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RESEARCH ARTICLE

Soybean performance under natural farming: Response to bio-formulations from indigenous and exotic cattle breeds

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Abstract

Conventional farming, characterized by the extensive use of chemical fertilizers, pesticides, mono cropping and intensive mechanization, has contributed to notable agricultural advancements. However, it also has adverse impacts on the environment, human health, and the long-term sustainability of agriculture. To address these concerns, a field experiment was conducted during the *Kharif* seasons of 2022 and 2023 at the Zero Budget Natural Farm (ZBNF) of the Department of Organic Agriculture and Natural Farming, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur. The study aimed to evaluate the effects of bio-formulations prepared using inputs from different cattle breeds namely Indigenous cow (*Pahari)* lactating, Indigenous cow (*Pahari)* dry, Indigenous cow (Sahiwal) lactating, Indigenous cow (Sahiwal) dry, Exotic cow (Jersey) lactating, Exotic cow (Jersey) dry, Indigenous bull (*Pahari)*on the growth and yield of soybean. The experiment was conducted in a randomized complete block design (RCBD) with three replications. The results revealed that the application of bio-formulations derived from inputs of the Indigenous cow (*Pahari*) dry significantly improved growth parameters such as plant height (71.4 cm and 77.8 cm), dry matter accumulation (218.6 g/m^2 and 224.7 g/m^2), and crop growth rate (1.3 g/m^2/day and 1.4 g/m^2/day) during both years. Yield parameters also showed superior performance with the same treatment, resulting in higher seed yields (1653.8 kg/ha and 1785.4 kg/ha), along with better yield-attributing characters. The enhancement in growth and yield attributes of soybean can be attributed to the organic matter contributed by the bio-formulations.

Keywords: bio-formulations; cattle breeds; natural farming; soybean

Introduction

Soybean (*Glycine max* (L.) Merril), often referred to as the "Golden Bean" or "Miracle Crop," holds a pivotal role in global agriculture as a major source of protein, oil, and industrial raw materials (1, 2). In India, it is the second-largest oilseed crop, after groundnuts, and is primarily cultivated for its nutrient-rich seeds, which contain 43.2 % protein, 19.5 % fat, and 20.9 % carbohydrates, along with essential nutrients such as calcium, phosphorus, iron, and vitamins (3, 4). Despite its significance, soybean productivity in India remains low (1.14 t/ha), with an area of 13.08 million hectares and a production of 14.98 MT, primarily due to cultivation under rainfed conditions and limited adoption of biofertilizers. The depletion of soil nutrients caused by intensive agricultural practices has exacerbated nutrient deficiencies, leading to declining soil fertility and sustainability (5, 6). Major constraints in soybean production include labour problems (shortage and higher wages during peak periods), poor irrigation facilities, weed management, marketing of produce, and pest and disease management. In irrigation, there has been a lack of irrigation facilities (81 %) in soybean cultivation. Besides the paucity of proper farm mechanisation and water conservation measures, the use of short-duration, drought-resistant varieties of soybean further contributes to the low production of soybeans (7). Hence, these challenges call for urgent need of eco-friendly solutions to enhance crop performance. Among the innovative strategies, the use of bio-formulations derived from natural sources has gained attention for their potential to improve soil health, plant growth, and yield while reducing environmental impact.

In ancient India, bio-formulations such as *Panchagavya*, *Punapajala*, and *Jeevamrit* were extensively used, as described in the Vedas. These formulations, composed of cow dung, cow urine, milk, curd, butter, jaggery, banana, palm nectar, flour, and animal/fish residues, were known to enhance soil fertility, promote plant health, and protect crops from pathogens (8). Although their use has declined, recent studies reaffirm their benefits, including improved soil properties, enhanced nutrient uptake, strengthened plant defence mechanisms, and increased yields in crops such as chickpea, tomato, chilli, and cowpea (9-12). Their revival as sustainable alternatives to chemical fertilizers aligns with global efforts to mitigate agricultural pollution and promote ecological balance (13).

