Devising a Selection Strategy for the Jamunapari Goat for Improving Lactation Performance

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Abstract

This study aims to evaluate the genetic potential of the Jamunapari goat and formulate a new selection strategy for improving the lactation traits. The data set included 4049 phenotypic records for lifetime milk yield at 90 days (MY90) and 140 days (MY140), total milk yield (TMY), and lactation length (LL) obtained from the progeny of 83 sires and 1643 dams between 1990 and 2019. Animal model employing average information restricted maximum likelihood (AIREML) was used to estimate genetic parameters for milk yield traits and LL. The direct additive heritability estimates for lifetime lactation traits, that used repeatability model were 0.10 ± 0.03, 0.08 ± 0.03 and 0.12 ± 0.02 for MY90, MY140 and TMY, respectively, while it was low for LL (0.06 ± 0.02). The repeatability estimates were moderate ranging from 0.17 to 0.22 for milk yield traits and LL, indicating persistent performance over the parities. Animal permanent environment influence (c^2) was significant in milk yield attributes, whereas additive maternal genetic effects were absent. As the early selection criteria based on first parity records is essential, we analysed the data for the first parity separately and obtained moderate h^2 estimates *viz*. 0.26 ± 0.05, 0.26 ± 0.06 and 0.25 ± 0.06 for MY90, MY140 and TMY, respectively. These estimates augurs further positive scope of selection in Jamunapari goats for higher milk yield. High and positive genetic correlation of MY90 with MY140 (0.97 ± 0.01) and TMY (0.91 ± 0.05) revealed the scope of using MY90 as the selection criterion.Based on these results, we recommend use of MY90 as a single trait selection criterion for genetic improvement of all lactation traits in Jamunapari goat.

Introduction

India has the world's largest goat population, with 148.88 million goats (DAHD, 2019). Goats not only provide subsistence for India's small marginal farmers, but also a convenient source of dietary protein for the family. Dairy goats are economically and socially important in India because of their capability to exploit inadequate vegetation in a variety of agro-climatic areas (Devendra and Liang, 2012). Goat milk has been used for therapeutic purposes since ancient times and has recently acquired popularity in human health due to its close proximity to human milk for easy digestion and its overall health promoting properties. Goat milk has on average 0.75 µm smaller fat globule diameter than bovine milk (Attaei and Richter, 2000). The goat milk is also used in infant feeding formula as it exhibits similarities to complex human milk fat globules, and has been found to improve digestion, cognition, and immunological development (Gallier et al. 2020). Goat milk contributes 3% of total milk production in India (DAHD, 2019), nevertheless, it fetches higher price in the urban region due to short supply and high demand. Its popularity is gradually rising and is likely to climb further in near future among health conscious people. Ergo, an increasing number of entrepreneurs are turning to goat dairy farming, particularly in peri-urban and metropolitan regions. There are 34 recognized goat breeds in India, and only a few are classified as milk breeds. Jamunapari is one of the most important dairy goat breed in India.

Setting acceptable selection criteria rather than ambitious performance goals would be the best strategy for any dairy breeding program. In livestock, genetic parameters are required for the planning of breeding strategies and accurate genetic evaluation (Willam et al., 2008). Genetic parameters are a property of the population from which they are computed, and they may vary over time as a result of selection and management decisions. Knowing the (co)variance components and heritability estimates for milk production traits can aid breeding methods by allowing breeders to pick animals with higher genetic merit in order to maximize selection response and improve dairy attributes as desired (Sullivan et al., 1986; Barillet, 2007).The majority of dairy goat breeding programmes have primarily centered on increasing milk production in the first lactation. However, choosing animals to be parents of next generation simply on the basis of the first lactation milk yield records may not be desirable, as genetic correlation across lactations may change (Oliveira et al., 2016; Brito et al., 2017).The lack of information for genetic evaluations of dairy goats between different lactations is undesirable, as this information is required to improve the overall genetic gain. Therefore, genetic analysis for whole lactation as well as among different lactations is very crucial for understanding the genetic relationship and further designing appropriate breeding strategy for higher genetic gains. Consequently, genetic evaluation of Jamunapari milk traits as a method of enhancing productivity through selection becomes critical. In this context, Animal model analyses are essential for obtaining valid and unbiased estimates of genetic parameters (Ayalew et al., 2017, Meyer, 2018).

