Indian J Dairy Sci 76(5): 487-492

https://doi.org/10.33785/IJDS.2023.v76i05.010

RESEARCH ARTICLE

Genetic parameters of fertility traits in Murrah buffaloes

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Received: 23 August 2022 / Accepted: 12 May 2023 / Published online: 21 October 2023

Abstract: The data pertaining to 662 Murrah buffaloes of 24 years (1996-2019) collected from history cum pedigree sheets maintained at Buffalo Farm, department of LPM, LUVAS, Hisar studied to determine the influence of non-genetic factors *viz.* period, season and parity and to estimate the genetic parameter of fertility performance traits using mixed linear model. The traits studied were: age at first calving (AFC), service period (SP), conception rate (CR), calving interval (CI), number of services per conception (NSC) and pregnancy rate (PR). Period of calving had non-significant effect on all fertility traits viz. SP, CR, CI, NSC and PR, except AFC. Season of calving reported to have highly significant ($P<0.01$) effect on SP, NSC and PR and significant ($P<0.05$) effect of season of calving was obtained on CR and CI. Highly ($P<0.01$) significant effect of parity was reported on SP and NSC and significant effect of parity at $P<0.05$ was also seen on CR, CI and PR. The least squares means of AFC, SP, CR, CI, NSC and PR were 1345.75±13.88 days, 153.87±4.34 days, 67.08±1.18 %, 459.53±4.50 days, 2.01±0.05 and 0.27±0.01 %, respectively. The heritability estimates among traits in overall lactation fertility traits viz. AFC, SP, CR, CI, NSC and PR were 0.36±0.21, 0.11±0.03, 0.09±0.02, 0.23±0.10, 0.04±0.01 and 0.07±0.01, respectively. PR had negative genetic and phenotypic correlations with SP, CI and NSC whereas positive genetic and phenotypic correlation with CR. It was concluded that selective breeding and better management can lead to enhancement in performance of buffaloes.

Keywords: Fertility traits, Heritability, Pregnancy rate, Murrah buffalo

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Introduction

India is the one of the leading producers of milk in the world having a compound annual growth rate in milk production of about 6.2 percent to reach 209.96 million tonnes in 2020-21 from 187 million tonnes in 2019. Livestock sector contributes 4.11% GDP and 25.6% of total Agriculture GDP (BAHS, 2019). Murrah is one of the best recognized breeds of buffalo and is the most efficient producer of milk, not only in the India but also in the Asia. The home tract of this breed is in Haryana and adjoining states of Punjab, UP and Delhi. Total buffalo population in the country is 109.85 million during 2019 (20^{th} Livestock census).

The economic worth of buffalo is primarily determined by these reproductive performances. Fertility is defined as the ability of the female animals to produce offsprings. These traits determine the lifetime production ability of the animals. Fertility traits add value to animal overall performance as they decide the economic life of the animal. Evaluation on fertility traits reduces the culling rate of farm as well as it increases the overall farm profit. Many researchers *viz.* Dev et al. 2015; Dash et al. 2015; Jamuna et al. 2015 and Patil et al. (2018) also reported varying degree of non-genetic effect on performance traits *viz.* AFC, CI, SP and CR in Murrah buffalo. The production of a dairy animal is an indication of its utility and is influenced by key fertility parameters such as calving intervals, length of each lactation and probability of surviving from one lactation period to the next (Zadeh, 2016). Likewise, the economic return of buffalo milk depends on the milk production and reproductive efficiency of animals, the latter being particularly affected by calving interval (Ramos et al. 2006). Therefore, fertility performance traits like AFC, SP, CR, CI, NSC and PR of Murrah buffalo require immediate attention of breeders for their evaluation.

Materials and Methods

The data of 662 Murrah buffaloes related to fertility traits over a period of 24 years from 1996 to 2019 was collected from history cum pedigree sheets maintained at Buffalo Farm, Department of Livestock Production Management, Lala Lajpat Rai University of Veterinary and Animal Sciences, Hisar. Climatic condition of Hisar is sub-tropical in nature and is situated in semi-arid region.

Geographically, Hisar is situated at 29°10' N latitude, 75°40' E longitude and 215.20 meters altitude.

Assuming that there was not much variation in adjacent years, entire period of 24 years was divided into six periods, each consisting of four consecutive years viz. 1996-1999 (Period 1), 2000-2003 (Period 2), 2004-2007 (Period 3), 2008-2011 (Period 4), 2012-2015 (Period 5) and 2016-2019 (Period 6). Each year was further delineated into four seasons of calving according to the geo-climatic conditions in the area viz.; Summer (April to June), Monsoon (July to September), Autumn (October to November) and Winter (December to March). Data up to third parity was included in the present study.