While natural farming systems have gained momentum, much of the research has generalized bio-formulation practices, overlooking the potential variability in efficacy based on cattle breed. Given the dominance of crossbred cattle, such as Jersey cows, in regions like Himachal Pradesh, and the limited availability of indigenous breeds, it is crucial to evaluate whether bio-formulations derived from crossbred cattle can perform as effectively as those from indigenous breeds. This is particularly important as frameworks like Subhash Palekar Natural Farming (SPNF) advocate for inputs from indigenous breeds, posing scalability challenges in regions dominated by crossbred cattle.

This study addresses this critical gap by systematically comparing the impact of bio-formulations derived from indigenous and crossbred cattle breeds on soybean growth and yield. By examining the adaptability and practicality of these formulations, the research seeks to provide insights that bridge the gap between traditional practices and contemporary farming needs. Furthermore, the findings are expected to contribute to policy-making and foster inclusive, sustainable farming practices, aligning with broader goals of ecological stewardship, food security, and agricultural sustainability.

Materials and Methods

Experimental materials and employed methods

Study site

A field experiment was conducted at the Zero Budget Natural Farm (ZBNF) under the Department of Organic Agriculture and Natural Farming, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, during the 2022 and 2023 *Kharif* seasons. The study area is situated in the Palampur Valley of Kangra District, Himachal Pradesh, at 32° 6' N latitude and 76°3' E longitude, at an elevation of 1,290.8 m above mean sea level (MSL). It is nestled in the foothills of the snow-capped Dhauladhar range in the North Western Himalayas. The soil at the site was predominantly silty clay loam, classified as "Alfisols" with "Hapludalfs" as the great group. Before the study, the experimental field was utilized for potato cultivation under natural farming practices. Soil samples were collected from a depth of 0-15 cm at random locations within the experimental area using a stainless steel auger. A composite soil sample was prepared by drying, grinding, and sieving the collected soil through a 2 mm sieve. The composite sample was then analyzed in the departmental laboratory to determine the soil's physico-chemical properties.

Experimental inputs

Beejamrit is a crucial organic input in natural farming, primarily used for seed treatment to enhance germination and protect crops against soil-borne diseases. It is a bio-enhancer made from locally available farm resources, including 5 kg of cow dung, 20 L of water, 5 L of cow urine, 50 g of lime, and a handful of soil serving as a microbial inoculum. To prepare *Beejamrit*, cow dung is soaked in water for 12 hr, squeezed into a water tub and then combined with lime, soil, and cow urine. The mixture is stirred thoroughly, left to ferment overnight and used for seed treatment the next day.

Jeevamrit is applied as a soil drench to enhance soil fertility, stimulate microbial activity, and provide essential nutrients to crops. It is prepared by mixing 10 L of cow urine, 10 kg of cow dung, 2 kg of jaggery, a handful of soil and 2 kg of gram flour in 200 L of water. The mixture is stirred twice daily in a clockwise direction and left to ferment in the shade for 48 hr before application.

Ghanjeevamrit is a solid bio-formulation commonly used as a soil amendment in natural farming. It is prepared by combining 100 kg of cow dung, 10 L of cow urine, 1 kg of jaggery, a handful of soil and 1 kg of gram flour. The ingredients are mixed thoroughly, shaped into small balls by hand and dried in the shade before use.

