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The Issue of Some Bay Colour Character Inheritance in Małopolski Horses

Problem dziedziczenia niektórych cech maści gniadej u koni małopolskich

The bay colour is common in horses and usually desired. In bays, breeders particularly like dark bay and seal brown shades considering them to be the most beautiful. The bay shades are registered in breeding documentation. The model of bay coat colour inheritance was found (1) and documented by molecular way (3). Two dominant *A* and *E* alleles from *Agouti* and *Extension* loci co-operate to control the bay colour. The allele frequency in the Małopolski horse population amounts to 0.74 and 0.51, respectively (9). The subject of bay shade inheritance in the Wielkopolski horse was taken up by Stachurska et al. (10). The results of the study performed on horses registered in the stud book, led to the conclusion that a few genes were responsible for producing the bay shades. Moreover, it was suggested that the recessive *a* allele resulted in a darker bay shade, whereas *e* allele lightened the shade. However, the problem has not been finally solved, perhaps because the shade in a horse is determined arbitrarily. For instance, it is difficult to decide if a horse is bay or dark bay when it shows intermediate properties between the two shades. Besides, it is not fully known if the bay shade classification is proper, i.e. if it agrees with the genetic mechanisms. In Poland, the following bay shades are distinguished: light bay, bay, dark bay and seal brown, but in other countries also brown colour or shade is often considered (5, 6, 7, 11). Many authors assume the seal brown shade to be the black colour dilution (2, 7, 11) and the dark bay shade to result from an additional agouti factor (11).

The purpose of the study was to estimate the heritability of detailed bay colour characters which can in future help to answer the question how the bay shades should be distinguished and how they are inherited.

MATERIAL AND METHODS

538 bay Małopolski horses at various age and mainly from former national studs were described in the summer season. The horse shade was determined according to Polish classification. The shade of parents, which were beyond reach, was taken from the stud book. Besides the shade, the following characters were taken into account: body flank colour (yellowish brown/reddish brown/brown/brownish black/black); head colour (lighter than the body flank colour/as the body flank/darker than the body flank); extension of black on legs (lack/over fetlocks/up to knees and hocks/up to elbows and stifles/dark horse); presence and extension of sootiness on the back (lack/withers-shoulder/loin-croup/withers–back-croup/dark horse); presence and extension of mealy effect (muzzle-inside legs–belly-buttocks/inside legs–buttocks/muzzle–inside legs/inside legs/legs); mane and tail colour (black and grey/black, red and grey/black and red/black); white markings presence and size on the head and legs (large/mean/small/lack); dorsal stripe presence (lack/presence). The age of the horses at description (in years) was registered.

The characters were analysed in progeny compared to dams and to sires and in case of the shade also compared to both parents. Since the material was not numerous, not all parent-foal dependencies could have been verified (χ^2 test). Only these character variants were considered which grouped at least 5 individuals in each class. They were: shade (bay/dark bay/seal brown), body flank colour (brownish black/brown), head colour (similar to body flank/darker than body flank), extension of black on legs (up to knees and hocks/up to elbows and stifles or higher), sootiness on the back (dark horse/dark withers and shoulder), mealy effect (presence/lack), mane colour (black/black and red), tail colour (black/black and red), white markings on head (presence/lack), white markings on legs (presence/lack), dorsal stripe (presence/lack).

Genetic parameters were estimated by multi-traits model (875 individuals in pedigree) with the use of restricted maximum likelihood method REML (4). The following factors were considered: dam and sire colour, random additive animal effect and additionally the animal age at description for the black on legs, back sootiness and mealy effect. The heritability values were transformed with the use of probit transformation.

RESULTS AND DISCUSSION

Percentage distributions of the characters are shown in Table 1. In the population, 2.8% horses have been light bay, 64.5% bay, 25.8% dark bay and 6.9% seal brown.

