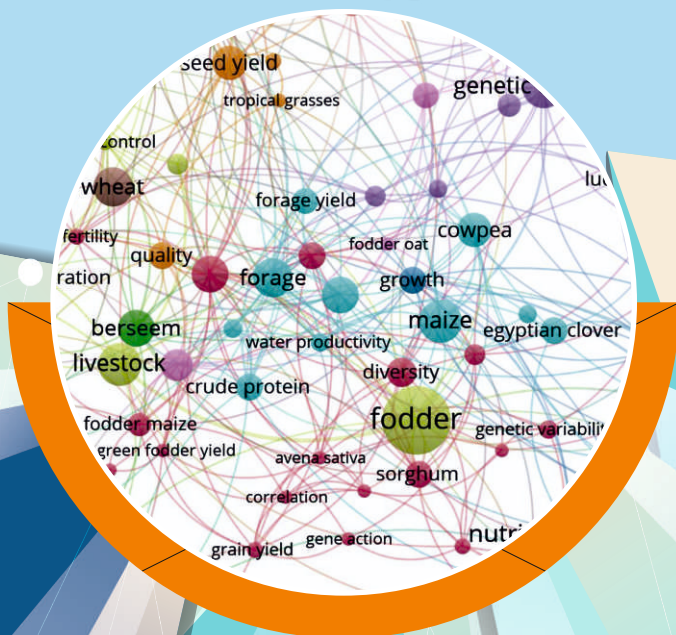




Tracking Legacy: Impact of 24 Years of Research at ICAR-IGFRI, Jhansi



ICAR-Indian Grassland and Fodder Research Institute
Jhansi-284 003 (U.P.) India

Towards Fodder - Plus India.....



Tracking Legacy: Impact of 24 Years of Research at ICAR-IGFRI, Jhansi

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FOREWORD

In India, the livestock production and agriculture are intrinsically linked and this scenario is expected to continue in the foreseeable future. Perhaps nowhere in the world do man and animal come together in such a rich and diversified cultural environment as in India and unlike in the west where the livestock are viewed purely on economic considerations. India, with around fifteen per cent share, has the world's largest livestock population. However, the productivity of our livestock often remains low due to inadequate and nutritionally unbalanced supply of feed and fodder. At present, the country is facing about 11% deficit in green fodder while for dry fodder the estimated deficit is 23%. ICAR-Indian Grassland and Fodder Research Institute, with more than six decades of experience in forage research and development, has developed numerous improved fodder crop varieties and technologies that can ensure year-round availability of quality feed, thereby enhancing animal productivity. The institute today stands as the leading R&D institution in South Asia for sustainable agriculture through quality forage production and grassland management for improved animal productivity.

I commend the authors for compiling 24 years of research achievements from ICAR-IGFRI, Jhansi, into this bulletin. They have utilized the Scopus database to provide an overview of the institute's research focus on fodder and grasslands from 2000 to 2023, while also highlighting the quality work of the scientific staff. I believe this bulletin will be very beneficial for policymakers to understand recent advancements in forage research and will assist other institutes in tracking their research achievements and impact. I wish the institute continued success in its mission to generate and share more knowledge on grassland and fodder research.



(Pankaj Kaushal)
Director

PREFACE

It is with great enthusiasm that we introduce the technical bulletin, "Tracking Legacy: Impact of 24 Years of Research at ICAR-IGFRI, Jhansi." This bulletin encapsulates the significant contributions of the Indian Grassland and Fodder Research Institute (IGFRI) in advancing forage science and enhancing the national forage resource base. Over the past 24 years, IGFRI has spearheaded major research programs that have revolutionized our understanding of grassland ecosystems and improved forage production techniques. This bulletin not only emphasizes the institute's crucial role in improving the quality and accessibility of forage resources throughout India but also reflects the impact of our research through a substantial number of quality publications over time. Additionally, it showcases IGFRI's strong outreach initiatives, which have successfully shared knowledge and innovations with farmers and stakeholders, promoting sustainable practices and community involvement. By documenting these achievements, we hope to inspire future research efforts and collaborations that will further bolster our national forage resource base. As we celebrate these milestones, we reaffirm our commitment to sustainable forage development, innovation, and the continuous improvement of our agricultural systems as a whole for the benefit of farmers and the environment alike.

Authors

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ICAR-IGFRI, Jhansi: A Brief Introduction

To address the forage needs of a nation with the largest livestock population globally and to conduct systematic scientific research on grasslands, fodder production, and their utilization, the Government of India established the prestigious 'Indian Grassland and Fodder Research Institute' (IGFRI) on 1st November 1962, in Jhansi, a biodiversity hotspot for grasses. Since April 1, 1966, the institute works under the administrative control of Indian Council of Agricultural Research (ICAR). The institute is mandated to conduct basic, strategic, applied and adaptive research; development and training in forage production and its utilization. With more than six decades of experience in forage research and development, IGFRI today stands as the leading R&D institution in South Asia for sustainable agriculture through quality forage production for improved animal productivity. The Institute has highly experienced and internationally trained human resources engaged in need-based and participatory research, and training and extension programmes on all aspects of forage production and utilization through inter-disciplinary approach.

As IGFRI celebrates its 63rd anniversary on November 1, 2024, it is an opportune moment to assess the institute's research impact and contributions over the years. How has IGFRI advanced the national forage resource base? What have been the primary research focuses of the institute? To what extent has IGFRI contributed to global and national scientific understanding of grasslands and fodder? How visible is IGFRI's research work? How many farmers have benefited from the institute's extension activities, and what has been the impact of its outreach programs? Additionally, how can the institute enhance its influence on grassland and fodder policies moving forward?

This bulletin offers an overview of the institute's research over the past 24 years (2000-2023), featuring publication and citation data along with independent impact assessments of the institute's outreach projects. While the evidence presented in the bulletin is grounded in scientific rigor, it should be viewed with some caution as it also reflects the perspectives of the authors who have conducted the evaluations based on the available data.

