

Agronomic biofortification of fodder crops:

A smart way to boost livestock nutrition

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Fodder crops are the backbone of livestock nutrition, especially in a country like India where more than 90% of livestock diets rely on poor-quality crop residues and unbalanced roughages causing low nutrient content particularly in micronutrients such as zinc, iron, and copper. This nutritional gap directly affects milk production, animal health, and reproductive efficiency. Biofortification, the enhancement of nutrient content in fodder crops through agronomic practices, offers a cost-effective, scalable, and environmental friendly solution. It enriches feed quality, improves livestock performance, and enhances rural income while preserving soil health.

Keywords: Cost effective, Feed quality, Livestock performance, Micronutrients

INDIA is the world’s largest milk producer, but average milk yield per animal is just 1,538 kg/year compared to the global average of 2,238 kg/year. This productivity gap is largely due to nutritional deficiencies in livestock diets, dominated by low-nutrient feeds. As per IGFRI Vision 2050, the country faces a 35.6% green fodder deficit, 10.9% dry fodder deficit, and a 44% shortfall in concentrate feeds. Farmers are forced to feed animals with low-digestibility residues like paddy straw, sugarcane tops, or

over-mature grasses, deficient in crude protein, calcium, phosphorus, and essential micronutrients.

The deficiencies of micronutrients lead to reduced productivity, weak immunity, delayed estruses, stunted growth, and poor milk composition. Overuse of high-analysis chemical fertilizers further depletes the vital micronutrients in the soil, compounding the problem. With shrinking land availability for fodder due to pressure from food and cash crops, it is essential to

maximize nutrient value per unit area. Agronomic biofortification, by enriching fodder with critical nutrients through balanced fertilization and eco-friendly inputs, provides a smart solution to improve feed quality, animal health, and overall farm profitability.

Agronomic biofortification

Agronomic biofortification is a farm-based approach that involves the application of essential nutrients—such as nitrogen (N), zinc (Zn), iron (Fe), copper (Cu),

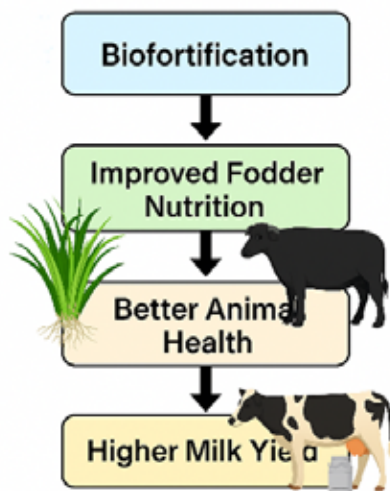
Table 1. Current scenario of biofortification in fodder crops in Indian

Issue	Current situation in India	How biofortification helps
Milk yield per animal	1,538 kg/year (vs. global avg. 2,238 kg/year)	Improves feed quality that enhances milk yield and reproductive performance
Green fodder deficit	35.6% shortfall (IGFRI Vision 2050)	Increases biomass and nutrient content per hectare
Feed quality	90% roughage-based, low in protein and minerals	Enhances crude protein, digestibility, and micronutrient levels
Micronutrient deficiencies	Widespread Zn, Fe, Cu, and Ca shortages in fodder crops	Site-specific application enriches fodder nutrient profile
Soil nutrient depletion	Due to imbalanced fertilization and overuse of chemical fertilizers	Restores soil fertility using balanced, fortified inputs (e.g. ZnSO ₄ , FYM, PGPR)
Fodder from crop residues	Often poor in digestibility and energy value	Supplemented biofortified green fodder improves total ration quality
Livestock health problems	Malnutrition, low growth, poor immunity, delayed breeding	Improves immunity, growth, milk fat, and overall productivity

Source: Supriya et al. 2024

and other micronutrients—directly to fodder crops through soil fertilization, foliar sprays, or seed treatments. It may also include the use of plant growth-promoting rhizobacteria (PGPRs) that help mobilize and make nutrients more available to plants in a natural and sustainable manner.

By improving the nutrient density of fodder, it enhances animal growth, milk production, immunity, and reproductive efficiency.



Biofortification pathway from improved fodder quality to enhanced livestock productivity

Unlike genetic biofortification (which involves breeding or genetic modification to raise nutrient levels within a crop variety), agronomic biofortification is quicker to implement, less expensive, and more adaptable to different agro-climatic zones. It does not require changing the crop variety or waiting for new cultivars to be developed. This makes it an ideal and scalable option for smallholder dairy and livestock farmers, especially those with limited access to concentrate feeds.

Key features of agronomic biofortification:

Quick response: Nutrient enrichment is seen within a single growing season.

Compatible with existing cropping systems: No change in crop variety needed.

Low investment, high return: Small input costs yield significant gains in fodder quality.

Flexible application methods: Nutrients can be applied through soil, foliar sprays, or seed treatment.

Synergy with organic inputs: Can be combined with FYM, compost, or PGPRs for better results.

