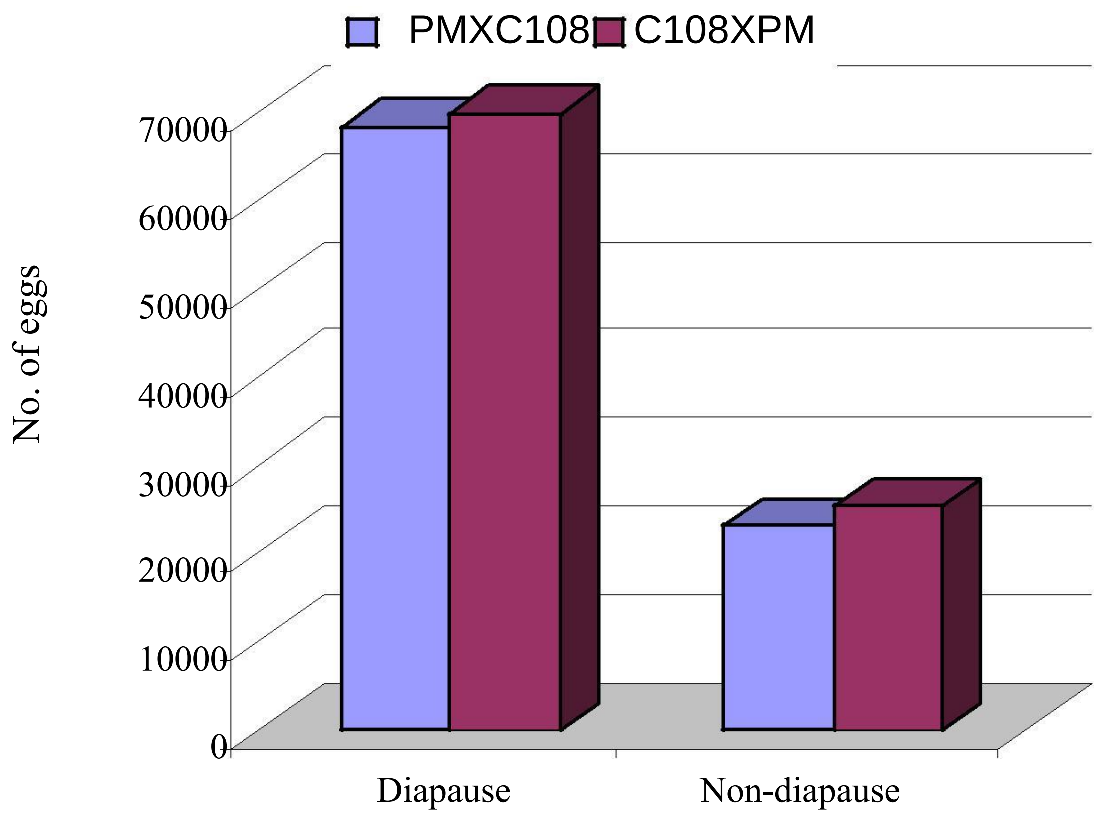

Figure 1. Diapausing and Non-diapausing egg segregation in F_2 progenies of PM × C_{108} and C_{108} × PM hybrids.