The occurrence of particular character variants in the progeny has been influenced by their presence in dams (Table 2). Such effect has not been found only in case of the mealy effect. The offspring shade has been significantly influenced by the shade in both parents and in dams but not affected by the sire's

Table 1. Phenotypic distribution (in %) of characters in bay horses (n = 538)

Shade	%	Flank colour	%	Head colour	%	Black on legs	%	Back sootiness	%	Mealy effect	%
Light	2.8	yellowish brown	2.6	lighter than flank	4.5	lack	5.0	lack	64.7	muzzle – inside legs – belly – buttocks	10.4
Bay	64.5	reddish brown	3.9	like flank	86.1	over fetlocks	2.0	withers – shoulder	3.0	inside legs – buttocks	5.6
Dark	25.8	brown	63.2	darker than flank	9.5	up to knees and hocks	73.0	loin – croup	3.2	muzzle – inside legs	6.7
Seal brown	6.9	brownish black	26.0			up to elbows and stifles	5.0	withers – back – croup	9.5	inside legs	6.3
		black	4.3			dark horse	14.9	dark horse	19.7	lack	71.0

Mane colour	%	Tail colour	%	Markings on head	%	Markings on legs	%	Dorsal stripe	%
Black and grey	1.9	black and grey	4.3	large	7.2	large	9.1	lack	75.1
Black red and grey	0.4	black. red and grey	0.7	mean	19.0	mean	16.7	presence	24.9
Black and red	34.4	black and red	29.7	small	44.1	small	25.1		
Black	63.4	black	65.2	lack	29.7	lack	49.1		

shade. Most of the sire – progeny dependencies have come out to be unimportant. More significant influences of the dams than that of the sires on the progeny may indicate a maternal effect or mitochondrial inheritance. Summing up, except the back sootiness and mealy effect, the χ^2 test results show a certain dependence of the analysed characters on the horse genotype.

Table 2. Significance (P) of the coincidence between the bay character occurrence in dams and sires versus the progeny

Character	Dams		Sires	
	N	P	N	P
Shade	380	xx	408	-
Flank colour	170	xx	87	-
Head colour	188	xx		
Black extension on legs	155	xx	89	xx
Back sootiness			83	-
Mealy effect	208	-	111	-
Mane colour	204	xx		
Tail colour	195	xx		
Markings on head	209	xx	111	-
Markings on legs	208	xx	110	-
Dorsal stripe	225	xx		
	Both parents			
Shade	173		xx	

xx – coincidence significant at P≤0.01

The heritability of the characters has been moderate and high (Table 3). High heritability has been found in case of the dorsal stripe, mane colour, head colour and extension of black on legs. However, the presence and size of white markings on head and legs has shown the highest heritability (0.706 and 0.721, respectively). Also, according to W o o l f (12) the heritability of these characters is high (0.68 and 0.69). The dorsal stripe appearance is probably controlled by two loci (8). Hence, its heritability turned out to be high. The heritability of the mealy effect has been relatively moderate. It has been noticed that this character is to a certain degree influenced by the horse age, which could have resulted in decreasing the h^2 value.

A lower heritability of the shade and flank colour, which determines the shade, is the most interesting. It may indicate that non-genetic factors play an important role in the shade appearance. The back sootiness and tail colour have been also of a lower heritability. It is difficult to explain why the mane colour heritability has been twice higher than that of the tail colour. These characters perhaps result from not the same factors.

Table 3. Heritability (h_x^2) and correlation (r_G) between the bay horse characters

Character	h_x^2	Shade	Flank colour	Head colour	Black on legs	Back sootiness	Mealy effect	Mane colour	Tail colour	Markings on head	Markings on legs
Shade	0.395										
Flank colour	0.324	0.905									
Head colour	0.517	-0.038	-0.170								
Black extension on legs	0.510	0.755	0.835	-0.119							
Back sootiness	0.384	0.863	0.837	-0.160	0.838						
Mealy effect	0.468	-0.204	-0.393	0.747	-0.328	-0.496					
Mane colour	0.559	0.117	0.055	0.611	0.140	0.188	0.265				
Tail colour	0.243	0.256	0.105	0.331	-0.033	0.244	0.088	0.435			
Markings on head	0.706	0.069	-0.004	-0.271	0.191	0.033	-0.055	-0.484	-0.030		
Markings on legs	0.721	0.159	0.218	-0.222	0.263	0.162	-0.267	-0.259	0.082	0.748	
Dorsal stripe	0.580	-0.102	-0.080	-0.639	-0.101	-0.064	-0.335	-0.435	-0.158	-0.003	-0.394