For instance, applying 25 kg/ha of zinc sulphate ($ZnSO_4$) in berseem or spraying 0.5% iron sulphate ($FeSO_4$) solution on cowpea can significantly improve the crude protein, digestibility, and mineral content of these fodder crops leading to improved milk yield and animal health. Overall, agronomic biofortification offers a farmer-friendly solution to tackle hidden hunger in livestock, improve the nutritional quality of available feed resources, and support climate-smart, low-cost livestock production.

Practical ways to biofortify fodder crops

Biofortifying fodder doesn't require expensive technology—it simply involves smart use of nutrients and good agronomic practices. The following are proven, cost-effective methods that farmers can adopt to improve the nutritional quality of their green fodder crops.

Nitrogen application for higher crude protein and yield: Nitrogen plays a central role in plant growth and protein synthesis, making it an essential input for enhancing the productivity of cereal fodders such as maize, sorghum, bajra, and oat. When applied at the right dosage typically between 120–180 kg N/ha depending on the crop and soil fertility, it significantly improves leaf development, dry matter accumulation, and crude protein content. To ensure efficient utilization, nitrogen should be applied in split doses: half at sowing and the remaining 30–35 days after sowing. Combining nitrogen with farmyard manure (FYM) or compost further enhances nutrient uptake by improving soil structure and promoting microbial activity. This integrated approach can result in a 25–30% increase in green fodder yield and an improvement in crude protein content by 1.5–2.5%.

Zinc enrichment for better growth and nutrient density: Zinc is a vital micronutrient

involved in enzymatic activity, chlorophyll formation, and protein metabolism in plants. Its deficiency is widespread in Indian soils, especially in regions with intensive farming practices. To address this, zinc can be applied through two primary methods: soil application of 20–25 kg/ha zinc sulphate ($ZnSO_4$) as basal or foliar sprays using a 0.5–1% $ZnSO_4$ solution between 30–45 days after sowing. These interventions are particularly effective in crops such as berseem, maize, cowpea, and oats. Zinc enrichment not only improves tillering and leaf surface area but also enhances the overall protein content by 2–4%. Moreover, its indirect benefits on livestock include better immunity and milk quality due to improved fodder nutrition.

Iron and copper supplementation for chlorophyll and protein boost:

Iron and copper are essential for photosynthesis, respiration, and protein metabolism. Deficiencies in these micronutrients can result in yellow leaves, reduced growth, and poor forage quality. To correct this, iron can be applied @20–25 kg $FeSO_4$ /ha or via a 0.5% foliar spray around 35 days after sowing. Similarly, copper can be applied at 5–10 kg $CuSO_4$ /ha or sprayed foliarly around 40 days after sowing. Integrating zinc, iron, and copper either in foliar formulations or in combination with organic amendments like FYM produces synergistic effects, improving chlorophyll content, forage palatability, and crude protein levels. These benefits are particularly pronounced in leguminous fodders such as lucerne and cowpea, making this a critical strategy for improving livestock nutrition.

Fodder-based intercropping:

A smart way to combine benefits: Legumes contribute to biological nitrogen fixation, improving soil fertility and protein content of the mixed fodder. Proven combinations include maize + cowpea and sorghum + cluster bean in a 2:1 row ratio for seasonal fodder systems, as well as bajra + lablab or Napier + cowpea for perennial fodder setups. This practice not only enhances total

Table 2. Effect of biofortification on growth performance of berseem (Case study I)

Treatments	Plant height (cm)			Leaf: Stem ratio			No. of regenerated stems		
	I Cut	II Cut	III Cut	I Cut	II Cut	III Cut	I Cut	II Cut	III Cut
T ₁ - Control	55.7	59.95	61.5	0.49	0.65	0.66	5.00	5.37	5.75
T ₂ - 100% RDF	69.5	71.90	72.5	0.50	0.66	0.67	5.60	5.80	6.04
T ₃ - RDF + Zn (basal)	84.6	86.93	88.4	0.52	0.77	0.75	7.28	7.73	8.40
T ₄ - RDF + Fe (basal)	82.0	82.27	84.0	0.51	0.75	0.71	6.72	7.00	7.60
T ₅ - RDF + 0.5% foliar Zn	81.3	81.57	83.2	0.50	0.73	0.69	6.07	6.57	6.87
T ₆ - RDF + 0.5% foliar Fe	79.3	79.99	80.3	0.49	0.69	0.67	5.63	5.93	6.19
T ₇ - 75% RDF + 0.5% Zn + 0.5% Fe	80.5	80.73	81.0	0.50	0.72	0.68	6.02	6.30	6.67
SEm ±	3.63	4.11	4.03	0.02	0.03	0.02	0.19	0.24	0.22
LSD (p=0.05)	11.2	12.65	12.4	NS	NS	NS	0.58	0.75	-

Source: Meenakshi *et al.* 2020

RDF, Recommended dose of fertilizer.

biomass by 20–40% but also improves digestibility and palatability of the fodder. Intercropping with legumes is particularly beneficial for silage-making, as the added sugars and proteins enhance fermentation and storage quality, making it a practical and profitable strategy for livestock farmers.