Several researchers have assessed genetic parameters for lactation yield traits in diverse goat populations across the globe (Kennedy et al., 1982; Boichard et al., 1989; Kominakis et al., 2000; Muller et al., 2002; Van der Linde, 2002; Valencia et al., 2007; Weppert and Hayes, 2004; Torrens-Vazquez et al., 2009; Rout et al., 2017). However, there have been a few works on the estimate of genetic parameters for Indian dairy goats pertaining to lifetime lactation as well as first lactation production traits. Therefore, the primary objective of this study was to estimate genetic parameters for milk yield traits and lactation length for across parities using average information restricted maximum likelihood (AIREML) approach. The outcome of this study will aid in the selection of an appropriate model in order to design a suitable breeding strategy.

Material And Methods

Flock and data description

Data on pedigree and milk performance were obtained from the breeding flock of Jamunapari goats managed at the ICAR-Central Institute for Research on Goats in Makhdoom. The institute farm is situated on the banks of the Yamuna River, at $78^{o}02'$ E Latitude and 27^{o} 10’ N Longitude, at an elevation of 169 meters above mean sea level. The average rainfall is around 379 milli meters, with most of it occurring during the monsoon season, which lasts from July to September. The average temperature ranges from 2 degrees Celsius (winter) to 48.5 degrees Celsius (summer), according to meteorological data. Jamunapari is large sized, tall, with large pendulous ears and prominent Roman nose. With an average body weight of 24.49 ± 0.08 kg at 12 months (Dige et al. 2021), the Jamunapari goat is well-known for its milk-producing potential. Because they evolved in the semi-arid tropics, these goats are extremely well adapted to adverse climatic conditions. The Jamunapari goat has been widely used as an improver breed in different countries to improve milk traits in other goat breeds. The Jamunapari goats were used in England to develop the well-known Anglo-Nubian breed of goats.

The institute is maintaining a nucleus flock of purebred Jamunapari animals that were raised under semi-intensive management with grazing (6–7 hours), stall feeding dry fodder/straw, and seasonally available green fodder. Besides, concentrate mixtures were supplied according to the animal's age group (kid, grower, and adult) and physiological stage (pregnant, breeding). Animals were typically housed separately based on their age, sex, physiological condition, and overall wellness. Does are mated when they reach the age of two years. Goats generally come in heat twice a year, with the first peak occurring from April to June and the second peak occurring from September to November. Thereafter, kidding occurs in the autumn (October to November) and spring (March to April) seasons, respectively. Selective breeding was employed. After kidding, both kids and dams were weighed on the same day, and the following information was recorded: sex, sire, dam, kind of birth, and season of birth.

After kidding, the kids and dams were kept in a solitary pen for 1–2 weeks. Afterwards, kids were housed separately and allowed to nurse twice a day. Weaning begun around the age of 15 weeks. Kids were allowed to graze apart from does in the adjacent region until they were 3 months old. From 3 weeks of age until weaning, suckling kids were given the concentrate mixture *ad libitum*. Following weaning, the male and female children were housed separately. After weaning, immunization against peste-des-petits (PPR), foot and mouth disease (FMD), and enterotoxaemia (ET) was used to protect the flock from these bacterial and viral illnesses. To control ectoparasites, animals were dipped on a regular basis under the supervision of a veterinarian. To address the endoparasitic infection, pre and post monsoon targeted deworming was implemented.

The phenotypic data set, comprised of 4049 records from 1643 does milked twice daily. The traits evaluated were estimated milk yield at 90 days (MY90), milk yield at 140 days (MY140), total milk yield (TMY), and lactation length (LL). The data were divided into 6 periods of 4 to 6 years interval [P1 (1990–1995), P2 (1996–2000), P3 (2001–2005), P4 (2006–2010), P5 (2011–2015), P6 (2016–2019)].