IGFRI's Major Research Programs

IGFRI's stated mandates are to conduct basic, strategic and adaptive research on improvement, production and utilization of fodder crops and grasslands; coordination of research on forages and grasslands for enhancing productivity and quality for enhancing livestock productivity, and technology dissemination and human resource development. To fulfill these mandates the institute constantly making strides with its seven multidisciplinary divisions: Crop Improvement (CI), Crop Production (CP), Farm Machinery and Post-harvest Technology (FMPHT), Seed Technology (ST), Social Sciences (SS), Grassland and Silviculture Management (GSM), and Plant Animal Relationships (PAR), with the latter two being particularly unique (Annual Report, 2023). The institute with its headquarter at Jhansi also has three regional stations in Dharwad (Karnataka), Avikanagar (Rajasthan), and Srinagar (Jammu & Kashmir) to conduct focused forage research in humid tropic, semi-arid to arid, and temperate climatic conditions, respectively, along with a grassland centre in Palampur (Himachal Pradesh).

The institute is currently focusing research on the following six programmes:

- i. Genetic enhancement of forage crops with emphasis on quality, multicut, stress tolerance & bio-fortification utilizing conventional, apomixis and new breeding tools.
- ii. Diversification and sustainable intensification of fodder production in different land use systems including assessment and rejuvenation of grasslands and other resources for improving productivity and livelihood options.
- iii. Management of natural resources and soil health of arable and non-arable lands for climate resilient sustainable fodder production.
- iv. Accelerating seed biology research and technology development for enhanced quality forage seed production and strengthening the national forage seed network.
- v. Nutritional evaluation and post-harvest management of forage resources for sustainable and improved crop-livestock production systems.
- vi. Social, economic, policy and translational research and capacity building.

The above research programmes encompasses a wide range of activities aimed at enhancing forage crop genetics, diversifying and intensifying fodder production, managing natural resources, advancing seed technology, and improving nutritional and post-harvest practices. IGFRI

also seeks to deliver its research findings to policymakers at regional, national and international levels through a range of communications and outreach activities. Researchers working on specific studies participate in workshops and seminars, interact with decision makers, and prepare briefs and other nontechnical papers that appeal to a wider audience than peer-reviewed research papers. Many of these activities are undertaken in collaboration with national and regional partners and involve IGFRI's out-posted staff. The institute along with Range Management Society of India (RMSI) also organizes national and international conferences on various forage issues to addresses broader social, economic, and policy issues and to support sustainable agricultural development and improve the livelihoods of farmers and pastoralists.

IGFRI's Role in Enhancing National Forage Resource Base

How successful has IGFRI been in enhancing forage resource base? The answer lies in the institute's crucial role in the breeder seed production of major forage crops, developing fodder plans for 22 Indian states and its crucial role in expanding non-conventional fodder namely spineless cactus.

Breeder seed production

Over the past 24 years, the institute has produced a total of 4,390.22 quintals of breeder seeds for *rabi* fodders (primarily oats and berseem) and 1,625.68 quintals for *kharif* fodders. This output has been instrumental in maintaining a consistent supply of high-quality seeds for farmers. The breeder seed production was particularly impressive during the period from 2005 to 2009, surpassing the indent for both *kharif* (Fig. 1a) and *rabi* (Fig. 1b) seasons. However, periodic evaluations indicate a marked preference for *rabi* fodders over *kharif* ones.

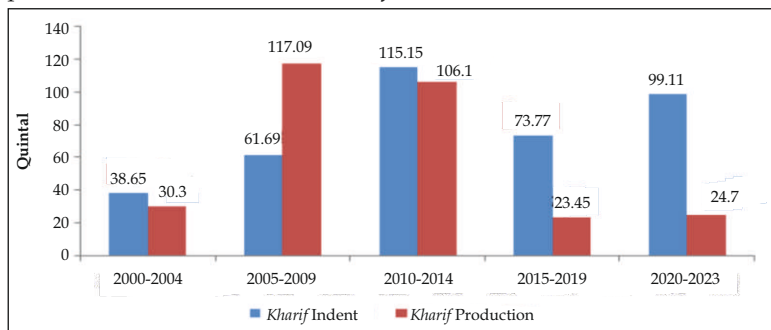


Fig. 1a: Breeder seed indent and production of fodder (*kharif* season) at IGFRI over the periods

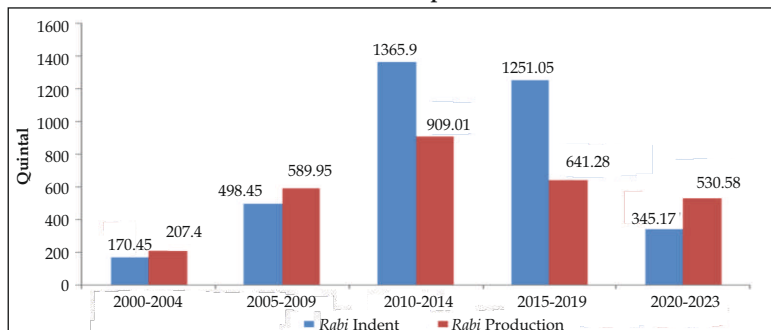


Fig. 1b: Breeder seed indent and production of fodder (*rabi* season) at IGFRI over the periods

Within the *kharif* fodder category, sorghum, maize, and cowpea have consistently dominated breeder seed production. Notably, the production of guar seeds peaked in the years 2003-04, 2005-06, and 2017-18, reaching 41.93%, 71%, and 68% of the total *kharif* seed output, respectively. For *rabi* fodders, oats have been the predominant crop, accounting for an average of 86% of breeder seed production.