Animals having lactation shorter than 150 days, suspected outliers on the basis of histograms and abnormal records like abortion, mastitis and chronic illness were excluded from present study. Completion of minimum one lactation in the herd for studying fertility traits were considered for those animals that have the information of their date of birth, date of first calving, date of disposal and subsequent calving.

The performance traits included under this study were age at first calving (AFC), service period (SP), conception rate (CR), calving interval (CI), number of services per conception (NSC) and pregnancy rate (PR) up to 3 calving. Pregnancy rate (PR) measures the per cent of eligible buffaloes that become pregnant during each oestrous cycle and was estimated as: PR = 21 / (Service Period – Voluntary Waiting Period + 11), suggested by USDA, (2003). The constant factors 11 centralize the measure of possible conception within each 21 days' time period. The Voluntary Waiting Period (VWP) is the period after calving during which no inseminations occur, voluntarily left by the management for better pregnancy rate. The standardized voluntary waiting period of Murrah buffaloes was taken as 63 days (Patil et al. 2014). All the reproductive traits of Murrah buffalo under the present study served as standard and hence can be used as a reference or standard at a glance to compare the performances of Murrah buffalo reared under different agro-climatic zones of India.

In order to overcome non-orthogonality of the data due to unequal subclass frequencies, least squares and maximum likelihood computer program (Harvey, 1990) using Henderson's method III (Henderson, 1953) was utilized to estimate the effect of various tangible factors on performance traits and to estimate genetic and phenotypic parameters. The following statistical model was used to explain the underlying biology of the traits included in the study:

$$\mathbf{Y_{ijklm} = \mu + S_i + P_j + N_k + A_l + e_{ijklm}}$$

Where Y_{ijklm} = is the m^{th} record of the individual belonging to i^{th} sire, j^{th} period, k^{th} season and l^{th} parity; μ = is the overall population mean; S_i= is the random effect of i^{th} sire (1 to n); P_j= is the fixed effect of j^{th} period of calving (1 to 6); N_k= is the fixed effect of i^{th} season of calving(1 to 4); A_l = is the fixed effect of l^{th} parity (1, 2 and 3); e_{ijklm}= is the random error associated with each observation, assumed to be normally and independently distributed with mean zero and variance $ó^2_e$.

Results and Discussion

The analysis of variance and the least squares means of fertility traits *viz.* AFC, SP, CR, CI, NSC and PR have been given in table 1 and table 2, respectively. The least squares mean of AFC was 1345.75±13.88 days which was in accordance with Wakchaure et al. (2008). Lower value was estimated by Jamuna et al. (2015) and higher values were estimated by Patil et al. (2018) and Jamal et al. (2018). This difference in age at first calving might be due to the difference in core herd, management practices and environmental conditions in various regions and within the same herd and region, management practices of different period may vary due to number

Table 1: Mean sum of squares of fertility traits

Source/Traits	Mean Sum of Squares					
	AFC	SP	CR	CI	NSC	PR
Sire	73832.75 (179)	11718.36 (152)	904.16 (152)	12299.78 (152)	1.58 (152)	0.05 (152)
Period	409816.09** (5)	12614.43 (5)	774.18 (5)	13398.25 (5)	1.04 (5)	0.04 (5)
Season	49741.07 (3)	69702.55** (3)	10451.01* (3)	75182.66* (3)	15.14** (3)	0.49** (3)
Parity	-	307019.66** (2)	14860.65* (2)	327424.09* (2)	17.82** (2)	0.58** (2)
Error	34941.98 (474)	9745.31 (809)	881.64 (809)	9840.86 (809)	1.47 (809)	0.039 (809)

Where AFC: age at first calving, SP: service period, CR: conception rate, CI: calving interval, NSC: number of services per conception and PR: pregnancy rate; *P<0.05, **P<0.01; figures in parenthesis denotes degree of freedom

Table 2: Estimates of least-squares means ± standard errors and effect of non-genetic factors on fertility traits

