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Serum mineral profiling as a tool for predicting bovine fertility in the central Ganga plain of India

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Research Article

Keywords: Bovine fertility, Mineral profile

Posted Date: July 28th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10401127/v1

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Abstract

The present study evaluated the serum mineral profile as a tool to predict the bovine reproductive condition in central Ganga plain of India.105 reproduction related problematic animals (heifer and lactating) were selected randomly for blood collection in 10 villages from 02 blocks of Prayagraj district of Uttar Pradesh, India. The major minerals (Ca, P, Mg, Na and K), trace minerals (Fe, Cu, Zn, Mn, and Co), and ultratrace minerals (Ba, Ni, Al and Cr) in the digested serum samples were determined in triplicate using an Agilent-5800 ICP-OES. The prevalence of reproductive disorders was 47.75% in dairy cattle. The serum profile of reproductive disorders dairy cattle were deficient in Ca, P, Na and K, marginal deficient in Cu, Zn, Mn and Ni and adequate/excess in Mg, Fe, Ba, Al and Cr minerals. The serum calcium concentration showed significant ($p < 0.05$) correlation with all minerals except manganese. Mg significantly correlated ($p < 0.05$) with rest minerals except P and Mn. P was correlated with Ca, Na, Zn and Ba. Na was not correlated with K, Co, Ba and Al. Principal Component Analysis (PCA) highlighted four key mineral groups that explained 79.67% of the variance. Serum mineral levels were significantly associated with reproductive conditions. Specific minerals such as Ca, Mg, P, Na, K, Fe Cu, Zn and Mn showed significant differences between different reproductive disorders, further indicating their role in reproductive health. It can be a tool to predict the reproductive conditions in dairy cattle.

Introduction

Globally, livestock contributes substantially to agricultural gross domestic product (GDP), nutritional security, and employment, particularly in developing countries where it serves as a major source of income for smallholder farmers (FAO 2018). In India, the dairy sector represents one of the most important components of agriculture, playing a pivotal role in economic growth, nutritional security, and rural employment. India has remained the world's largest milk producer, with continuous growth in milk production driven by improvements in animal husbandry, breeding and dairy management practices. Uttar Pradesh is the leading milk-producing state in India, contributing approximately 16% of the country's total milk production. The livestock sector contributes nearly 7% to the Gross Domestic Product (GDP) of Uttar Pradesh, highlighting its substantial economic importance in the state (DAHD 2024). Prayagraj district, formerly known as Allahabad, is one of the major agricultural regions of Uttar Pradesh where dairy farming constitutes an important livelihood activity for rural households. However, reproductive disorders remain a significant constraint to profitable dairy production in northern India. These disorders reduce reproductive efficiency, prolong calving intervals, decrease milk yield, increase veterinary and management costs, and ultimately diminish the profitability of dairy enterprises. Consequently, they contribute to substantial economic losses and limit the socioeconomic advancement of livestock-dependent farming communities (Butler 2021).

Reproductive performance is influenced by numerous interacting factors, including genetics, management practices, infectious diseases, environmental stressors, and nutritional status. Among these, nutrition is recognized as one of the most critical determinants of reproductive efficiency. Although considerable progress has been made in understanding nutritional regulation of reproduction, the complex interactions among metabolic signals, endocrine pathways, and reproductive physiology remain only partially understood. Nutrient-mediated regulation of reproduction occurs through both direct effects on ovarian and uterine tissues and indirect modulation of the hypothalamic-pituitary-gonadal axis, thereby influencing follicular development, ovulation, conception, and maintenance of pregnancy (Santo et al. 2021). Minerals constitute an essential component of animal nutrition because they participate in numerous physiological, biochemical, and endocrine processes that regulate growth, immunity, metabolism, and reproduction. Both macro and micro minerals including calcium, phosphorus, magnesium, copper, zinc, selenium, manganese, cobalt, and iron are indispensable for maintaining normal reproductive function. Deficiencies, imbalances, or toxicities of these minerals impair ovarian activity, hormone synthesis, embryo survival, immune competence, and uterine involution, thereby increasing the incidence of reproductive disorders in dairy animals (Goff 2023). Understanding the nutritional and mineral-related determinants of reproductive disorders is essential for developing effective, sustainable, and region-specific intervention strategies aimed at improving reproductive efficiency in dairy herds. Considering the economic significance of dairy farming in Prayagraj district and the high prevalence of reproductive disorders among bovines, the present study was undertaken to evaluate the serum mineral profile of bovines with different reproductive conditions. The findings of this investigation may contribute to the development of predictive tools for early diagnosis of reproductive disorders and support evidence-based nutritional interventions to enhance reproductive performance and productivity of dairy animals in Uttar Pradesh.