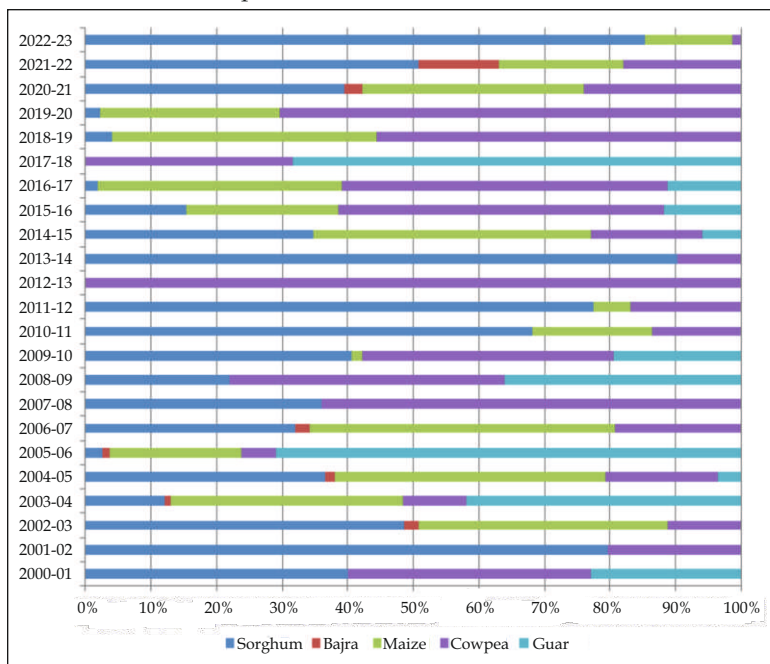


Fig. 2: Share of crops in breeder seed production during *kharif* over the years

The observed trend suggests that while the institute's efforts have been substantial, there may be underlying issues affecting seed production, such as abiotic stresses that need to be addressed in future to ensure continued support for the fodder sector. Nevertheless, a significant increase in breeder seed production at IGFRI is expected due to the institute's recent strategic initiatives. The emphasis on targeted research programs for *kharif* fodders such as maize, pearl millet, and cowpea will be key in diversifying the production focus for breeder seeds.

Complementing this, a robust monitoring and evaluation system has been implemented to meticulously track production processes, assess seed performance, and identify areas for improvement. This system enables data-driven decision-making, facilitating continuous enhancements in production practices and seed quality. Additionally, the recent opening of IGFRI's seed processing infrastructure would play a crucial role in

boosting production efficiency. Modernized processing facilities will streamline seed cleaning, sorting, and packaging, thereby reducing waste and ensuring that seeds meet the highest standards of quality. Together, these advancements will create a synergistic effect, enhancing the overall efficiency and output of breeder seed production at IGFRI, ultimately supporting the institute's goal of meeting increasing demands of high-quality fodder seeds.

Development of community pasturelands

In recent years, IGFRI has made significant strides in the development of community pasturelands across several critical regions of India, including the Bundelkhand region of Uttar Pradesh, Sheopur district of Madhya Pradesh, and Tonk district of Rajasthan. These regions, known for their arid and semi-arid conditions, have traditionally faced challenges related to insufficient fodder resources. The IGFRI's intervention aims to address these challenges by establishing well-managed grasslands that can substantially improve both fodder availability and livestock productivity in these areas.

The newly established grasslands in these regions are designed to produce between 6 to 8 tons of dry matter per hectare per year. This level of productivity is a significant enhancement over traditional grazing lands, providing a more reliable and consistent source of feed for livestock. In practical terms, the improved pasturelands can support 2 to 2.5 Adult Cattle Units (ACU) per hectare. An Adult Cattle Unit is a standard measure used to estimate the feed requirements of cattle, with one ACU representing the feed needs of one adult cow. By increasing the carrying capacity of the land, these grasslands play a crucial role in supporting the local livestock population, which is vital for the livelihoods of the communities in these areas.

One of the notable achievements of the IGFRI's grassland development projects is the favorable benefit-to-cost ratio. Over a period of 10 years, the benefits derived from these grasslands are estimated to range between 1.5 to 2 times the cost of development. This positive ratio highlights the economic viability and sustainability of the investment in grassland development. The benefits include not only the increased production of fodder but also enhanced soil health, improved biodiversity, and greater resilience of the ecosystem to climate variability.

Non-conventional fodder: Spineless cactus

IGFRI has played a pivotal role in promoting spineless cactus as a viable nonconventional fodder resource in the semi-arid regions of India, especially during the critical 3-4 months of summer when traditional fodder is scarce (Kumar *et al.*, 2021). IGFRI spearheaded the evaluation and establishment of spineless cactus varieties obtained from ICARDA (Mexico, Brazil and Morocco). These varieties were tested for their

suitability in Bundelkhand's semi-arid climate, proving their potential as a significant fodder source. Cactus plants can produce up to 80 kg of fresh weight per plant after three years of plantation. A single row of cactus, spanning 100 meters and spaced at 1-meter intervals, can provide sufficient fodder for one Adult Cattle Unit (ACU) for up to four months, thereby addressing fodder shortages during summer months. This characteristic makes spineless cactus an invaluable supplementary feed source, capable of replacing up to 30% of traditional green fodder, hay, and straw in livestock diets without serving as the sole feed.

Spineless cactus is highly valued for its impressive nutritional profile, containing 7-9% crude protein (CP) and 85-92% water. This high moisture content is crucial for livestock during droughts and summer heat, addressing the lack of adequate fodder resources during these periods. The economic feasibility of spineless cactus has also been a significant factor in its promotion. The cost of production stands at approximately Rs. 74 per quintal of green fodder, with a net return of Rs. 75,500 per hectare from the second year onwards. The benefit-cost ratio of 1.87 underscores the economic viability of cultivating spineless cactus, further incentivizing its adoption by farmers.

The spread of spineless cactus technology has been impressive, reaching over 1,000 farmers across 10 states, including Uttar Pradesh, Madhya Pradesh, Rajasthan, Odisha, Jharkhand, Karnataka, Maharashtra, Gujarat, Telangana and Andhra Pradesh. This expansion, covering an area of approximately 250 acres, has been facilitated through collaborative efforts involving Krishi Vigyan Kendras (KVKs), non-governmental organizations (NGOs), state line departments, the National Dairy Development Board (NDDB), and the Bharatiya Agro Industries Foundation (BAIF). The success of this initiative highlights the potential of spineless cactus as a key component in enhancing livestock nutrition and resilience, particularly in areas prone to extreme climatic conditions. The integration of this fodder crop into traditional farming systems not only helps address fodder shortages but also contributes to the sustainable management of degraded lands and farm boundaries.

State Fodder Plans

Another ambitious effort of IGFRI to address the country's fodder deficit is launch of "National Initiative for Fodder Technologies Adoption (NIAFTA)" in the year 2019. NIAFTA is a strategic initiative to devise a comprehensive and implementable fodder resource development plan tailored to each state and Union Territory (UT) across India. The primary objective of NIAFTA is to utilize regional resources efficiently to achieve self-sufficiency in fodder production and utilization. By focusing on state-specific niches, the initiative aims to enhance fodder productivity and address the existing gap between demand and supply.