Ind. Var.	AFC (days)	SP (days)	CR (%)	CI (days)	NSC	PR (%)
OVERALL	1345.75±13.88 (662)	153.87±4.34 (972)	67.08±1.18 (972)	459.53±4.50 (972)	2.01±0.05 (972)	0.27±0.01 (972)
Period of calving						
1996-1999	1200.88^{a}±44.36 (96)	143.66±19.40 (95)	71.03±5.98 (95)	448.01±19.53 (95)	1.86±0.24 (95)	0.21±0.04 (95)
2000-2003	1442.20^{bc}±33.58 (113)	143.75±11.64 (172)	72.88±3.57 (172)	447.17±11.76 (172)	1.84±0.15 (172)	0.26±0.03 (172)
2004-2007	1175.00^{a}±33.36 (86)	173.35±10.68 (177)	64.59±3.23 (177)	477.91±10.80 (177)	2.16±0.13 (177)	0.24±0.03 (177)
2008-2011	1372.71^{b}±33.95 (121)	145.94±11.77 (158)	64.85±3.63 (158)	450.45±11.88 (158)	2.08±0.15 (158)	0.28±0.03 (158)
2012-2015	1384.81^{bc}±33.46 (117)	157.73±12.14 (211)	65.31±3.69 (211)	464.24±12.25 (211)	2.05±0.15 (211)	0.31±0.03 (211)
2016-2019	1498.93^{c}±52.06 (129)	158.77±18.14 (159)	63.79±5.60 (159)	469.37±18.27 (159)	2.07±0.23 (159)	0.31±0.04 (159)
Season of calving						
Summer (April to June)	1318.58±19.63 (186)	156.5^{ab}±8.15 (205)	65.01a^{b}±2.41 (205)	463.02^{ab}±8.26 (205)	1.96^{b}±0.10 (205)	0.26^{a}±0.02 (205)
Monsoon (July to September)	1363.15±19.02 (214)	133.1^{a}±6.21 (370)	75.5^{b}±1.81 (370)	437.89^{a}±6.34 (370)	1.7^{a}±0.08 (370)	0.34^{b}±0.02 (370)
Autumn (October to November)	1349.01±22.55 (122)	149.41^{ab}±8.05 (197)	69.20^{b}±2.51 (197)	454.45^{ab}±8.16 (197)	2.02^{b}±0.10 (197)	0.26^{a}±0.02 (197)
Winter (December to March)	1352.29±21.61 (140)	176.46^{b}±8.05 (200)	58.59^{a}±2.40 (200)	482.73^{b}±8.17 (200)	2.36^{c}±0.10 (200)	0.22^{a}±0.02 (200)
Parity of calving						
First	-	191.39^{c}±5.56 (479)	58.49^{a}±1.58 (479)	498.32^{c}±5.71 (479)	2.29^{c}±0.07 (479)	0.21^{a}±0.01 (479)
Second	-	152.76^{b}±6.42 (304)	67.43^{b}±1.91 (304)	458.23^{b}±6.54 (304)	2.04^{b}±0.08 (304)	0.26^{b}±0.02 (304)
Third	-	117.45^{a}±8.10 (189)	75.30^{c}±2.45 (189)	422.03^{a}±8.21 (189)	1.69^{a}±0.10 (189)	0.34^{c}±0.02 (189)

Where AFC: age at first calving, SP: service period, CR: conception rate, CI: calving interval, NSC: number of services per conception and PR: pregnancy rate; Means superscripted by different letters differ significantly among themselves; figures in parenthesis are number of observations

of animals replaced in different periods and selection criteria used during the period. Estimated least squares means value of SP in present study was 153.87±4.34 days which was near to the estimated values of Wakchaure et al. (2008) and Dev et al. (2015). The difference in values of service period mainly occurred due to heat detection efficiency in various herds as effective heat detection was the sole reason for better service period in this herd. Least squares mean value of CR came out to be 67.08±1.18%, similar to the value of Dash et al. (2015) which was 68.80±1.18%. Conception rate vary from individual to individual and the sire used, therefore the overall result was the outcome of summation of individual performance. The least squares mean of CI was 459.53±4.50 days which lied around the values of Seno et al. (2010) and Jamal et al. (2018). Calving interval depends solely on service period, improvement in service period would lead to improvement in calving interval. Least squares mean of NSC was estimated out as 2.01±0.05. Lower values were reported by Patil et al. (2018) and higher value was obtained by Thiruvenkadan et al. (2014). This was due to use of various sires on different dams randomly over the periods. The estimated least squares mean value of PR was 0.27±0.01%. Higher values were obtained by Dash et al. (2015) and Jamuna et al. (2015). This was due to intensive use and skill in practicing artificial insemination.