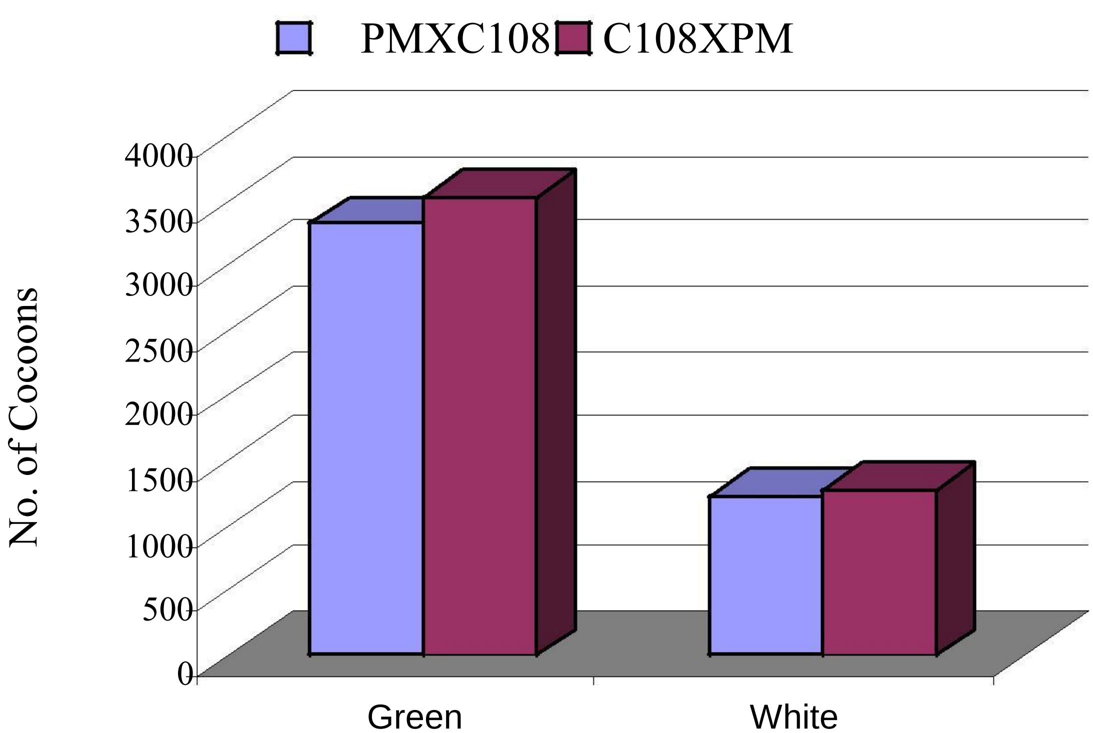

Figure 2. Green and White cocoon segregation in F_2 progenies of PM × C_{108} and C_{108} × PM hybrids.

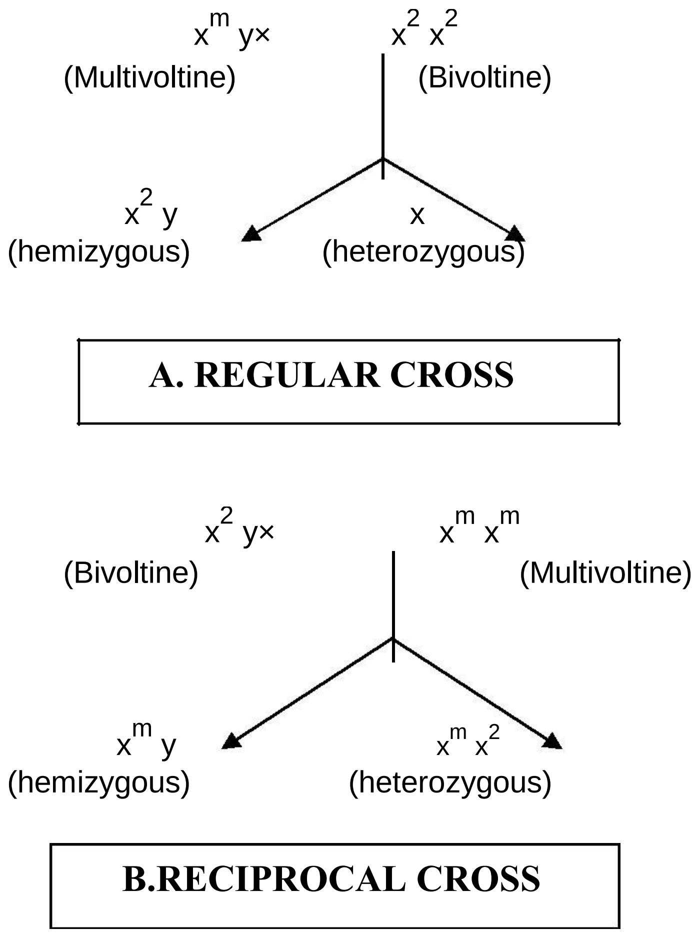

Figure 3. Schematic representation of the parental and F_1 genotypes in a cross between multivoltine females × bivoltine males and its reciprocal cross.

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