A key component of NIAFTA is the extension of cutting-edge research findings and technologies to various stakeholders, including policy planners, management personnel, and field-level functionaries. This knowledge dissemination is crucial for boosting the country's fodder productivity. The initiative emphasizes capacity building and skill enhancement among fodder producers and livestock keepers, ensuring that they are well-informed about emerging technologies. Additionally, NIAFTA facilitates interaction between these stakeholders and scientists, providing a platform for real-time feedback and impact assessment regarding fodder supply and its influence on farmers' livelihoods.

To date, IGFRI has successfully developed fodder plans for 28 states. Notable examples of proactive adoption include states like Arunachal Pradesh, Assam, Uttar Pradesh, Madhya Pradesh, Rajasthan and Andhra Pradesh which have embraced these plans and started expanding their forage resource bases. This proactive approach by these states is a positive step towards mitigating the national and seasonal forage deficit. The success stories from these states highlight the potential benefits of adopting such plans on a broader scale.

For broader implementation, it is crucial that other states follow the suit. To facilitate this, establishing state-specific fodder development committees could ensure that the plans are tailored to the unique needs and conditions of each region. These committees may consist of scientists, local experts, farmers, and extension officers who can provide valuable insights and feedback.

IGFRI's Research Impact

How successful has IGFRI been as a research institute? To answer this question comprehensively, it is essential to examine the institute's performance from an overarching perspective. One can assess IGFRI's influence and impact through two primary external sources of evidence. The first is its published output, which includes the quantity and quality of research papers, reports, and other scholarly articles produced by the institute. The second source is citations, which reflect how frequently these publications are referenced by other researchers and institutions.

Research publications

Research publications are the tangible evidence of institute's scholarly output and contribute significantly to its reputation within the academic community. High-quality publications demonstrate the institute's ability to conduct valuable and innovative research, while the volume of publications indicates its productivity.

Before analyzing publication status from the institute over the past 24 years, we examined the institute's key research areas. This step is crucial because it provides context for assessing the relevance and impact of the research output. By identifying the main focus areas, we can better understand the significance of the publications and their alignment with contemporary trends and advancements in the field.

We performed co-occurrence analysis for author's keywords to find out the most focused and accentuate keywords related to IGFRI publications. While doing this, a total of 105 keywords with frequency ≥ 5 were selected from 2076 authors keywords and the co-occurrence was performed on these 105 keywords.

Figure 3 visualizes the network of the keywords which frequently occurred in "fodder" research. The nodes in the network represent each of 30 keywords, and the size of a node and font size indicates the number of occurrences of a keyword across different studies. While the lines among nodes, if there, point out the two-connected keywords co-occurred in a research study. The thickness of the connection line is proportional to the co-occurrence strength, which means that the thicker the connection line, the more times the two keywords co-occur. The most commonly used other keywords are "*Cenchrus ciliaris*", "*ship*" and "*apomixis*" with frequency of occurrences of 22 times followed by "*nutrient utilization*", "*livestock*" and "*rapd*" each of with occurrences frequency of 18 and "*maize*" "*genetic diversity*" and "*wheat*" with occurrences frequency of 17.

The colours show which clusters the nodes belong to. As seen in Figure 3, there are total eleven clusters for IGFRI research. The larger four clusters

are Cluster 1: Sheep, *Dichanthium annulatum*, digestibility, energy value, gas production, goat, grasses, growth, methene, nitrogen balance, nutrient utilization, nutritive value, rumen metabolites, tree leaves. Cluster 2: Carbon management index, carbon sequestration, chickpea, conservation agriculture, fodder sorghum, microbial biomass carbon, rainfed, soil health, soil organic carbon, sorghum, system productivity, zonate leaf spot. Cluster 3: Fodder yield, Diversity, draught, fodder maize, correlation, green fodder yield, nutrient uptake, oat, principal component analysis, soil fertility, weed control efficiency. Cluster 4: Fodder, forage, maize, Buffalo, Cenchrus, Egyptian clover, genetic variability, heritability, isozyme, maize, management, variability, water productivity.

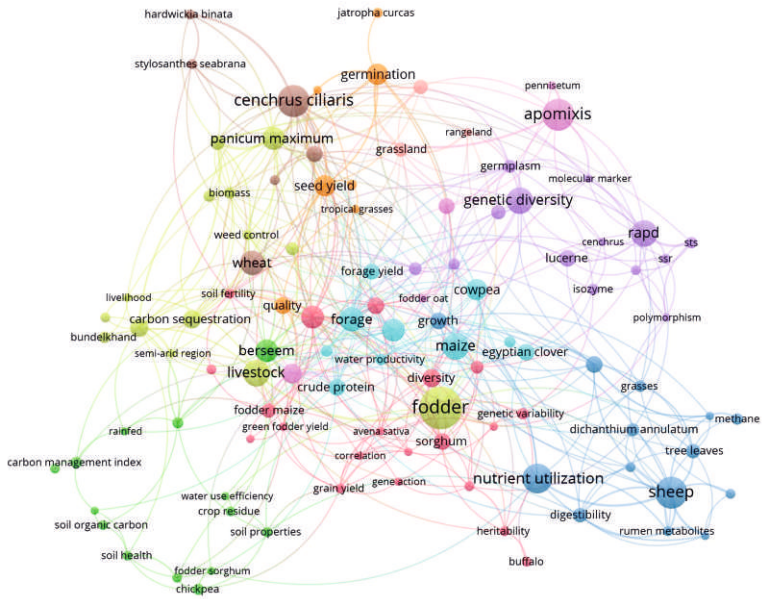


Fig 3: Network visualization of the most co-occurred keywords

Publication data for the period 2000-2023 were sourced from the Scopus bibliometric database. Scopus was selected for this study due to its reputation as a widely used and trusted database, which includes a comprehensive record of high-quality research publications and remains a major bibliographic resource. The search process involved two main options on the Scopus interface: "search within" and "search documents." We used the "search within" option to input the affiliation and the "search documents" option to specify the "Indian Grassland and Fodder Research Institute," with the date range set from 2000 to 2023. This search initially retrieved 1,110 publications, including journals, book series, books, and other types of publications. After efforts have consistently adhered to and

supported the institute's vision, addressing critical areas of interest applying various filters to narrow the results, we focused exclusively on research articles and ultimately identified 884 relevant articles.