Effect of non-genetic factors on fertility traits

Period of calving (POC) had no effect on all fertility traits viz. SP, CR, CI, NSC and PR, except AFC. Significant ($P<0.01$) effect of POC was obtained on AFC which was in same plane with Charlini

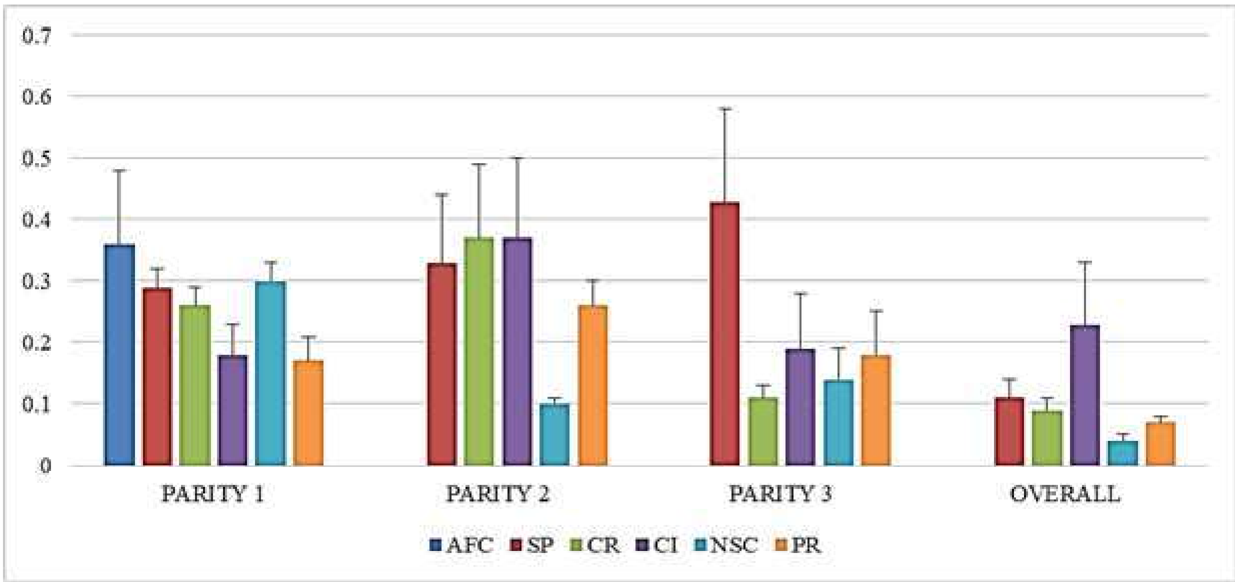

Fig.1 Diagram showing heritability of fertility traits in all three lactations and overall lactation along with their standard error

and Sinniah (2015) whereas non-significant effect of POC was reported by Naqvi and Shami (1999). Age at first calving was minimum in third period calvers (2004-2007) valued as 1175±33.36 days and maximum in sixth period calvers came out to be 1498.93±52.06 days. The overall AFC increased over several periods, is not a desirable factor for selection, as if, we are much concerned with early AFC for breeding. AFC increased from 1200.88 days in first period (1996-1999) to 1498.93 days in sixth period (2016-2019) indicating that this fertility trait needs to address in order to have more calf crop in the lifetime of buffaloes.

Service period showed irregular change over the period being the lowest in first period calvers as 143.66±19.40 days and highest in third period calvers as 173.35±10.68 days and went on decreasing without any trend till sixth period. Conception rate decreased with period from 71.03±5.98% to 63.79±5.60%. Chaudhari (2015) and Jamal et al. (2018) reported non-significant effect of POC on SP and CI whereas Jamuna et al. (2015) reported significant effect of POC on SP. Moreover, Sarkar et al. (2006) reported that POC had significant effect on conception rate in Murrah buffaloes. Calving interval showed irregular change, it was highest in third period calvers valued 477.91±10.80 days and lowest in second period calvers valued as 447.17±11.76 days. Patil et al. (2014) and Thiruvenkadan et al. (2014) reported that POC had significant effect on NSC while Kumar et al. (2003) obtained contrary results and reported non-significant effect of POC on NSC. Number of services per conception also had the irregular pattern of change being the lowest in second period calvers valued 1.84±0.15 and highest in third period calvers valued as 2.16±0.13. Overall PR gets increased from 0.21±0.04% to 0.31±0.04% with period (Table 2). All the fertility traits showed irregular pattern over the periods depending on the management and environmental conditions prevailed at that time.