Statistical Analysis

The data was initially assessed using general linear model in SPSS version 25.0 (IBM Corporation, 2017) to identify the major significant fixed effects. Correcting the data for major environmental sources of variation is crucial for unbiased genetic evaluation. Hence, the effects of fixed factors such as birth period (6 periods), kidding season (Season 1-spring and Season 2-autumn), birth type (single and multiple), and kid's sex (2 levels) were analyzed. For the repeatability model, the parity was also included in the fixed effect model. In the models that were utilized for genetic evaluation, only significant effects ($P \leq 0.05$) were included.

The (co)variance components for each trait were estimated by Average Information Restricted Maximum Likelihood (AIREML) algorithm for estimating the additive direct, maternal direct and maternal permanent environmental components employing animal model. Univariate analyses were performed for each of four traits under investigation using WOMBAT (Meyer, 2007). The first parity traits were analysed using two models (I and II) below which accounted for the direct and maternal genetic effects. The lifetime performance traits were evaluated using models III, IV and V which accounted for permanent environment of the animal effect (repeatability model) along with direct and maternal additive effects.

The five models which account for the direct and maternal effects including repeatability were constructed as follows:

$\mathbf{y = X}\,\beta + \mathbf{Z_a a} + \varepsilon$ (I)

$\mathbf{y = X}\,\beta + \mathbf{Z_a a + Z_m m} + \varepsilon$ withCov $(a_m, m_o) = 0$ (II)

$\mathbf{y = X}\,\beta + \mathbf{Z_a a + Z_{pe} pe} + \varepsilon$ (III)

$\mathbf{y = X}\,\beta + \mathbf{Z_a a + Z_m m + Z_{pe} pe} + \varepsilon$ withCov $(a_m, m_o) = 0$ (IV)

$\mathbf{y = X}\,\beta + \mathbf{Z_a a + Z_m m + Z_{pe} pe} + \varepsilon$ withCov $(a_m, m_o) = \mathbf{A}\sigma_{am}$ (v)

Where **y** is the vector of records; β, **a, m, pe** and ε are vectors of fixed, direct additive genetic effect, maternal additive genetic effect, permanent environmental effect of the animal, and residual effect, respectively; with association matrices $\mathbf{X}$, $\mathbf{Z_a}$, $\mathbf{Z_m}$ and $\mathbf{Z_{pe}}$; **A** is the numerator relationship matrix between animals; and σ_{am} is the covariance between additive direct and maternal genetic effects. Assumptions for variance (**V**) and covariance (**Cov**) matrices involving random effects were

$\mathbf{V}(a) = \mathbf{A}\sigma^2_a$, $\mathbf{V}(c) = \mathbf{I}\sigma^2_c$, $\mathbf{V}(e) = \mathbf{I}\sigma^2_e$, and $\mathbf{Cov}(a,m) = \mathbf{A}\sigma_{am}$

Where, **I** is an identity matrix and σ^2_a, σ^2_c and σ^2_e are additive direct, maternal permanent environmental and residual variances, respectively. The most efficient univariate model for each trait was chosen using Likelihood Ratio Tests (LRT) (Meyer, 1992).

For the first lactation traits, concerning milk production viz. MY90, MY140 and TMY we ran multi-variate analysis using model I above. The estimates of genetic and phenotypic correlations were obtained using the multi-variate analysis.

Results And Discussion

Data were analyzed for the 2 sets. First set was only for the first parity and the second set was all the parities of animals over lifetime. Table 1 shows the summary statistics for lactation traits across lifetime. For Jamunapari goat, the least squares means for MY90, MY140, and TMY were 78.62 ± 0.44, 113.45 ± 0.59, and 121.05 ± 0.73 kg, respectively. The average lactation length was 175.33 ± 0.68 days, which was comparatively longer than that of other Indian breeds. Jamunapari goats were in production until the seventh parity; nevertheless, some goats persisted to be productive until the eleventh parity. Over the years, parity and period of birth had a significant ($P \leq 0.01$) effect on milk traits. The season of birth exhibited a significant (P ≤ 0.01) effect on MY90 and MY140. Does with multiple kids produced more milk than those with single kid. Higher estimates than the current study for milk traits were reported by Valencia et al. (2007) in Saanen goat (800kg, 338Kg and 285 days for TMY, MY120 and LL, respectively) and Kominakis et al. (2000) in Skopelos dairy goat of Greece (164.7kg and 239.2Kg for MY90 and TMY, respectively), owing to breed differences.