Experimental layout

The soybean variety "Harit Soya" was used for the experiment. Organic inputs such as *Beejamrit*, *Jeevamrit*, and *Ghanjeevamrit* were prepared on-site following the standard procedures outlined by Subash Palekar (14). The experiment was conducted using a randomized complete block design (RCBD) with seven treatments; each replicated three times to ensure reliable and accurate results. The treatments aimed to study the impact of bio -formulations derived from the inputs of different cattle breeds on soybean. Table 1 provides detailed information on the seven treatments. Three cattle breeds were selected for the study, tagged, and kept in isolation to prevent contamination. These cattle were fed a uniform diet for 10 days prior to the collection of dung and urine, which were used to prepare various bioformulations. The experimental plots had a gross size of 9.0 m^2 (3 m × 3 m), with rows spaced 30 cm apart. The recommended plant spacing of 30 × 10 cm was adhered to throughout the experiment. The initial soil analysis revealed an acidic pH of 5.76 and an organic carbon content of 0.60 %. The available nitrogen, phosphorus, and potassium levels were recorded at 230.5 kg/ha, 15.8 kg/ha, and 220.6 kg/ha, respectively. Field preparation during the first year involved a power tiller, followed by manual leveling and layout of the experimental design. For subsequent years, manual preparation was employed to prevent contamination, and permanent plots were maintained. Before sowing, the seeds were treated with *Beejamrit* @ 100 mL/kg of seed. *Ghanjeevamrit* was applied @ 500 kg/ha during sowing, and *Jeevamrit* was applied through soil drenching @ 500 L/ha every 20 days.

Data collection

For collection of data related to growth and yield attributes of soybean such as plant height (cm), dry matter accumulation (g/m^2), crop growth rate (g/m^2/day), leaf area, no. of branches per plant at harvest, dry weight of root nodules per plant at flowering (g), no. of effective nodules per plant at flowering, no. of nodules per plant at flowering, no. of pods per plant, no. of seeds per pod five plants were randomly selected from each plot (15). After the

Table 1. Experimental details

S.No.	Treatment details
T_1	Indigenous cow (*Pahari)* lactating
T_2	Indigenous cow (Pahari) dry
T_3	Indigenous cow (Sahiwal) lactating
T_4	Indigenous cow (Sahiwal) dry
T_5	Exotic cow (Jersey) lactating
T_6	Exotic cow (Jersey) dry
T_7	Indigenous bull (*Pahari)*

crop was harvested and sun-dried for a week, it was manually threshed to separate the seeds, which were used to determine the seed yield. The remaining biomass, after the seeds were removed, was measured as the straw yield for each respective treatment.

Statistical analysis

The data obtained and collected from the field and laboratory experiments were subjected to statistical analysis according to the procedures outlined as per the standard procedure (16). Where the effects exhibited significance at a 5 % probability level, a critical difference (CD) was calculated to interpret the treatment differences. The effect of bio-formulation prepared from the inputs of different cattle breeds on growth and yield of different crops was analyzed with the help of randomized blocks design.