Season of calving (SOC) reported to have highly significant ($P<0.01$) effect on SP, NSC and PR and significant ($P<0.05$) effect of SOC was obtained on CR and CI whereas non-significant effect of SOC was reported on AFC. Chaudhari (2015) also found non-significant effect of SOC on AFC in Murrah buffalo whereas Jamal et al. (2018) obtained significant effect of SOC on AFC. Age at first calving was the highest in monsoon season calvers estimated as 1363.15 days and the lowest in summer season calvers as 1318.58 days. Jamuna et al. (2015); Chaudhari (2015); Jakhar et al. (2016) and Jamal et al. (2018) found the significant effect of SOC on SP and CI. Service period was the highest in winter season calvers valued as 176.46 days and lowest in monsoon season calvers as 133.10 days. CR valued as 75.5±1.81%, highest in monsoon season calvers and lowest value in summer season calvers as 58.59±2.40%. Pasha et al. (1986) reported conception rate as 47.07%, 41.51%, 39.81%, and 51.96% in winter, spring, summer and autumn, respectively in Nili-Ravi buffaloes with significant effect of season on conception rate. Patil et al. (2014) and Thiruvenkadan et al. (2014) reported significant effect of SOC on NSC. Calving interval and number of services per conception both were highest and lowest in winter and monsoon season calvers valued as 482.73±8.17 days and 437.89±6.34 days and 2.36±0.10 and 1.7±0.08, respectively. PR had its highest value in monsoon season calvers as 0.34±0.02% and lowest in winter season calvers as 0.22±0.02%. Critical appraisal of the results indicated that monsoon season calvers (July to September) excelled in performance for all fertility traits except AFC and the better performance of monsoon season calvers could be attributed to plenty of green fodders availability to these animals at the time of calving.

Highly ($P<0.01$) significant effect of parity was reported on SP and NSC and significant effect of parity at $P<0.05$ was also seen on CR, CI and PR. Likewise, Chaudhari (2015), Jamuna et al. (2015);

Jakhar et al. (2016) and Jamal et al. (2018) obtained significant effect of parity on SP. Service period decreased with lactation order from 191.39±5.56 days to 117.45±8.10 days which is a required character for reproductive worth of the animal. CR increased with parity from 58.49±1.58% to 75.30±2.45% indicates improvement of trait with parity order. Catillo et al. (2001) reported non-significant effect of parity on calving interval whereas Chaudhari (2015), Jakhar et al. (2016) and Jamal et al. (2018) recorded significant effect of parity on CI. Calving interval and number of services per conception had the right direction of selection as these traits went down from 498.32±5.71 days to 422.03±8.21 days and 2.29±0.07 to 1.69±0.10 with increasing lactation order. Pregnancy rate increased with parity from 0.21±0.01% to 0.34±0.02% indicated towards the effective fertility performance. Better performance of all fertility traits in third lactation is a matter of attainment of physiological maturity and increased efficiency of buffaloes to convert dietary nutrients into milk due to attainment of adult weight of buffaloes.

Heritability estimates of fertility traits

Heritability estimates for first lactation performance traits ranged from 0.17±0.04 (PR) to 0.36±0.12 (AFC), for second lactation 0.10±0.01(NSC) to 0.37±0.12 (CR), for third lactation 0.11±0.02 (CR) to 0.43±0.15 (SP) and for overall production performance traits ranged from low (0.04±0.01) of NSC to high (0.23±0.10) of CI (Table 3). Maximum estimates of heritability were seen in second lactation and minimum heritability estimates were obtained in overall lactations. Heritability of fertility traits of all three lactations and overall lactation along with their standard error has been shown in figure 1. However, NSC exhibited maximum heritability in first lactation. Age at first calving was found to be moderately heritable (0.36±0.21) and service period was reported to be low (0.11±0.03) heritable in overall lactation which lied same with the results of Patil et al. (2018). CR was reported low (0.09±0.02) heritable, similar to Dash et al. (2015). CI was found moderately (0.23±0.10) heritable trait which was similar to Jakhar et al. (2016). Heritability estimate of NSC was found very low (0.04±0.01), similar to Patil et al. (2018). PR had low (0.07±0.01) heritability estimates as reported by Dash et al. (2015) and Jamuna et al. (2015). Fertility traits exhibited low to moderate heritability in first, second, third and overall lactations.