Materials and methods

The present study was conducted in the Prayagraj district, located in southern segment of Uttar Pradesh, India at 25.45^0N 81.84^0E, which is one of the most religious city due to the convergence of three rivers; Ganga, Yamuna and Saraswati.

Location, data and sample collection

Ten villages from two blocks of Prayagraj district were selected randomly and from each village total 10–12 farmers were randomly chosen for data collection in standard questionnaire related to livestock reproduction and production. Out of total cattle affected from reproductive disorders observed during survey, 105 problematic animals (heifer and lactating) were selected for blood collection. Approximately 10 ml blood was collected from jugular vein in the morning and kept on ice. Serum was harvested by centrifugation at 1000–1500 pm for 10 minutes at room temperature within two hours of collection.

Wet digestion of samples

Serum samples (0.5-1.0 ml) were digested in triplicates using compact microwave digestion system (Milestone Helping Chemists) with concentrated nitric acid and hydrochloric acid (5:1 ratio) and volume was made upto 50 ml with deionized water.

Mineral analysis

Agilent- 5800 ICP-OES (Inductively Coupled Plasma Optical Emission spectroscopy) instrument was used to determine major (Ca, P, Mg, Na, K) trace (Cu, Zn, Mn, Fe, Co) and ultra-trace elements (Ba, Ni, Al, Cr). A set of standard solutions was prepared. Each solution contains accurately known concentrations of elements (0.00, 0.05, 1.00, 5.00, 20.00 and 80.00 ppm). The concentrations of the elements in each sample solution were determined from the calibration graphs. The concentrations in the original sample were then calculated from the measure concentrations of the elements in the sample solution and the known dilution factor. ICP-OES analysis delivered results that list the concentration of the selected elements, typically in $\mu g/g^{-1}$ or $\mu g/ml^{-1}$.

Statistical analysis

All the data generated was statistically analyzed using SPSS Statistics 20 Software and subjected to mean with standard error. For mineral values, a principal component analysis (PCA) was run with the data from all measurements. Principal component analysis is a multivariate technique that reduces the dimensionality of data by transforming a number of related variables into a set of uncorrelated variables, while retaining as much variation as possible. The new transformed variables, referred to as principal components (PCs), are linear combinations of the original variables. The first PC (PC1) accounts for the maximum variability, whereas the other PCs (PC2, PC3, PC4, n = number of variables) describe the remaining variability of the data. As each PC is independent of and orthogonal to the others, and thus represents more than one mineral, these principal components were further used to determine the concerted variations of minerals during the transition period and to address whether they were related to reproductive performance. The resulting data matrix was rotated through the Varimax procedure and Kaiser Normalization, and the regression scores were used for further statistical analyses. Raw data from nutrients as well as the principal components resulting from PCA were subjected to a mixed model (repeated measures) followed by a post-hoc Bonferroni's test for pair-wise comparisons.

The association of reproductive conditions with the mineral concentration of reproductive affected animals was tested using the Multivariate Analysis of Variance (MANOVA). Individual ANOVA tests were then used to test the association of each reproductive condition on the mineral composition of affected animals. For the significant ANOVA tests, a post-hoc test (Tamhane T2) was used to determine the statistical significance and magnitude of the differences in the mean levels of each mineral between pairs of reproductive conditions (mean Ca in Anoestrus – mean Ca in ROP= mean difference). Tamhane T2 is a post-hoc test for determining the significance and the magnitude of the difference in means based on treatment. Since the animal under each type of treatment (reproductive conditions) are unequal, equality of variance is not assumed in this study and Tamhane T2 is known to give accurate results when equality of variance is not assumed (De Muth, 2014).

Results

Prevalence of reproductive disorder in cows

Total 490 dairy cattle were found during survey in Prayagraj district of Uttar Pradesh. Out of this, 234 (47.75%) dairy cattle were found to be affected by at least one or more reproductive health problems. The relative frequency of anestrous, repeat breeding, dystocia, ROP, prolapse and abortion was 33.34%, 26.49%, 15.81%, 26.49%, 11.98%, 6.83% and 5.55% respectively (Figure: 1).