Fig. 4 illustrates the overall trends in the number of publications from IGFRl over the years. Despite some fluctuations, the data generally show an upward trajectory in publication output. Notably, more than half of the research articles—approximately 53%—were published between 2016 and 2023. Among the years, 2021 saw the most significant increase in the number of articles compared to the previous year, while 2011 experienced the steepest decline.

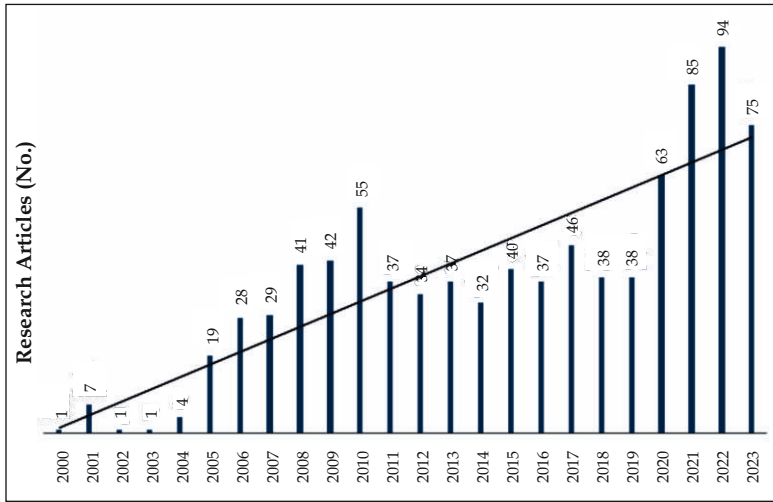


Fig. 4: The total number of research publications from IGFRl by years

When analyzing the publication data in five-year intervals, the period from 2020 to 2023 stands out as the most productive phase for IGFRl in terms of research output (see Fig. 5). This period reflects a marked acceleration in publication activity, highlighting a period of substantial research productivity and growth for the institute.

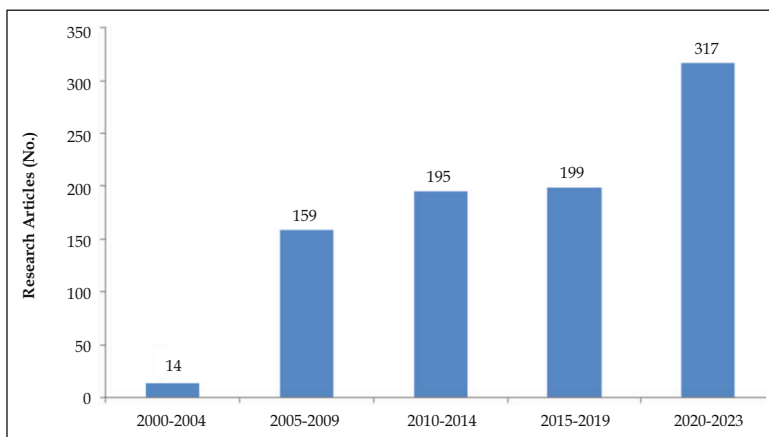
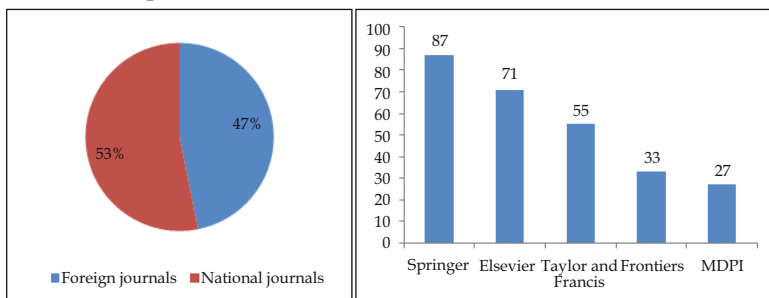


Fig. 5: Research articles over the periods from IGFRI

Further categorization of the papers by journal reveals that approximately 47% of IGFRI's research has been published in foreign journals, indicating the institute's high-caliber output (Fig 6a). The top foreign publishers are Springer with 87 papers, Elsevier with 71 papers, Taylor & Francis with 55 papers, Frontiers with 33 papers, and MDPI with 27 papers (Fig 6b). This distribution emphasizes IGFRI's significant presence and influence in the global research arena, showcasing the institute's commitment to delivering impactful and high-quality research through leading international platforms.



a) Share in foreign and national journals

b) Count of papers in foreign publishers

Fig. 6: Research articles from IGFRI in foreign and national journals

Fig. 7 displays the percentage contributions of the seven divisions of IGFRI to the total number of publications in the last 24 years. It is important to note that research articles authored as the first author by scientists from IGFRI's regional research stations were categorized according to the scientists' subject specializations. The data indicate that the *Crop Improvement (CI) Division* leads with the highest share, accounting for 28% of the total articles, which amounts to 252 publications. This is closely

followed by the *Crop Production (CP) Division*, which contributed 201 articles, representing 23% of the total. Other notable contributions come from the *Plant-Animal Relationship (PAR) Division* and the *Grassland & Silviculture Management (GSM) Division*, with 170 and 138 publications, respectively.