The differences in heritability estimates of various research studies and their standard errors may be due to the changes in recording procedure, the correction for different non-genetic parameters and the methodology or model used for the estimates of heritability for the trait. In addition to this, herd size, feeding management of the different farm and climatic condition of the country may also be cause of such variations. The estimates for the fertility traits with low heritability indicated a good scope for refinement in these traits by providing uniform environment. Further improvement in these traits would require information from other relatives and enhancement in managemental practices. In general, fertility traits were influenced by environment and exhibited low heritability indicated that improvement could be possible through selective breeding, adjusting management practices and nutrient intake.

Correlation between the fertility traits

Table 3: Heritability of fertility traits in three lactations and in overall lactation

TRAITS	PARITY 1	PARITY 2	PARITY 3	OVERALL
AFC	0.36 ± 0.12			
SP	0.29 ± 0.03	0.33 ± 0.11	0.43 ± 0.15	0.11 ± 0.03
CR	0.26 ± 0.03	0.37 ± 0.12	0.11 ± 0.02	0.09 ± 0.02
CI	0.18 ± 0.05	0.37 ± 0.13	0.19 ± 0.09	0.23 ± 0.10
NSC	0.30 ± 0.03	0.10 ± 0.01	0.14 ± 0.05	0.04 ± 0.01
PR	0.17± 0.04	0.26 ± 0.04	0.18 ± 0.07	0.07 ± 0.01

Where AFC: age at first calving, SP: service period, CR: conception rate, CI: calving interval, NSC: number of services per conception and PR: pregnancy rate

Table 4: Heritability, genetic (below diagonal) and phenotypic correlation (above diagonal) among overall lactation fertility traits

Traits	AFC#	SP	CR	CI	NSC	PR
AFC	0.36±0.21	-0.07±0.02	0.07±0.02	-0.06±0.05	-0.05±0.01	0.04±0.001
SP	0.02±0.07	0.11±0.03	-0.65**±0.17	0.95**±0.25	0.68**±0.18	-0.27**±0.11
CR	0.08±0.09	-0.64±0.17	0.09±0.02	-0.62**±0.19	-0.69**±0.24	0.28**±0.12
CI	0.04±0.08	0.47±0.08	-0.52±0.15	0.23±0.10	0.64**±0.25	-0.26**±0.11
NSC	-0.03±0.07	0.81±0.06	-0.20±0.13	0.70±0.07	0.04±0.01	-0.21**±0.11
PR	0.05±0.09	-0.28±0.14	0.22±0.14	-0.18±0.14	-0.69±0.18	0.07±0.01

Where AFC: age at first calving, SP: service period, CR: conception rate, CI: calving interval, NSC: number of services per conception and PR: pregnancy rate: *P<0.05, **P<0.01; #first lactation only

In overall lactations, the minimum and maximum genetic correlation was found between NSC/PR and SP/NSC, valued as -0.69±0.18 and 0.81±0.06, respectively. The range of phenotypic correlation varied from -0.69±0.24 (CR/NSC) to 0.95±0.25 (SP/CI), respectively which was highly significant as given in table 4.

Service period exhibited negative genetic and phenotypic correlation with CR valued as -0.64±0.17 and -0.65±0.17. Similarly, CR was reported to have negative genetic and phenotypic correlation with CI valued as -0.52±0.15 and -0.62±0.19 and with NSC valued as -0.20±0.13 and -0.69±0.24, respectively. Moreover, it was found that PR had negative genetic and phenotypic correlation with SP valued as -0.28±0.14 and -0.27±0.11, with CI had the values as -0.18±0.14 and -0.26±0.11 and with NSC values reported were -0.69±0.18 and -0.21±0.11 which were highly significant.

Chakraborty et al. (2010) and Dev et al. (2015) reported the high genetic and phenotypic correlation between FSP and FCI but in this study, moderate to highly positive genetic and phenotypic correlation between SP and CI. Pregnancy rate showed moderately positive genetic and phenotypic correlation with CR which was 0.22±0.14 and 0.28±0.12, respectively. CR had highly negative genetic correlation with SP (-0.64±0.17), CI (-0.52±0.15) and NSC (-0.20±0.13).

Conclusion

It is concluded that conception rate and pregnancy rate had negative association with all other fertility traits but these traits are positively correlated with each other. Fertility traits showed low to moderate genetic and phenotypic correlation with each other except with AFC. Their association with each other indicated that improvement in one trait would result in enhancement of other traits as well.

Acknowledgement

We are thankful to Vice Chancellor for the data of Buffalo Farm, Department of LPM, LUVAS, Hisar.

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