Mineral concentration in dairy cows

The concentrations of major minerals (Ca, Mg, P, K and Na) in the serum sample of dairy cattle are presented in the Table 1. The Ca concentration was significantly ($p < 0.05$) lower in dystocia and prolapsed than normal value while anoestrus, repeat breeding and ROP affected cattle had marginal calcium concentration. Mg concentration was significantly ($p < 0.05$) higher in anoestrus, repeat breeding and ROP while marginally higher in prolapse and dystocia. Phosphorus followed the similar pattern to calcium and significantly ($p < 0.05$) lower. The Na was significantly ($p < 0.05$) lower in dystocia and ROP while marginally low in other reproductive disorders. The potassium was significantly ($p < 0.05$) lower in dairy cattle suffering from any reproductive disorders like anoestrus, dystocia, repeat breeding, prolapse and ROP. The overall average of Ca, P, Na and K was lower in affected animals while Mg was higher.

Table 1
Major mineral concentration (Mean ± SE) in dairy cows of Prayagraj district of India

Reproductive conditions	Calcium (ppm)	Magnesium (ppm)	Inorganic Phosphorus (ppm)	Potassium (ppm)	Sodium (ppm)
Anoestrus	93.77 ± 5.30	45.84 ± 1.64*	37.48 ± 1.10*	184.16 ± 5.50*	2952.53 ± 73.76
Dystocia	59.20 ± 1.02*	32.49 ± 1.64*	21.99 ± 0.50*	161.39 ± 3.29*	1673.49 ± 24.61*
Prolapse	68.39 ± 5.34*	33.35 ± 3.97*	21.64 ± 7.92*	117.28 ± 19.93*	2944.68 ± 186.11
Repeat Breeding	95.02 ± 5.0	61.86 ± 6.32*	34.31 ± 1.91*	176.59 ± 3.96*	4033.81 ± 135.72
ROP	91.89 ± 6.72	55.36 ± 4.50*	40.70 ± 1.08	188.99 ± 7.87*	1701.91 ± 8.49*
Overall avg.	82.85 ± 7.89*	43.78 ± 5.83*	31.22 ± 3.97*	165.68 ± 12.97*	2661.28 ± 444.13*
Normal range	90–120	18–24	40–60	514–742	3500–7000
* Data below/above normal range					

The trace mineral (Fe, Cu, Zn, Mn and Co) concentration in dairy cows of Prayagraj district is presented in the Table 2. The iron concentration was significantly ($p < 0.05$) higher in anoestrus, repeat breeding and ROP affected animals. Copper concentration was significantly ($p < 0.05$) lower in anoestrus, dystocia and prolapse while rest reproductive conditions had marginal low concentration. In all reproductive disorder conditions zinc level in serum was adequate. Anoestrus, prolapsed and ROP affected cattle showed the marginal manganese level while dystocia and repeat breeding cattle showed significantly ($p < 0.05$) lower concentration of manganese element. Co concentration was adequate in all reproductive conditions. The overall average of Fe, Zn and Co was higher in affected cows while Mn and Cu were in the range.

The ultra trace minerals (Ba, Ni, Al and Cr) concentration in dairy cows of Prayagraj district is presented in the Table 3. The Ba concentration was significantly ($p < 0.05$) higher in repeat breeding reproductive condition of dairy cattle. The Ni concentration was significantly ($p < 0.05$) lower in anoestrus and dystocia while rest reproductive conditions had marginal Ni level. The overall average of Ba, Al and Cr were higher in affected cows while Ni was lower.

Table 2
Trace mineral concentration (Mean ± SE) in dairy cows of Prayagraj district of India

Reproductive conditions	Iron (ppm)	Copper (ppm)	Zinc (ppm)	Manganese (ppm)	Cobalt (ppm)
Anoestrus	17.96 ± 3.97*	0.99 ± 0.02*	3.52 ± 0.78	24.35 ± 4.89	0.08 ± 0.01*
Dystocia	7.52 ± 2.46	0.62 ± 0.04*	1.94 ± 0.27	20.99 ± 3.21*	0.08 ± 0.02*
Prolapse	10.24 ± 1.18	0.95 ± 0.10*	5.05 ± 1.14	25.08 ± 7.31	0.09 ± 0.01*
Repeat Breeding	44.42 ± 0.40*	1.17 ± 0.02	6.28 ± 0.10	20.51 ± 0.90*	0.08 ± 0.05*
ROP	21.68 ± 5.80*	1.48 ± 0.17	3.91 ± 0.22	30.85 ± 11.44	0.08 ± 0.01*
Overall avg.	20.36 ± 6.53*	1.04 ± 0.14	4.14 ± 0.73*	24.36 ± 6.75	0.08 ± 0.03*
Normal range	2.5–4.50	0.8–1.50	0.7–2.20	25–40	0.05
* Data below/above normal range					