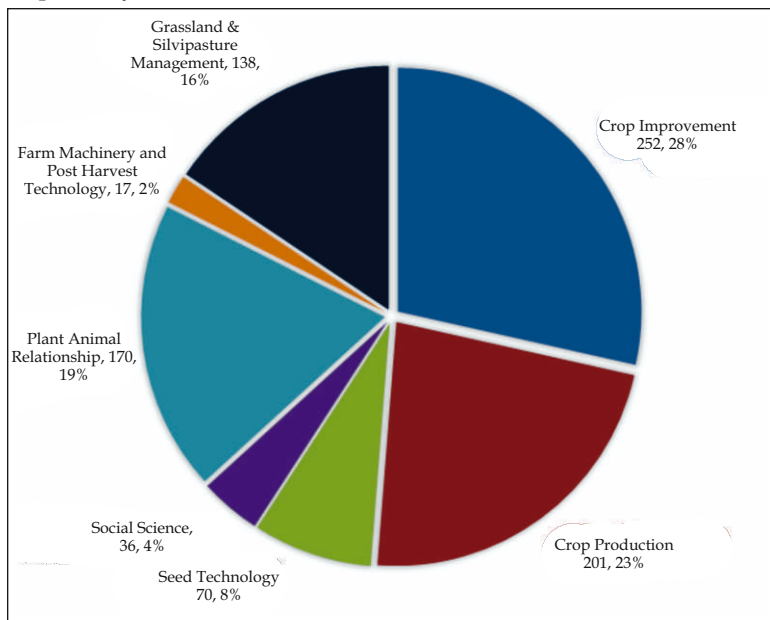


Fig. 7: Research articles by division at IGFRI (2000-2024)

However, the performance of these divisions varied across different time periods. For instance, from 2005 to 2009, the PAR division achieved the highest number of publications (59), whereas the CP division excelled during the period 2015-19 (Fig. 8). In contrast, the divisions of *Seed Technology (ST)*, *Social Science (SS)*, and *Farm Machinery and Post Harvest Technology (FMPHT)* exhibit relatively lower publication output over the past 24 years. However, the performance of these divisions has notably improved from 2020 to 2023.

During this period, the ST division published 51% of its total research articles, while both the SS and FMPHT divisions published 47% of their total research articles (Fig. 9). While the potential opportunities for increased publication from these divisions cannot be denied, boosting their scientific strength and expanding their team of experts would improve IGFRI's overall research output.

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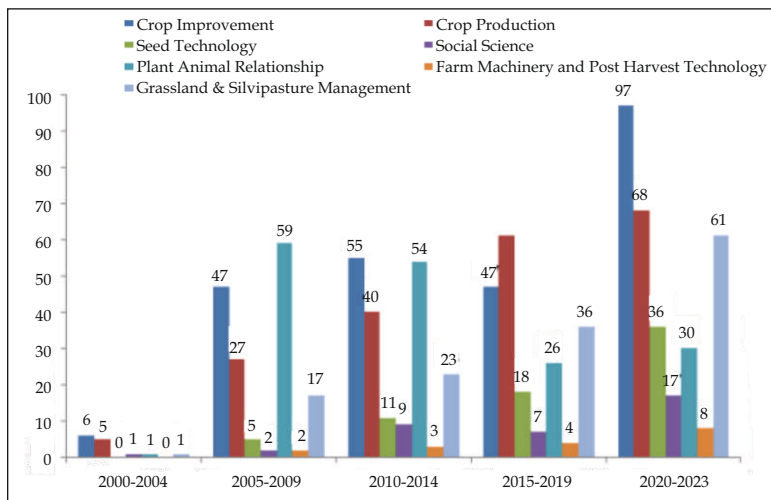


Fig. 8: Research publications by divisions across the time periods

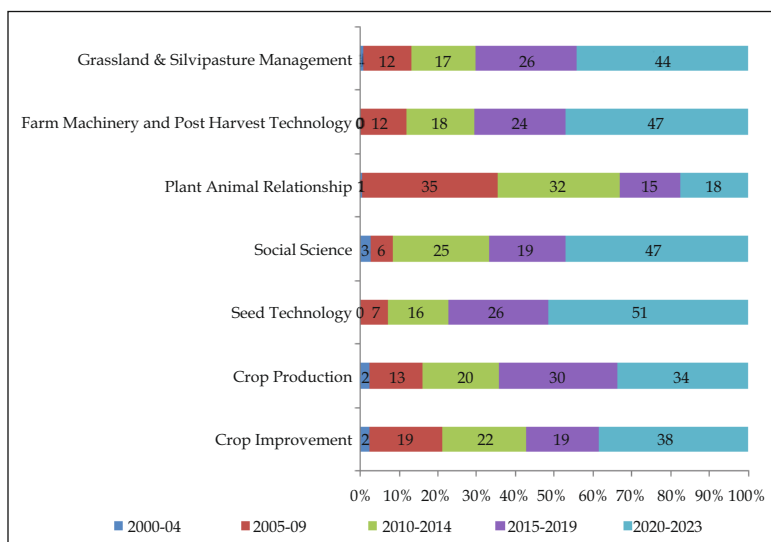


Fig. 9: Self-performance of the divisions over the period

Citations

Citation analysis helps in gauging the real-world impact of IGFRI research, identify high-performing areas, and highlight the value of their

scholarly output. Google scholar was chosen as it is the most broadly representative database of citations (Hewitt 2008). It includes citation information from peer-reviewed and non-peer-reviewed papers, theses, books, abstracts, and articles, from academic publishers, professional societies, pre-print repositories, universities, and other scholarly organizations. To a greater extent than some other citations databases, it includes less formal research materials such as policy briefs, discussion papers, working papers conference papers, and dissertations. The 884 research papers published over the past 24 years have accumulated a total of 10,570 citations. Although there is a steady increase in citations over time (Fig. 10), papers published in 2020 has achieved the highest citation count (Fig. 11), totaling 1,085. Papers from 2021 and 2022 have also been cited extensively. This indicates that more recent publications are becoming increasingly impactful in the field.

We also used VOS viewer software to analyze the global citation distribution of articles having affiliations of IGFRI. Out of 52 countries, we selected 20 countries that met the criterion of having published at least 2 documents. Fig. 12 shows that the citations from different countries were organized into 14 distinct clusters, each represented by a different color. Among these clusters, 5 are notably larger than the others. The size of each cluster corresponds to the volume of citations, indicating that countries with larger clusters tend to have more substantial citation counts. The highest number of citations (7,167) received from India itself, followed by the USA with 1,121, Australia with 585, Poland with 250, and the UK with 248.