Results and Discussion

Growth parameters

Bioformulations prepared from the inputs of indigenous cow (Pahari) dry resulted in significantly taller plants of soybean at all growth stages of the crop during both seasons of experimentation (Table 2). At 30 DAS, significantly taller plants were observed with the application of bio-formulations prepared from the inputs of indigenous cow (Pahari) dry. However, it was found to be comparable to bio-formulations prepared from the inputs of Indigenous cows (Pahari) lactating during the *kharif* 2023 season. At 60 DAS significantly taller plants were observed by application of bio-formulations prepared from the inputs of Indigenous cow (*Pahari)* dry and it was found to be at par with bio-formulations prepared from the inputs of Indigenous cow (*Pahari)* lactating and Indigenous bull (*Pahari)* during *kharif* 2023. At later growth stages, i.e., 90 DAS and 120 DAS, plant height showed a similar trend to that of 60 DAS. Smaller plants of soybean were observed with the application of bio-formulations prepared from the inputs of an exotic cow (Jersey) lactating cow. During both the years, application of bio-formulations prepared from the inputs of Indigenous cow (*Pahari)*dry resulted in significantly higher dry matter accumulation and crop growth rate (Table 3 & 4) at all stages of crop growth which was followed by bio-formulations prepared from the inputs of Indigenous cow (*Pahari)* lactating and Indigenous bull (*Pahari)*, while the lowest values were recorded with application of bio-formulations prepared from the inputs of exotic cow (Jersey) lactating. At the time of flowering, significantly higher number of nodules per plant and dry weight of nodules per plant (Table 5) were observed by application of bio-formulations prepared from the inputs of Indigenous cow (*Pahari)* dry which was found to be at par with bio-formulations prepared from the inputs of Indigenous cow (*Pahari)* lactating during *kharif* 2022 and bio-formulations prepared from the inputs of Indigenous cow (*Pahari)* lactating and Indigenous bull (*Pahari)* during *kharif* 2023, while the lowest values were recorded with application of bio-formulations prepared from the inputs of exotic cow (Jersey) lactating. A similar pattern was observed in the second year of planting, with an increase in the number of nodules per plant and the dry weight of nodules per plant recorded, irrespective of the treatments. A perusal of data pertaining to number of effective nodules at the time of flowering and number of branches at the time of harvest revealed that application of bio-formulations prepared from the inputs of Indigenous cow (*Pahari)*dry resulted in significantly higher no of effective nodules and branches as compared to other treatments (Table 5). Bioformulations can stimulate enzymatic activities (e.g., dehydrogenase, urease, phosphatase), which are key indicators of microbial function and contribute to the mineralisation of nutrients (17). The addition of organic matter increases the soil's CEC, improving its ability to retain essential nutrients like calcium, magnesium, potassium, and ammonium, making them more available to plants (18). Another reason for the better growth of crops may be that beneficial microbes introduced through bioformulations often synthesise phytohormones, such as auxins, gibberellins, and cytokinins, which stimulate root development and enhance plant growth (19). An increase in the number of nodules and dry weight of nodules per plant was also observed which might be the cumulative effect of different bio-formulations which may have resulted in a favorable rhizosphere environment and the presence of organic acids and microbial metabolites which can chelate micronutrients (e.g., Fe, Zn, Mn), enhancing their solubility and uptake by plants (20). Bio-formulations often support the colonization of symbiotic organisms such as mycorrhizal fungi and rhizobia, which enhance phosphorus acquisition and biological nitrogen fixation, respectively in addition to the essential plant nutrients supplied by these bio-formulations (21, 22).

Yield attributes and yield

Significantly higher yield attributes (Fig. 1) such as number of plants per m^2, number of pods per plant and number of seeds per pods was recorded by application of bio-formulations prepared from the inputs of Indigenous cow (*Pahari)* dry which was found to be at par with bio-formulations prepared from the inputs of Indigenous cow (*Pahari)* lactating and Indigenous bull (*Pahari)* during both year of experimentation. However, an increase in the number of plants per m^2, the number of pods per plant, and the number of seeds per pod was observed in the second year of experimentation compared to the first year. Highest test weight was recorded by application of bio-formulations prepared from the inputs of Indigenous cow (*Pahari)* dry followed by bio-formulations prepared from the inputs of Indigenous cow (*Pahari)* lactating and Indigenous bull (*Pahari)*. Seed yield of soybean differed among bio-formulations prepared from different cow breeds (Table 6). The application of bioformulations prepared from the inputs of Indigenous cow (Pahari) dry resulted in significantly higher seed yields during both years of experimentation, followed by bioformulations prepared from the inputs of Indigenous cow (Pahari) lactating and Indigenous bull (*Pahari)*. However, an increase in the seed yield was observed in the second year of experimentation as compared to the first year. The lowest seed yield was recorded when bio-formulations were prepared from the inputs of exotic cows (Jersey) that were lactating. The highest number of plants per m^2, number of pods per plant, number of seeds per pods and test weight might be due to high nutrient content in the bio-formulations prepared from the inputs of *Pahari* dry cow and organic matter added by use of various bio-formulations acting as a source of energy for soil microbes, allowing them to convert the nutrients present in the soil into forms that can be easily used by plants and fast N mineralization and regular N supply by various bio-formulations which led to increased number of pods