Table 3
Ultratrace mineral concentration (Mean ± SE) in dairy cows of Prayagraj district of India

Reproductive conditions	Barium (ppm)	Nickel (ppm)	Aluminum (ppm)	Chromium (ppm)
Anoestrus	0.45 ± 0.12	0.38 ± 0.07*	9.80 ± 4.90*	0.64 ± 0.14*
Dystocia	0.18 ± 0.04	0.25 ± 0.03*	4.69 ± 0.76*	0.33 ± 0.07
Prolapse	0.41 ± 0.05	0.39 ± 07.05	8.45 ± 1.42*	0.44 ± 0.45
Repeat Breeding	0.58 ± 0.02*	1.02 ± 0.02	19.01 ± 0.22*	1.68 ± 0.01*
ROP	0.62 ± 0.08	0.76 ± 0.17	18.05 ± 2.51*	1.36 ± 0.34*
Overall avg.	0.44 ± 0.07*	0.56 ± 0.14*	12.00 ± 2.79*	0.89 ± 0.26*
Normal Range	0.01–0.06	0.65-2.00	0.09-2.00	0.06–0.30
* Data below/above normal range				

Correlation Matrix between minerals

The correlation between minerals in dairy animals affected by the reproductive problem of Prayagraj district is presented in the Tables 4 and 5. The serum calcium concentration showed significant ($p < 0.05$) correlation with all minerals except manganese. Mg significantly correlated ($p < 0.05$) with rest minerals except P and Mn. P was correlated with Ca, Na, Zn and Ba. Na was not correlated with K, Co, Ba and Al. Like that K was also not correlated with Na, P, Mn, Ba, Ni and Al. Fe was not correlated with phosphorus, cobalt, barium and aluminium. Mn was not correlated with calcium, magnesium, phosphorus, cobalt, barium and aluminium while rest trace and ultratrace minerals were significantly ($p < 0.05$) correlated with each other.

Table 4
Correlation Matrix between major minerals in dairy cows of Prayagraj district of India

Correlation	Ca	Mg	P	Na	K	Fe	Cu	Zn	Mn	Co	Ba	Ni	Al	Cr
Ca	1.000	.768	.262	.334	.283	.306	.374	.205	− .115	.160	.698	.432	.700	.313
Mg	.768	1.000	.114	.241	.205	.244	.482	.290	− .098	.300	.898	.544	.921	.357
P	.262	.114	1.000	.206	− .090	.118	.027	.305	.087	.142	.152	− .017	.094	− .054
Na	.334	.241	.206	1.000	.050	.554	.235	.224	− .444	.050	.068	.520	.092	.516
K	.283	.205	− .090	.050	1.000	.170	.194	− .274	.127	− .344	− .006	.066	.050	.182
Sig. (1 tailed)														
Ca	-	.000	.002	.000	.001	.000	.000	.013	.107	.042	.000	.000	.000	.000
Mg	.000	-	.110	.004	.013	.004	.000	.001	.145	.000	.000	.000	.000	.000
P	.002	.110	-	.013	.166	.101	.385	.000	.175	.063	.050	.426	.155	.282
Na	.000	.004	.013	-	.294	.000	.005	.007	.000	.297	.231	.000	.162	.000
K	.001	.013	.166	.294	-	.033	.018	.001	.086	.000	.474	.240	.295	.024

Table 5
Correlation Matrix between trace and ultratrace minerals in dairy cows of Prayagraj district of India