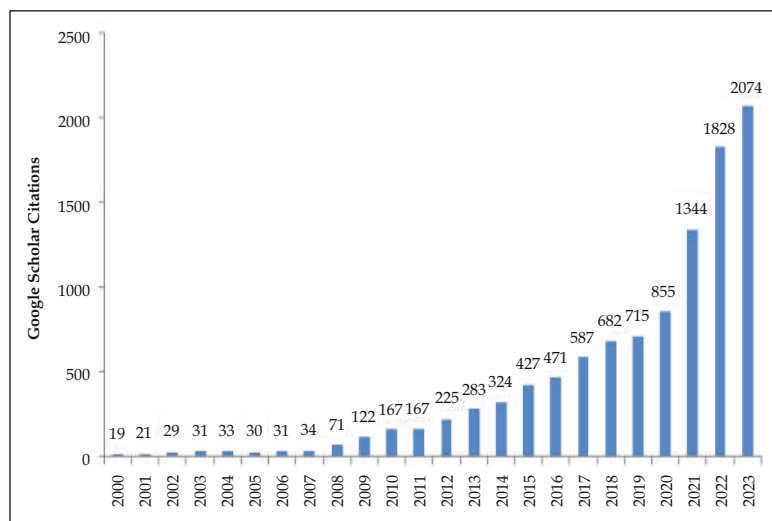


Fig. 10: Total number of citations per year (2000–2023)

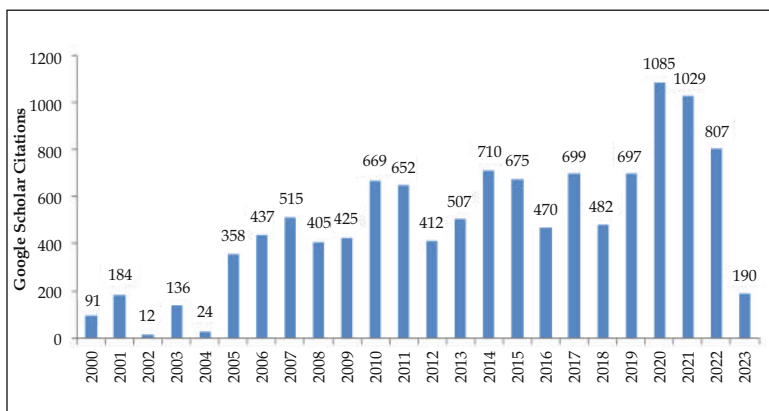


Fig. 11: Citations of papers published in various years

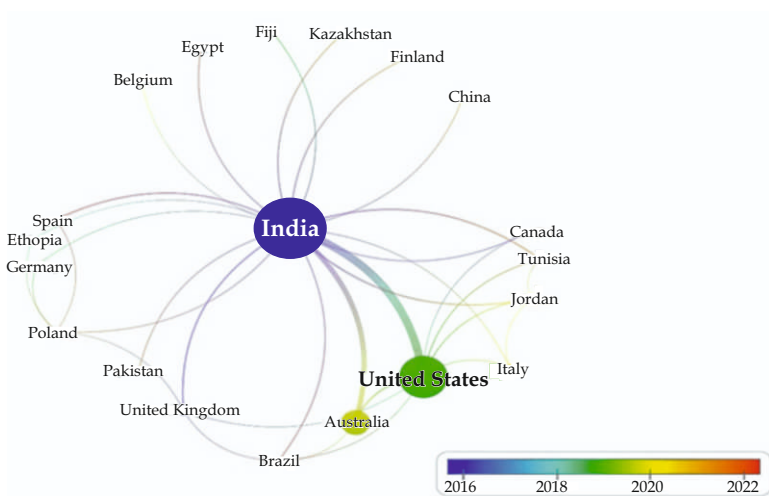


Fig. 12: Network visualization of the IGFRI papers cited in various countries

Citation indices

Based on the citation analysis we also calculated various citation indices of IGFRI publication. The IGFRI publication's i-10 index of 331 and h-index of 48 underscore the institute's strong impact in its research domain. The i-10 index reflects the number of publications with at least ten citations each, signaling that a substantial number of IGFRI's research papers have achieved notable recognition and influence in the academic community. An i-10 index of 331 indicates that a large proportion of their publications are well-cited, highlighting ongoing relevance and the ability to engage with key topics in their field.

Table 1: Citation indices of IGFRI publications

Name of Index	Google scholar
i10	331
h-index	48

Note: based on citation count from 2000-2023 only

Most influential researchers and papers

We also sought to identify the most influential researchers and research articles published by IGFRI. Over the past 24 years, the top 10 researchers by publication count are Sultan Singh, A.K. Roy, Amaresh Chandra, Sunil Kumar, D.R. Malaviya, Pankaj Kaushal, M.M. Das, S.K. Mahanta, R.V. Kumar, and Dibyandu Deb (see Fig. 13). However, these results should be viewed with caution, as some of these individuals have either retired (*e.g.*, D.R. Malaviya) or been transferred to other institutions (*e.g.*, Amaresh Chandra, Pankaj Kaushal, S.K. Mahanta, and Dibyandu Deb) during the period under consideration.

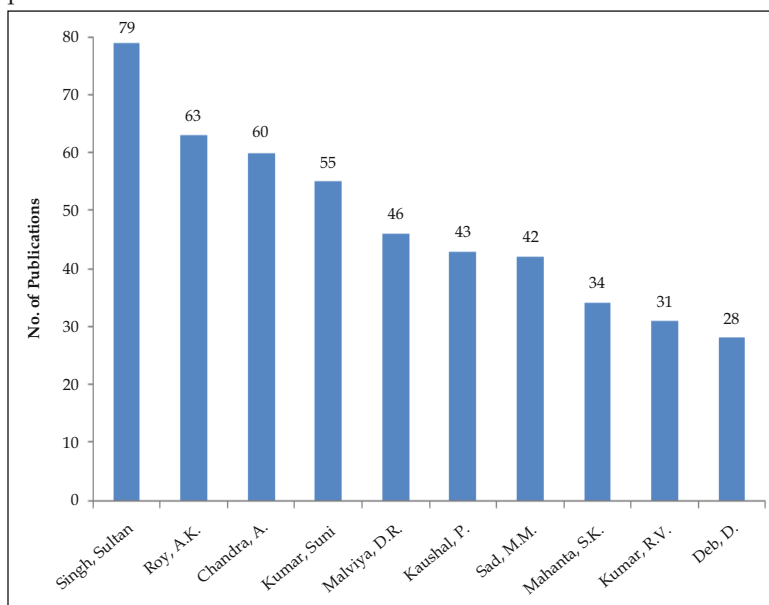


Fig. 13: Top 10 researchers in terms of publication count (2000-2023).