Table 2. Effect of bio-formulations prepared from different cattle breeds on plant height of soybean

Bio- formulations prepared from	Plant height (cm)											
	30 DAS			60 DAS			90 DAS			120 DAS		
	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean
T_1 Indigenous cow (*Pahari*) lactating	21.4	26.4	23.9	45.1	48.2	46.7	57.4	62.7	60.1	70.6	76.4	73.5
T_2 Indigenous cow (*Pahari*) dry	23.8	27.8	25.8	46.8	49.8	48.3	59.7	63.4	61.6	71.4	77.8	74.6
T_3 Indigenous cow (Sahiwal) lactating	17.5	21.4	19.5	40.4	43.2	41.8	53.2	58.4	55.8	65.4	71.4	68.4
T_4 Indigenous cow (Sahiwal) dry	18.8	23.1	21.0	42.6	45.1	43.9	55.4	60.4	57.9	67.2	73.5	70.4
T_5 Exotic cow (Jersey) lactating	16.0	19.5	17.8	39.1	40.9	40.0	51.1	55.1	53.1	62.7	67.9	65.3
T_6 Exotic cow (Jersey) dry	16.4	20.2	18.3	39.6	42.2	40.9	52.1	56.9	54.5	64.8	69.3	67.1
T_7 Indigenous bull (*Pahari*)	19.6	24.4	22.0	43.9	46.4	45.2	56.1	61.1	58.6	68.8	74.4	71.6
LSD (P=0.05)	1.5	1.9	4.55	1.4	3.5	0.95	3.7	3.7	1.33	5.5	4.4	1.79

DAS- Days after sowing

Table 3. Effect of bio-formulations prepared from different cattle breeds on dry matter accumulation of soybean

Bio- formulations prepared from	Dry matter accumulation (g/m^2)											
	30 DAS			60 DAS			90 DAS			120 DAS		
	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean
T_1 Indigenous cow (*Pahari*) lactating	46.4	51.9	49.2	110.4	118.4	114.4	164.7	169.5	167.1	204.4	211.2	207.8
T_2 Indigenous cow (*Pahari*) dry	48.6	53.4	51.0	120.4	129.4	124.9	176.8	182.6	179.7	218.6	224.7	221.7
T_3 Indigenous cow (Sahiwal) lactating	40.4	44.6	42.5	90.1	96.7	93.4	139.7	143.6	141.7	174.3	183.2	178.8
T_4 Indigenous cow (Sahiwal) dry	43.2	45.3	44.3	95.6	105.4	100.5	146.5	152.7	149.6	185.3	192.6	189.0
T_5 Exotic cow (Jersey) lactating	35.2	39.6	37.4	79.4	88.7	84.1	124.8	132.2	128.5	154.2	169.8	162.0
T_6 Exotic cow (Jersey) dry	38.6	41.5	40.1	83.6	92.4	88.0	132.8	138.7	135.8	164.2	176.9	170.6
T_7 Indigenous bull (*Pahari*)	44.2	47.6	45.9	102.8	111.4	107.1	155.4	160.4	157.9	194.3	201.6	198.0
LSD (P=0.05)	3.3	3.3	1.19	8.3	4.5	2.39	7.6	4.9	2.28	13.4	5.8	3.68

DAS- Days after sowing

Table 4. Effect of bio-formulations prepared from different cattle breeds on crop growth rate of soybean