Correlation	Ca	Mg	P	Na	K	Fe	Cu	Zn	Mn	Co	Ba	Ni	Al	Cr
Fe	.306	.244	.118	.554	.170	1.000	.374	.432	− .807	.016	.048	.829	.090	.906
Cu	.374	.482	.027	.235	.194	.374	1.000	.253	− .294	.231	.433	.495	.322	.515
Zn	.205	.290	.305	.224	− .274	.432	.253	1.000	− .295	.359	.346	.496	.299	.362
Mn	− .115	− .098	.087	− .444	.127	− .807	− .294	− .295	1.000	.056	.049	− .794	− .021	− .852
Co	.160	.300	.142	.050	− .344	.016	.231	.359	.056	1.000	.315	.272	.249	.154
Ba	.698	.898	.152	.068	− .006	.048	.433	.346	.049	.315	1.000	.345	.957	.125
Ni	.432	.544	− .017	.520	.066	.829	.495	.496	− .794	.272	.345	1.000	.415	.940
Al	.700	.921	.094	.092	.050	.090	.322	.299	− .021	.249	.957	.415	1.000	.182
Cr	.313	.357	− .054	.516	.182	.906	.515	.362	− .852	.154	.125	.940	.182	1.000
Sig. (1 tailed)														
Fe	.000	.004	.101	.000	.033	-	.000	.000	.000	.431	.303	.000	.168	.000
Cu	.000	.000	.385	.005	.018	.000	-	.003	.001	.006	.000	.000	.000	.000
Zn	.013	.001	.000	.007	.001	.000	.003	-	.001	.000	.000	.000	.000	.000
Mn	.107	.145	.175	.000	.086	.000	.001	.001	-	.275	.298	.000	.412	.000
Co	.042	.000	.063	.297	.000	.431	.006	.000	.275	-	.000	.001	.003	.047
Ba	.000	.000	.050	.231	.474	.303	.000	.000	.298	.000	-	.000	.000	.088
Ni	.000	.000	.426	.000	.240	.000	.000	.000	.000	.001	.000	-	.000	.000
Al	.000	.000	.155	.162	.295	.168	.000	.000	.412	.003	.000	.000	-	.024
Cr	.000	.000	.282	.000	.024	.000	.000	.000	.000	.047	.088	.000	.024	-

Correlation between principal components and reproductive disorders

The PCA of mineral concentration in 105 serum samples yielded four principal components which are shown in the Tables 6 and 7. The four principal components were yielded because they had more than 1 Eigenvalues. These four principal components could explain up to 79.67% of the total variance, as follows: 38.94% (PC1), 20.59% (PC2), 11.91% (PC3) and 8.23% (PC4). The first component (PC1) contained Na, Fe, Cu, Ni and Cr; the second component (PC2) included Ca, Mg, Ba and Al. The third component (PC3) contained Zn and Co. The fourth component (PC4) included only P.

Table 6
Total variance and Egenvalues of minerals during Principal Component Analysis

Principal Component (PC)	Initial Eigenvalues		
	Total	**% of Variance**	**Cumulative %**
1	5.45	38.94	38.94
2	2.88	20.59	59.53
3	1.66	11.91	71.44
4	1.15	8.23	79.67
5	0.78	5.63	85.30

Table 7
Principal component (PC 1–4) loadings in the first four eigenvectors for minerals determined in 105 serum samples in dairy animals of Prayagraj district

Elements	PC 1	PC 2	PC 3	PC 4
Ca	0.20	0.79	-0.17	0.30
Mg	0.19	0.95	-	-
P	-	-	0.14	0.91
Na	0.60	-	-	0.44
K	0.10	0.23	-0.83	-
Fe	0.93	-	-	0.17
Cu	0.44	0.48	-	-0.10
Zn	0.38	0.22	0.59	0.31
Mn	-0.91	-	-	-
Co	-	0.29	0.71	-
Ba	-	0.94	0.19	-
Ni	0.88	0.36	0.15	-
Al	-	0.94	0.12	-
Cr	0.96	0.17	-	-

Tool to predict reproductive conditions

To predict the reproductive disorders in dairy cattle an association of reproductive conditions with the concentration of serum minerals was established. Table 8 shows that all the multivariate test (Pillai's Trace, Wilk's Lambda and Hotteling's Trace) were significant ($P < 0.05$) and indicating that the reproductive conditions were dependent on the mean serum concentration of mineral in Kaurihar and Naini block of Prayagraj district. Table 9 showed that any mineral concentration in serum was not dependent on the reproductive disorders.

The multiple comparison of mineral among the reproductive disorders is presented in the Table 10. The multiple comparison of mineral in anoestrus with other reproductive disorders showed few significant result. The Ca and Mg level in anoestrus, repeat breeding and ROP animals was significantly ($P < 0.05$) higher than dystocia and prolapse. The phosphorus in anoestrus, prolapse and repeat breeding animals was significantly ($P < 0.05$) higher than dystocia and ROP. Serum sodium level was significantly ($P < 0.05$) higher in anoestrus and prolapse than dystocia and ROP while significantly ($P < 0.05$) lower than repeat breeding condition. The K level in anoestrus, repeat breeding and ROP animals was significantly ($P < 0.05$) higher than dystocia and prolapse. Serum iron level was significantly ($P < 0.05$) higher in anoestrus than dystocia and prolapse while significantly ($P < 0.05$) lower than repeat breeding condition. The Cu and Zn level in anoestrus, prolapse and ROP animals was significantly ($P < 0.05$) higher than dystocia while significantly ($P < 0.05$) lower than repeat breeding. Serum Mn level was significantly ($P < 0.05$) lower in repeat breeding in comparison to rest other reproductive conditions. Cobalt did not show any significant difference between reproductive conditions. Ba, Al and Cr serum level were significantly ($P < 0.05$) lower in dystocia in comparison to rest other reproductive conditions of dairy cattle in Prayagraj. The Ni in anoestrus, and prolapse animals was significantly ($P < 0.05$) higher than dystocia while significantly ($P < 0.05$) lower than repeat breeding and ROP.