It should be pointed out that solely the black on legs has been of high heritability and simultaneously this character in progeny has depended on its occurrence both in dams and in sires. The most important characters for the horse colour: shade and flank colour, had a lower heritability and their occurrence in the offspring was influenced by the presence in dams and in both parents, but not in sires. This may indicate a relatively higher effect of dams on the progeny. A similar phenomenon may be considered in case of the markings on the head and legs, the more so as these characters showed high heritability. Since the heritability is high and the presence of the character does not coincide in sires and progeny but does agree in dams and progeny, maternal effect should be suggested. The results document to a certain degree the hitherto hypothesis, which attributes the marking appearance to the so-called developmental noise in the embryo (12). Instead, the back sootiness and mealy effect seem to depend in a lesser degree on the genetic factors. This is not consistent with Sponenberg's (7) hypothesis on single loci which control these characters.

High genetic correlation has been found between: 1) the shade versus flank colour, the extension of black on legs and the back sootiness, 2) the flank colour versus the black extension on legs and the back sootiness, 3) the head colour versus mealy effect, 4) the black extension on legs versus the back sootiness, 5) the markings on the head versus the markings on legs (Table 3). The results show that the assumed shade classification is proper and the variants of the characters are distinguished correctly. The high correlation between the markings on the head and legs (0.748) could indicate that certain genes are common to both characters. According to W o o l f (12), this correlation is considerably lower (0.42). The difference may result from a lower number of examined horses in the present study, different ways of determining the quantity of markings and different methods of estimating the correlation.

Summing up: the analysis shows mostly high heritability and correlation of bay colour characters, however the findings need to be documented on a larger material.

CONCLUSION

1. In the light of the analysis, the shade and the flank colour in the bay horse are of moderate heritability, whereas the black extension on legs, the head colour, as well as the mane colour are highly inherited.

2. The results indicate that the appearance of the white markings may be influenced by the maternal effect, which would be possible to prove more precisely by molecular genetic methods.

3. The back sootiness and mealy effect in the bay horse seem to depend in a lesser degree on genetic factors.

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STRESZCZENIE

Podział odcieni maści gniadej u koni oparty jest wyłącznie na cechach fenotypowych, gdyż ich dziedziczenie nie zostało dotąd poznane. W pracy podjęto analizę dziedziczenia poszczególnych cech maści gniadej celem przybliżenia ostatecznego rozwiązania problemu odcieni.

Materiał badań stanowiło 538 gniadych koni małopolskich, wśród których zgodnie z polską klasyfikacją 2,8% miało odcień jasnogniady, 64,5% gniady, 25,8% ciemnogniady i 6,9% skarogniady. Na podstawie szczegółowego opisu koni przeanalizowano zgodność występowania poszczególnych cech u matek i potomstwa oraz u ojców i potomstwa. Odziedziczalność i korelacje między badanymi cechami zostały oszacowane przy wykorzystaniu metody największej wiarygodności REML z transformacją probitową.

W świetle badań odcień maści i barwa sierści na boku u konia gniadego są cechami średniodziedziczalnymi, natomiast zasięg podpalania kończyn, barwę głowy i grzywy charakteryzuje wysoka odziedziczalność. Uzyskane wyniki wskazują na to, że występowanie odmian można wiązać z efektem matecznym. Zaciemnienie grzbietowe oraz przejaśnienia u koni gniadych wydają się w mniejszym stopniu zależeć od czynników genetycznych.