Bio- formulations prepared from	Crop growth rate (g/m^2/day)								
	30-60 DAS			60-90 DAS			90-120 DAS		
	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean
T_1 Indigenous cow (*Pahari*) lactating	2.1	2.2	2.2	1.8	1.7	1.8	1.3	1.3	1.3
T_2 Indigenous cow (*Pahari*) dry	2.4	2.5	2.5	1.8	1.7	1.8	1.3	1.4	1.4
T_3 Indigenous cow (Sahiwal) lactating	1.6	1.7	1.7	1.6	1.5	1.6	1.1	1.3	1.2
T_4 Indigenous cow (Sahiwal) dry	1.7	2.0	1.9	1.7	1.5	1.6	1.2	1.3	1.3
T_5 Exotic cow (Jersey) lactating	1.4	1.6	1.5	1.5	1.4	1.5	0.9	1.2	1.1
T_6 Exotic cow (Jersey) dry	1.5	1.7	1.6	1.6	1.5	1.6	1.0	1.2	1.1
T_7 Indigenous bull (*Pahari*)	1.9	2.1	2.0	1.7	1.6	1.7	1.3	1.3	1.3
LSD (P=0.05)	0.11	0.15	0.04	0.14	0.12	0.04	0.05	0.10	0.03

DAS- Days after sowing

Table 5. Effect of bio-formulations prepared from different cattle breeds on number of branches per plant at harvest and different parameters of root nodules at flowering of soybean

Bio- formulations prepared from	No. of branches per plant at harvest			Dry weight of root nodules per plant at flowering (g)			No. of effective nodules per plant at flowering			No. of nodules per plant at flowering		
	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean
T_1 Indigenous cow (*Pahari*) lactating	6.1	7.0	6.6	0.45	0.50	0.5	31.4	34.8	33.1	41.4	45.2	43.3
T_2 Indigenous cow (*Pahari*) dry	6.8	7.8	7.3	0.47	0.51	0.5	32.6	37.2	34.9	42.6	46.7	44.7
T_3 Indigenous cow (Sahiwal) lactating	3.9	5.1	4.5	0.41	0.45	0.4	26.1	28.6	27.4	37.1	42.7	39.9
T_4 Indigenous cow (Sahiwal) dry	4.8	5.8	5.3	0.42	0.46	0.4	26.4	30.1	28.3	38.4	43.2	40.8
T_5 Exotic cow (Jersey) lactating	2.8	3.8	3.3	0.38	0.42	0.4	22.6	26.8	24.7	34.2	39.6	36.9
T_6 Exotic cow (Jersey) dry	3.1	4.6	3.9	0.36	0.44	0.4	24.4	27.6	26.0	35.4	41.4	38.4
T_7 Indigenous bull (*Pahari*)	5.9	6.7	6.3	0.44	0.48	0.5	28.2	33.5	30.9	39.6	44.8	42.2
LSD (P=0.05)	0.35	0.41	0.13	0.02	0.03	0.01	1.59	2.72	0.80	2.10	2.42	0.81