Table 8
Multivariate Test (MANOVA) of mineral concentration of dairy cattle having different reproductive disorders in Prayagraj district of India

Effect	Value	F	Hypothesis df	Error df	Sig.
RD Pillai's Trace	2.15	8.61	56	412.00	0.000
Wilks' Lambda	0.03	9.82	56	391.15	0.000
Hotelling's Trace	6.18	10.88	56	394.00	0.000
Roy's Largest Root	3.02	22.24	14	103.00	0.000
df= degree of freedom, sig= Significance level at 5%					

Table 9
Serum mineral concentration associated with reproductive condition of dairy cows in Prayagraj district of India

Source	Dependent Variable	df	F	Sig.
Reproductive conditions	**Ca**	4	9.17	0.000
	Mg	4	6.68	0.000
	P	4	17.04	0.000
	Na	4	54.29	0.000
	K	4	13.11	0.000
	Fe	4	20.65	0.000
	Cu	4	20.94	0.000
	Zn	4	6.06	0.000
	Mn	4	12.06	0.000
	Co	4	0.45	0.762
	Ba	4	1.98	0.101
	Ni	4	24.53	0.000
	Al	4	2.43	0.050
	Cr	4	22.09	0.000

Table 10

Multiple Comparison of mineral concentration among the reproductive disorders in dairy cows of Prayagraj district of India

Dependent Variable	(I) RD	(J) RD	Mean Difference (I-J)	Std. Error	Sig.
Ca	Anoestrus	Dystocia	81.14	10.67	0.000
		Prolapse	62.75	11.41	0.000
		Repeat Breeding	-30.49	19.56	0.732
		ROP	15.75	17.16	0.991
Mg	Anoestrus	Dystocia	-46.25	1.66	0.000
		Prolapse	12.48	2.40	0.000
		Repeat Breeding	-16.01	6.54	0.165
		ROP	-9.514	4.79	0.551
P	Anoestrus	Dystocia	15.48	1.21	0.000
		Prolapse	-3.21	1.12	0.061
		Repeat Breeding	3.17	2.21	0.812
		ROP	15.84	1.10	0.000
Na	Anoestrus	Dystocia	1279.04	77.76	0.000
		Prolapse	-18.14	123.42	1.000
		Repeat Breeding	-1081.27	154.47	0.000
		ROP	1250.56	74.25	0.000
K	Anoestrus	Dystocia	22.77	6.41	0.009
		Prolapse	61.87	13.15	0.001
		Repeat Breeding	7.56	6.78	0.952
		ROP	-4.82	9.60	1.000
Fe	Anoestrus	Dystocia	10.43	2.49	0.002
		Prolapse	7.714	2.51	0.038
		Repeat Breeding	-26.46	4.67	0.000
		ROP	-3.72	6.37	1.000
Cu	Anoestrus	Dystocia	0.37	0.05	0.000
		Prolapse	0.04	0.06	0.991
		Repeat Breeding	-0.18	0.05	0.007
		ROP	-0.48	0.18	0.244
Zn	Anoestrus	Dystocia	1.57	0.29	0.000
		Prolapse	-1.52	0.61	0.163
		Repeat Breeding	-2.75	0.83	0.017
		ROP	-0.38	0.35	0.964
Mn	Anoestrus	Dystocia	-0.63	3.33	1.000
		Prolapse	9.27	4.63	0.403
		Repeat Breeding	33.84	5.85	0.000
		ROP	23.50	11.80	0.572
Co	Anoestrus	Dystocia	0.04	0.04	1.000
		Prolapse	-0.01	0.01	0.902