Case Study I: Effect of biofortification on growth performance of berseem

A field study was conducted to evaluate the effects of different nutrient management strategies on fodder growth, regeneration, and quality. The experiment compared conventional fertilizer use with biofortification practices such as basal and foliar applications of zinc and iron in a multi-cut forage system. The results were promising. Treatments involving zinc and iron supplementation, especially RDF + basal Zn and RDF + Fe, significantly improved plant height, leafiness, and regeneration capacity over three successive cuts. These improvements directly translate to better green fodder availability and nutritive value for livestock.

The data clearly indicated that integrating micronutrient biofortification with existing fertilizer regimes can significantly enhance not just fodder yield but also its quality and regrowth potential. The practice is both cost-effective and sustainable, making it a viable option for progressive dairy and livestock farmers across India. Incorporating such nutrient-smart practices will be crucial for climate-resilient livestock production,

ensuring both animal health and rural income security in the years to come.

Case Study II: Zinc biofortification improved fodder maize nutrition

A field trial evaluated the effect of zinc sulphate application on zinc content and uptake in fodder maize. Six treatments included control (no zinc), basal application (10 or 20 kg/ha ZnSO₄), foliar sprays (0.5% ZnSO₄ at 30 or 30 and 45 DAS), and a combined basal + foliar spray.

Table 3. Zinc biofortification of improved fodder maize nutrition (Case Study II)

Treatment	Zn Content (mg/kg DM)	Zn Uptake (g/ha)
Zn ₀ (Control)	32.13	325.13
Zn ₁	42.99	514.26
Zn ₂	46.76	662.09
Zn ₃	40.39	467.27
Zn ₄	44.95	586.16
Zn ₅	45.24	611.84

Source: Kumar *et al.* 2017

The highest Zn uptake (662.09 g/ha) and content (46.76 mg/kg dry matter) were recorded with 20 kg/ha ZnSO₄ as basal dose (Zn₂), followed closely by combined treatments. Thus, soil or foliar zinc application can substantially improve fodder quality, benefiting livestock nutrition.

Case study III: Zinc-biofortified sorghum stover improves sheep health in Karnataka

In small ruminants like sheep, zinc plays a vital role in immunity, enzyme activity, and growth.

Traditional feeding practices often rely on non-fortified crop residues, which are inherently low in micronutrients, leading to poor animal performance. A pioneering study conducted at Bengaluru by Giridhar *et al.* (2022) investigated the impact of feeding zinc-biofortified sorghum stover to Deccani breed sheep, and the findings were remarkable. Two groups of sheep were given two different fodder i.e. fortified sorghum stover (142 ppm Zn), and non-fortified sorghum stover (73 ppm Zn). Over a 4-month period, blood plasma zinc levels, antioxidant activity, and immunity markers were monitored. SOD (Superoxide Dismutase), a key antioxidant enzyme, was significantly higher in the fortified group. Fortified stover led to better zinc retention in the liver and muscle. Immune response was more robust, as seen from the improved inhibition levels at 15 days post-feeding.

Table 4. Key results of case study III

Parameter	Non-Fortified Sorghum Stover	Fortified Sorghum Stover
Average Blood Plasma Zn (ppm)	0.90	1.14
Liver Zn (ppm)	130	150
Muscle Zn (ppm)	107	115
SOD Activity (unit/min)	10.3	15.3
Immunity (% inhibition)	24.0	16.7
Immunity @15 days (%)	60.0	76.8

Source: Giridhar *et al.* 2022

Why it matters

This study clearly shows that zinc biofortification of fodder crops like sorghum is a viable and cost-effective strategy to 1) Improve trace mineral nutrition in sheep, 2) Enhance immunity and oxidative balance, and 3) Reduce dependency on costly mineral mixtures. In low-input livestock systems, particularly in semi-arid and rainfed zones of India, biofortified fodder could be a game-changer for improving smallholder livelihoods.

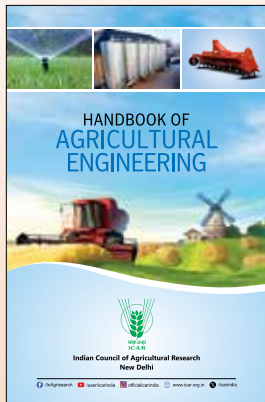
SUMMARY

Fodder biofortification is emerging as a practical and sustainable approach to address nutritional deficiencies in livestock. Through the strategic use of nutrients like nitrogen, zinc, iron, and beneficial microbes, agronomic biofortification significantly improves the crude protein content, micronutrient density, and digestibility of fodder crops. Case studies demonstrated enhanced plant growth, regrowth capacity, and positive impacts on animal

health and productivity, including increased milk yield and improved immunity in sheep. These outcomes make biofortification a cost-effective and scalable solution for smallholder farmers. By adopting such nutrient-smart practices, Indian livestock farming can become more resilient, productive, and profitable under changing climatic and economic conditions.

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