Table 1
Basic statistics and data structure for lactation traits in Jamunapari goat

Particulars	**MY90**	**MY140**	**TMY**	**LL**
Number of records	3947	3261	4049	4049
Mean (Kg)	78.62 ± 0.44	113.45 ± 0.59	121.05 ± 0.73	175.33 ± 0.68
Standard deviation	26.82	35.73	49.64	45.89
CV (%)	32	31	41	26
Number of animals in total	1666	1548	1643	1643
Number of animals with records	1429	1294	1443	1443
Number of sires with progeny in data	83	81	83	83
Number of dams with progeny in data	240	226	232	232
Effect of non-genetic factors				
Parity	*	*	*	*
Year	*	*	*	*
Season	*	*	NS	NS
Type of birth	**	NS	**	NS

MY90 = 90 days milk yield; MY140 = 140 days milk yield; TMY = total milk yield; LL = lactation length; CV = coefficient of variation

Genetic parameter estimates for lifetime lactation traits

Table 2 displays the parameter estimates considering all parities for milk yield traits and lactation length. The animal model 3 (out of model 3, 4 and 5) fitting the permanent environment was the most acceptable model for MY90, MY140 and TMY. For LL, the model 5 was most appropriate (Table 2). Since milk yield is greatly influenced by the animal's permanent environment, model 3 appeared to be the most appropriate model for the MY90, MY140, and TMY. MY90, MY140, and TMY had estimates of direct additive heritability as 0.10 ± 0.03, 0.08 ± 0.03 and 0.12 ± 0.02, respectively. These estimates for lifetime milk production traits were low to moderate. For LL, the direct heritability was 0.06 ± 0.02, which was low. The maternal genetic effect was also important for LL, although maternal heritability was low (0.04 ± 0.02). Because of the large datasets, heritability estimates for different traits were considerably different from zero, with small standard errors (0.02–0.03).

Table 2
Estimates of (co) variance component and genetic parameters for lifetime lactation traits by univariate analyses in Jamunapari goat

Trait	MY90	MY140	TMY	LL
σ^2_a	65.42 ±19.68	92.10 ± 33.86	267.33 ± 51.81	106.82 ± 32.66
σ^2_m				72.70 ± 35.52
σ^2_c	72.58 ±18.88	116.97 ± 34.57	155.05 ± 39.66	12.03 ± 38.74
σ^2_e	502.66 ± 13.67	931.38 ± 28.21	1844.34 ± 48.59	1693.43 ± 43.76
σ^2_p	640.66 ± 15.71	1141.35 ± 28.88	2266.72 ± 54.66	1944.90 ± 52.97
h^2	0.10 ± 0.03	0.08 ± 0.03	0.12 ± 0.02	0.06 ± 0.02
c^2	0.11 ± 0.03	0.10 ± 0.03	0.07 ± 0.02	0.006 ± 0.02
m^2				0.04 ± 0.02
rep	0.22 ± 0.02	0.18 ± 0.02	0.19 ± 0.02	0.17 ± 0.59
Log L	**-14604.636**	**-13032.170**	**-17542.462**	**-17231.809**

MY90 = 90 days milk yield; MY140 = 140 days milk yield; TMY = total milk yield; LL = lactation length; σ^2_a = additive direct genetic variance; σ^2_m = maternal genetic variance; σ^2_c = animal permanent environmental variance; σ^2_e = residual variance; σ^2_p = phenotypic variance; h^2 is heritability; m^2 is σ^2_m/σ^2_p; c^2 is σ^2_c/σ^2_p; rep = repeatability; log L is log likelihood.