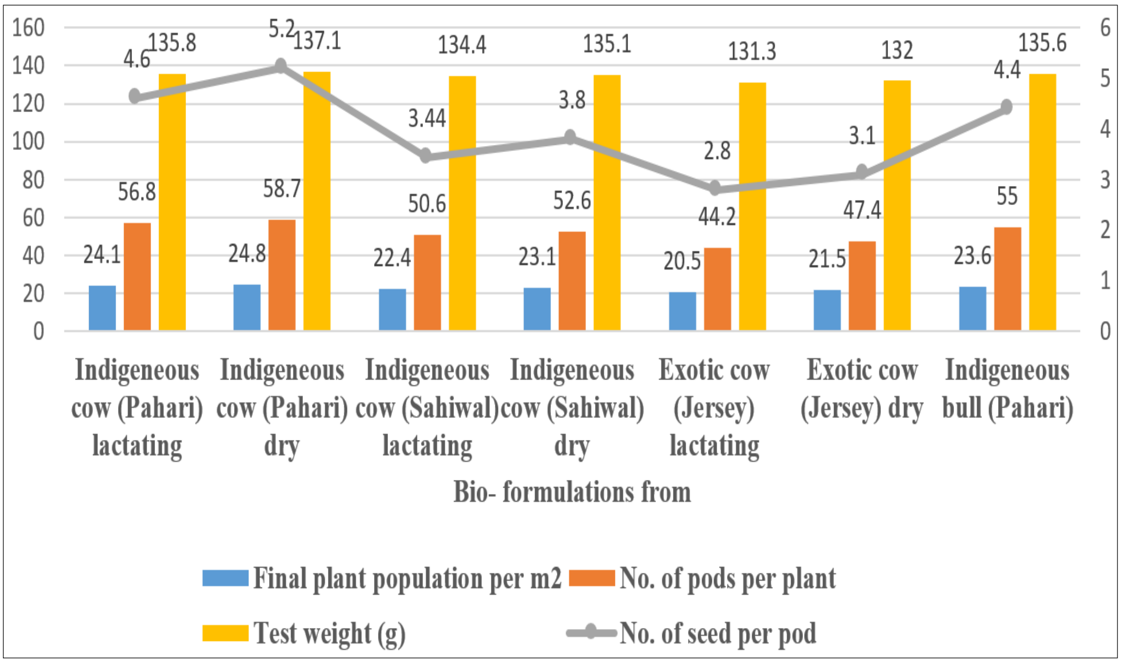

Fig. 1. Effect of bio-formulations prepared from different cattle breeds on yield attributes of soybean.

per plant and number of seeds per pod and higher dry matter accumulation which in turn lead to higher seed yield (23-25). Organic amendments can moderate soil pH, making the environment more favorable for microbial activity and nutrient availability, especially in acidic or alkaline soils (26). Bioformulations often support the colonisation of symbiotic organisms, such as mycorrhizal fungi and rhizobia, which enhance phosphorus acquisition and biological nitrogen fixation, respectively (27). Some beneficial microbes exhibit antagonistic activity against pathogenic fungi and bacteria, thereby promoting healthier root systems and improved nutrient uptake (28, 29). Another reason for higher seed yield values may be attributed to continuous mineralisation and the availability of nutrients at later stages of plant growth (30).

Conclusion

The findings of this study underscore the potential of bio-formulations derived from Indigenous Pahari dry cow inputs in enhancing soybean growth and yield under natural farming conditions. The superior performance observed in key agronomic traits and yield parameters highlights the role of breed-specific organic inputs in promoting soil health, nutrient availability, and plant productivity. These results advocate for the integration of locally adapted livestock resources into sustainable farming practices, offering a viable alternative to conventional inputs while supporting ecological and long-term agricultural sustainability.

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Authors' contributions

AS conceived the idea for the article, conducted the literature search and data analysis, and contributed to figure preparation and initial drafting. RK also helped with the concept and critically revised the manuscript for intellectual content. AK helped in the literature search and supported data analysis. SK assisted in data analysis, figure preparation, and drafting the manuscript. PS contributed to figure design and drafting of the manuscript. SM was involved in preparing figures and organizing the content layout. DR supported figure development and manuscript structure. All authors read and approved the final version of the manuscript.

Compliance with ethical standards

Conflict of interest: The authors declare no conflict of interest.

Ethical issues: None

Table 6. Effect of bio-formulations prepared from different cattle breeds on seed yield of soybean

Bio- formulations prepared from	Seed yield (kg/ha)		
	2022	2023	Mean
T_1 Indigenous cow (*Pahari*) lactating	1467.3	1538.6	1503.0
T_2 Indigenous cow (*Pahari*) dry	1653.8	1785.4	1719.6
T_3 Indigenous cow (Sahiwal) lactating	1205.3	1367.4	1286.4
T_4 Indigenous cow (Sahiwal) dry	1284.5	1428.1	1356.3
T_5 Exotic cow (Jersey) lactating	1103.8	1194.6	1149.2
T_6 Exotic cow (Jersey) dry	1156.2	1238.6	1197.4
T_7 Indigenous bull (*Pahari*)	1394.7	1521.2	1458.0
LSD (P=0.05)	79.08	100.03	31.93

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