Dependent Variable	(I) RD	(J) RD	Mean Difference (I-J)	Std. Error	Sig.
		Repeat Breeding	-0.03	0.01	1.000
		ROP	-0.01	0.01	1.000
Ba	Anoestrus	Dystocia	0.26	0.04	0.000
		Prolapse	0.03	0.04	0.991
		Repeat Breeding	-0.13	0.12	0.972
		ROP	-0.17	0.06	0.672
Ni	Anoestrus	Dystocia	0.13	0.03	0.005
		Prolapse	-0.01	0.04	1.000
		Repeat Breeding	-0.63	0.08	0.000
		ROP	-0.37	0.17	0.500
Al	Anoestrus	Dystocia	5.13	0.79	0.000
		Prolapse	1.37	0.97	0.832
		Repeat Breeding	-9.18	5.00	0.538
		ROP	-8.22	2.66	0.133
Cr	Anoestrus	Dystocia	0.31	0.07	0.002
		Prolapse	0.21	0.07	0.138
		Repeat Breeding	-1.03	0.16	0.000
		ROP	-0.71	0.35	0.563

Discussion

The incidence of reproductive disorders is in agreement with Dixit et al. (2020) reported reproductive abnormalities of 32.13%, 33.85%, 30.23%, 49.29% and 47.7% respectively. The serum mineral status are in the line of Tewari et al. (2016), analyzed the blood sample in cross bred cattle in Malwa region of M.P and found that Ca, P, Zn were marginally lower and Cu was deficient but Fe was high. According to Kumar et al. (2023) calcium, phosphorus, sodium, potassium, copper and zinc were statistically low in anestrus and repeat breeding cows when compared with normal animals. The present result was in the accordance with Mueno et al. (2024) revealed that the PCA of mineral concentration in serum samples yielded three principal components, on which first component (PC1) contained Na, K, and Cl; the second component (PC2) included Ca, Mg and Fe. The third component (PC3) contained Mn, Co, and Mo. These three principal components could explain up to 52.56% of the total variance, as follows: 22.61% (PC1), 17.71% (PC2), and 12.24% (PC3). Sodium is essential in maintaining the osmotic balance, helps in cellular uptake of glucose and in amino acid transport (NRC, 1989). Iron is very essential for the synthesis of hemoglobin and myoglobin, and various other enzymes that help in the formation of ATP through the electron transport chain (Bhalakiya et al., 2019). Copper is a significant trace element involved in processes such as antioxidative defense, hormone synthesis, cell signaling, and gametogenesis, all of which are vital for the reproductive health of cattle. Cu deficiency associated with reduced conception rates, delayed estrus, early embryonic loss, and impaired overall fertility (Wang et al., 2026). Ni is essential element for dairy animals for proper function of immune response, participates in formation of ribonucleic acid, and has special affinity for bone and skin. Cr is implicated in different metabolic pathways (e.g., glucose tolerance and clearance rate) related to growth and homeostasis (Palomares, 2022). Calcium is essential for both structural and physiological functions and is the most abundant mineral in the body. An imbalance in the calcium-to-phosphorus (Ca:P) ratio can disrupt ovarian function by interfering with pituitary activity, leading to delayed estrus, ovulation, dystocia, placenta retention, uterine prolapse, and delayed uterine involution. Reduced reproductive efficiency causes a loss of appetite due to magnesium deficiency (Yashothi, 2014). Barium is present in the body in various tissues like lung, fat tissue, skin, eye tissue (Fischer et al. 2014). Zinc is crucial for immune system function and reproductive health. It aids in the repair of the uterine lining after parturition, contributing to a quicker return to normal reproductive function and earlier postpartum estrus. Zinc deficiency can lead to abortion, fetal mummification, reduced birth weight, and prolonged labor (Wang et al., 2026). Cobalt is essential for the synthesis of vitamin B12, which is necessary for optimal reproductive function. A deficiency in cobalt can lead to delayed uterine involution, irregular estrus, and reduced conception rates (Pulls, 1994). Phosphorus deficiency in dairy cows can lead to a range of reproductive issues, including delayed puberty, silent or irregular estrus, inactive ovaries, low conception rates and prolonged calving intervals (Reddy et al., 2004). Due to availability of least literature, association between serum minerals and reproductive disorders is not well explained; however (Larson et al., 1980) stated that blood analysis has not demonstrated a consistent relationship to fertility.

Conclusion

The present study revealed that approximately 50% of dairy cattle in two blocks of Prayagraj district, Uttar Pradesh, were affected by one or more reproductive disorders, with anoestrus being the most prevalent condition. The deficiency/excess of macro trace and ultra trace minerals are closely associated with impaired reproductive performance in dairy animals, emphasizing the critical role of balanced mineral nutrition in maintaining reproductive health. Assessment of serum mineral profiles may therefore serve as a valuable diagnostic and management tool for the early identification of animals at risk of reproductive disorders. Further more study is warranted in large area and number of animals to improve reproductive efficiency, enhancing productivity, and supporting the economic sustainability of dairy farming systems.