The estimates of direct additive heritability in the current study for MY90, MY140, TMY and LL are pursuant with previous findings in literature (Kominakis et al., 2000; Valencia et al., 2007; Weppert and Hayes, 2004; Torrens-Vazquez et al., 2009). In Greece, the heritability of MY90 and total milk production in the Skopelos breed was 0.15 and 0.14, respectively (Kominakis et al 2000). Weppert and Hayes (2004) reported heritability estimates of 0.13 for milk yield in the Alpine, Toggenburg, Saanen, and Nubian breeds. In Mexico, the heritability for total milk production, MY120 (milk yield at 120 day), and LL were 0.22, 0.12, and 0.04, respectively (Valencia et al., 2007), and 0.17 for milk yield in Saanen goats (Torres-Vázquez et al., 2009). However, higher estimates than current study were reported by (Kennedy et al., 1982; Boichard et al., 1989; Muller et al., 2002). Kennedy et al. (1982) reported heritability of 0.68, 0.61, 0.54, and 0.30 for milk yield in the Alpines, Saanens, Toggenburgs, and Nubian goat breeds respectively. Boichard et al. (1989) obtained heritability estimates of 0.29–0.31for milk yield in French Alpine and

Saanen primiparous goats. Muller et al. (2002) estimated the heritability of milk yield in South African Saanens to be 0.23.

The variance component indicates that almost all milk traits are largely controlled by environmental factors, with the σ^2_a contributing little to total variance. Animal permanent environment influence (c^2) played a significant role in milk yield attributes, owing to repeated nature of these traits in each parity. The estimates for c^2 for MY90, MY140, TMY and LL were 0.11 ± 0.03, 0.10 ± 0.03, 0.07 ± 0.02 and 0.006 ± 0.02, respectively. We find that for the 90 and 140 days milk yield, the individual permanent environment remains significant source and contributes for more than 10% of total variance due to similar intrauterine environment and nursing for kids born to same mother over lifetime. For milk yield traits, the additive maternal genetic effects were absent, and only for LL the m^2 was observed which was contributing for 4% of total variance. Maternal genetic variations for lactation milk yield have been found to be minimal and non-significant across literature (Van Vleck and Bradford, 1966; Reed and Van Vleck, 1987; Kirkpatrick and Dentine, 1988; Schutz et al., 1992; Albuquerque et al., 1995; Khattab et al., 2005) in dairy cattle and in dairy goats by Weppert and Hayes, (2004).

Estimates of repeatability set upper bounds on heritability estimates. The milk production traits had modest repeatability estimates of 0.22, 0.18, 0.19 and 0.17 for MY90, MY140, TMY and LL, respectively. Estimates of moderate repeatability suggest that successful selection for that trait is possible. Our estimates of repeatability were lower than those reported by other researchers (Montaldo et al., 1982; Constantinou et al., 1985; Ilahi et al., 1998; Bagnika and Lukaszewics, 1999; Van der Linde, 2002; Valencia et al., 2007; Torres-Vázquez et al., 2009). Montaldo et al. (1982) estimated 0.59 and 0.23 repeatabilities for TMY and LL, respectively, in Mexico. Constantinou et al. (1985) reported repeatabilities of 0.43, 0.36, 0.39, and 0.08 for MY90, MY150 (milk yield at 150 day), TMY, and LL, respectively in Damascus goat. Ilahi et al. (1998) computed a repeatability of 0.53 for milk yield of French Alpines. Bagnika and Lukaszewics (1999) reported a repeatability of 0.42 for milk yield in polish goat, while Van der Linde (2002) obtained a value of 0.55 for the same trait in the dairy goat of Netherlands. Valencia et al. (2007) reported repeatability estimates of 0.40, 0.27 and 0.11 for TMY, M120 and LL, respectively in Saanen goat. Torres-Vázquez et al. (2009) observed a repeatability of 0.43 for milk yield in the Mexican Saanen goat. Valencia (1992) reported lower repeatability estimates for TMY and LL (0.12 and 0.00) in Mexican goats than the current investigation.

Genetic analysis revealed use of 90-day milk yield as a suitable criterion of selection for further improvement

Table 3 shows the parameter estimates for milk yield traits and lactation length for first parity. Among models 1 and 2, the animal model 1 with its own additive effect was the most appropriate model for MY90 and MY140, TMY and LL. Estimates of direct heritability for MY90, MY140 and TMY were 0.26 ± 0.05, 0.26 ± 0.06 and 0.25 ± 0.06, respectively, which were moderate to high and indicate sufficient scope for selection, if further improvement in traits is desired. For LL, the estimate of h^2 was 0.03 ± 0.04, which was low and defines that the LL cannot be further improved. Similar within range estimates for direct additive heritability for milk yield traits as compared to present study were reported earlier (Belichen et al., 1999; Montaldo et al., 2010; Rupp et al., 2011). Belichen et al. (1999) reported heritability estimates of 0.34 and 0.32 for milk yield in Alpine and seamen goat, respectively. Weppert and Hayes, (2004) obtained heritability for milk yield as 0.36, 0.38, 0.35 and 0.36 in Alpine, LaMancha, Nubian, Saanen and Toggenberg goats, respectively. Montaldo et al. (2010) found heritability for milk yield ranged from 0.35 to 0.38 in Alpine, LaMancha, Nubian, Saanen, and Toggenberg goat's breeds. Rupp et al. (2011) observed heritability for milk yield of 0.30 and 0.34 in Alpine and seamen, respectively. However, lower estimates for heritability (0.13) than current study were reported by Weppert and Hayes (2004) in Alpine, Saanen, Toggenberg and Nubian breeds of goats. Moderate h^2 estimates for first lactation yield traits suggested the presence of significant additive genetic variance for these traits, indicating the prospect of selection for future genetic progress in these traits.

Table 3
Estimates of (co) variance component and genetic parameters for first lactation traits in Jamunapari goat

Trait	MY90	MY140	TMY	LL
σ^2_a	140.07 ± 30.79	148.55 ± 30.08	465.20 ± 110.78	57.05 ± 70.76
σ^2_p	534.60 ± 21.78	945.25 ± 41.82	1876.99 ± 76.18	1740.09 ± 67.85
σ^2_e	394.53 ± 28.69	701.24 ± 56.59	1411.80 ± 103.60	1683.04 ± 93.83
h^2	0.26 ± 0.05	0.26 ± 0.06	0.25 ± 0.06	0.03 ± 0.04
Log L	**-4758.420**	**-4303.180**	**-5631.986**	**-5601.328**

MY90 = 90 days milk yield, MY140 = 140 days milk yield, TMY = total milk yield, LL = lactation length,σ^2_a = additive direct genetic variance, σ^2_e = residual variance and σ^2_p = phenotypic variance; h^2 is heritability; log L is log likelihood

The genetic correlation estimates of MY90 with MY140 and TMY were 0.97 ± 0.01 and 0.91 ± 0.05, respectively (Fig. 1). The genetic correlation of MY140D with TMY was 0.98 ± 0.02. The estimates of phenotypic correlation between these three traits were also high and significant (0.86 to 0.97). In accordance with our findings, higher genetic and phenotypic correlations among lactation traits have also been reported in goats (Kominakis et al., 2000, Valencia, 2007; Roy and Mandal, 2010; Mucha et al., 2014). Results indicated that MY90 is the most suitable trait for early selection of the animals for milk yield owing to very high genetic correlation of MY90 with later expressed traits for milk production in Jamunapari goats. Hence, we recommend use of MY90 as the trait for early selection of animals.

Conclusion

Analysis in the present investigation demonstrates persistence of the lactation performance across the parities. First parity, being expressed early in the lifetime, is very important for making selection decisions. Moderate additive genetic variance for first lactation traits suggests that there is sufficient scope for selection for increasing milk yield in Jamunapari goats. On the basis of results in this study we recommend use of 90-day milk yield in Jamunapari goat as the selection criteria as it has sizable additive genetic variance and very high genetic correlation with later expressed milk production traits.

Declarations

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Conflict of interest/Competing interest:

Authors of this manuscript declare that there is no conflict of interest for this research work.