Declarations

Data Availability

Data will be made available on reasonable request.

Acknowledgement

The authors would like to thank Acharya Narendra Deva University of Agriculture and Technology, Ayodhya for providing all facilities for conducting the present research.

Contributions

Ankur Mishra, Dharmesh Tewari and V.K. Singh contributed to the study's conception and design. Material preparation, animal care, data collection, and laboratory analysis were conducted by Ankur Mishra. Data curation and analysis were performed by Sandeep Kumar Chaudhary. The first draft of the manuscript was written by Shubham Tripathi, Manish Singh and Dharmesh Tewari. All authors commented on and reviewed the manuscript. All authors have read and approved the final manuscript.

Competing Interest

The authors declare no competing interest.

Ethics Approval

This study was performed in line with the principle of Institutional Animal ethics Committee (IAEC) of College of Veterinary Science & A.H.. All animal care, handling, and procedures described herein were approved by the Institutional Animal ethics Committee (IAEC) of College of Veterinary Science & A.H.

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Figures

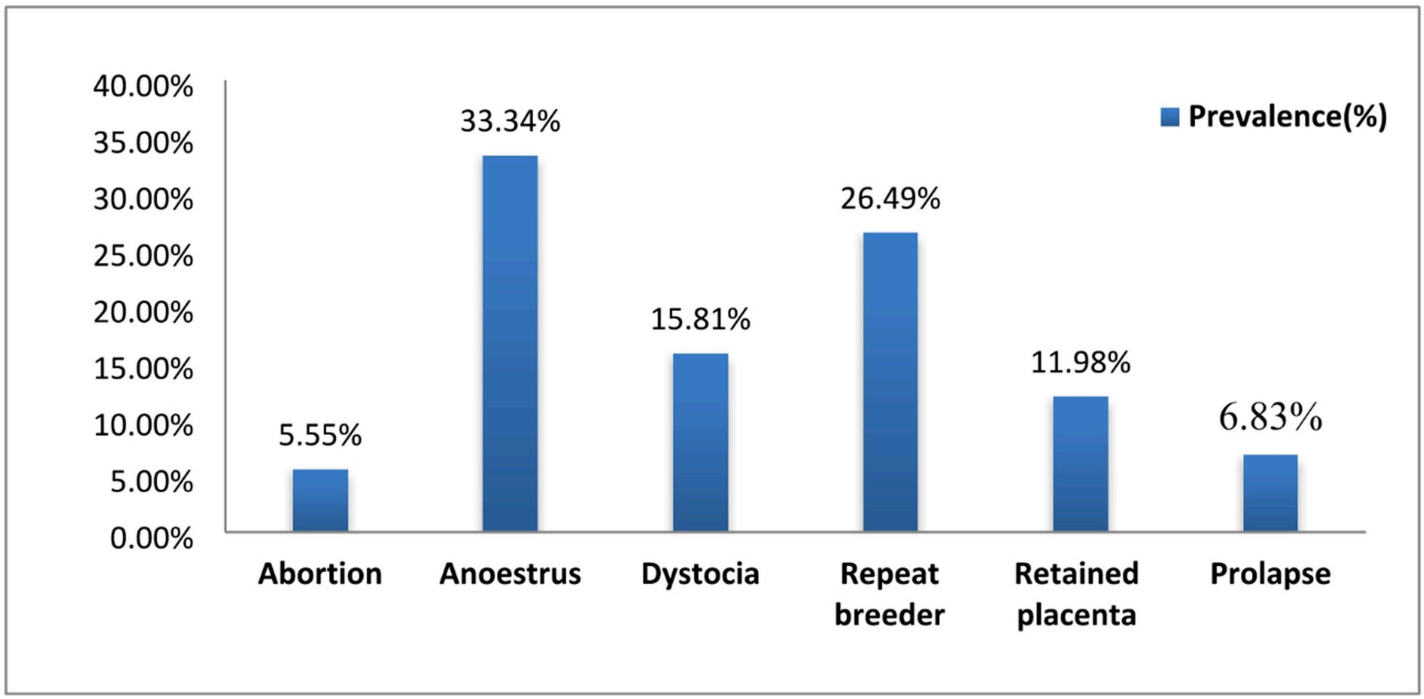


Figure 1

Incidence of reproductive problems in dairy cows