Ethics approval

All the experimental procedures on animals were carried out according to the recommendations and approval of the Institute Animal Ethics Committee (IAEC) as per the guidelines set forth by the Institutional Committee for the Purpose of Control and Supervision of Experiments on Animals (CPCSEA).

Consent to participate

Not applicable.

Consent for publication

All authors gave their consent for publication of the research.

Availability of data and material:

All the data that supports the findings of this study are available with the data repository of

Animal Genetics & Breeding Division, ICAR-Central Institute for Research on Goats, Makhdoom. Access rights to the data are available with the permission of Director, ICAR

Central Institute for Research on Goats, Makhdoom.

Code availability:

Not applicable

Author's contribution:

M S Dige: Project administration, Resources, Investigation, Formal analysis, Writing; Original Draft. **P K Rout**: Supervision, Visualization, Funding acquisition, Writing; Review/Editing. **S Bhusan**: Writing; Review/Editing. **G R Gowane**: Conceptualization, Methodology, Formal analysis, Writing; Review/Editing

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Figures

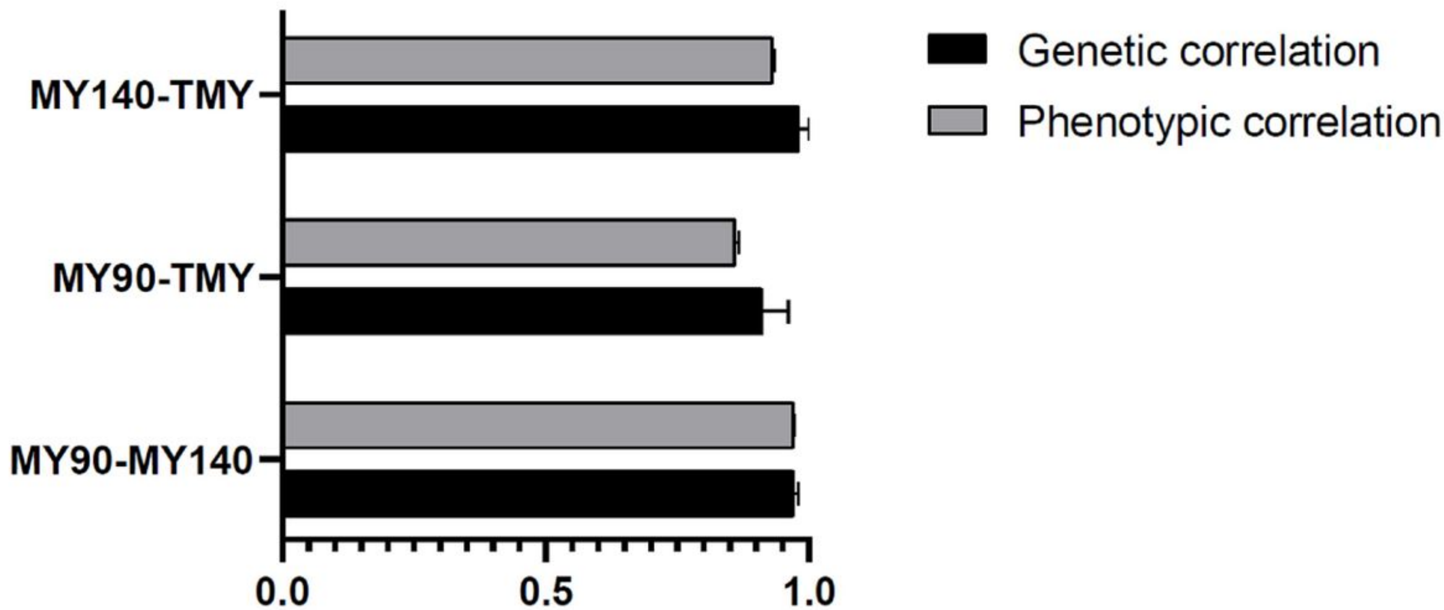
Genetic correlation
Phenotypic correlation
MY140-TMY
MY90-TMY
MY90-MY140
0.0
0.5
1.0

Figure 1