From the 884 publications analyzed, only 61 papers are cited more than 50 times. The top 5 most influential publications are presented in Table 2. The article by R.P. Sah *et al.* entitled “Impact of water deficit stress in maize: Phenology and yield components” published in 2020 is the most cited research article with 269 citations. The other most cited papers were published during 2011 to 2015.

Table 2: Top ten cited papers from IGFRI

SN	Research title	Authors	Journal Name	GS Citation
1	Impact of water deficit stress in maize: Phenology and yield components	Sah, R.P., Chakraborty, M., Prasad, K., Pandit, M., Tudu, V.K., Chakravarty, M.K., Narayan, S.C., Rana, M. & Moharana, D. (2020)	Scientific Reports, 10, 2944	269
2	Assessment of future climate change impacts on water resources of Upper Sind River Basin, India using SWAT model	Narsimlu, B., Gosain, A.K. & Chahar, B.R. (2013)	Water Resource Manage, 27, 3647-3662	230
3	SWAT Model Calibration and Uncertainty Analysis for Streamflow Prediction in the Kunwari River Basin, India, Using Sequential Uncertainty Fitting	Narsimlu, B., Gosain, A.K., Chahar, B.R., Singh, S.K. & Srivastava, P.K. (2015)	Environmental Processes, 2, 79-95	220
4	Poor efficacy of herbicides in biochar-amended soils as affected by their chemistry and mode of action	Nag, S.K., K., Rai, Smith, L., Krull, E., Lynne M., Macdonald & Gill, G. (2011)	Chemosphere, 84, 1572-1577	136
5	<i>In vitro</i> ruminal fermentation, protein and carbohydrate fractionation, methane production and prediction of twelve commonly used Indian green forages	Singh, S., Kushwaha, B.P., Nag, S.K., Mishra, A.K., Singh, A. & Anele, U.Y. (2012)	Animal Feed Science and Technology, 178 (1-2), 2-11	127
6	Identification of causal relationships among traits related to drought resistance in <i>Stylosanthes scabra</i> using QTL analysis	Thumma, B.R., Naidu, B.P., Chandra, A., Cameron, D.F., Bahnisch, L.M. & Liu, C. (2001)	Journal of Experimental Botany, 52 (355), 203-214	111

7	Effect of salicylic acid on morphological and biochemical attributes in cowpea	Chandra, A., Anand, A. & Dubey, A. (2007)	Journal of Environmental Biology, 28 (2), 193-196.	109
8	Land forming and tillage effects on soil properties and productivity of rainfed groundnut (<i>Arachis hypogaea</i> L.)-rapeseed (<i>Brassica campestris</i> L.) cropping system in northeastern India	Kuotsu, K., Das, A., Lal, R., Munda, G.C., Ghosh, P.K. & Ngachan, S.V. (2014)	Soil and Tillage Research, 142, 15-24	98
9	Intake, digestion and microbial protein synthesis in sheep on hay supplemented with prickly pear cactus [<i>Opuntia ficus-indica</i> (L.) Mill.] with or without groundnut meal	Misra, A.K., Mishra, A.S., Tripathi, M.K., Chaturvedi, O.H., Vaithyanathan, S., Prasad, R. & Jakhmola, R.C. (2006)	Small Ruminant Research, 63 (1-2), 125-134.	91
10	Energy auditing and carbon footprint under long-term conservation agriculture-based intensive maize systems with diverse inorganic nitrogen management options	Jat, S.L., Parihar, C.M., Singh, A.K., Kumar, B., Choudhary, M., Nayak, H.S., Parihar, M.D., Parihar, N. & Meena, B.R. (2019)	Science of the Total Environment, 664, 659-668	89

IGFRI'S Outreach Programmes

Apart from the critical role of research publications in advancing scientific knowledge, the service provided by research institutes to the ultimate beneficiaries i.e. farmers, is equally vital. This aspect of service often plays a crucial role in translating research outcomes into practical benefits, fostering tangible improvements in agricultural practices, and enhancing livelihoods. We undertook a comprehensive analysis of the extension services and outreach activities conducted by the IGFRI over the past 24 years, focusing on how effectively these initiatives have reached and impacted farmers.

IGFRI has been notably proactive in implementing various outreach programs designed to bridge the gap between research and its practical application at farmer's fields. These programs have included a range of activities such as training, visits and field demonstrations under various outreach programmes like IVLP, Farmer FIRST, MGGMG, SCSP, TSP and NEH. Number of trainings conducted by the institutes has increased from 134 from 2000-04 to 214 during 2020-23. Field visits by the scientist were also above 150 across the different periods (Fig. 14).

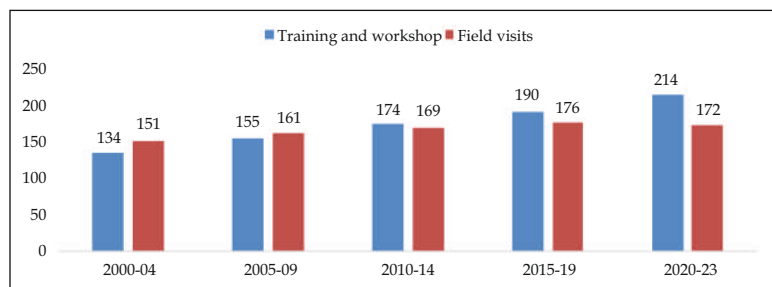


Fig. 14: Training and visits of IGFRI scientist over the periods

It is important to emphasize that the impact of extension activities has grown dramatically over the years. The total number of farmers benefiting from these programs has surged more than tenfold, from 3,765 individuals in the period from 2000 to 2004 to an impressive 39,213 from 2020 to 2023 (Fig. 15). This notable increase underscores the institute's heightened commitment to extending its outreach and support in recent years. Furthermore, the benefits of these extension activities have not been limited to farmers alone. Other significant stakeholders have also reaped substantial rewards. Government employees, including KVK staff, forest officials, and veterinary officers, have gained from these efforts. Students, NGOs, and private sector entities involved in the forage industry have

likewise seen considerable advantages. This broad impact highlights the extensive and inclusive nature of the institute's approach to supporting various groups through its extension activities.

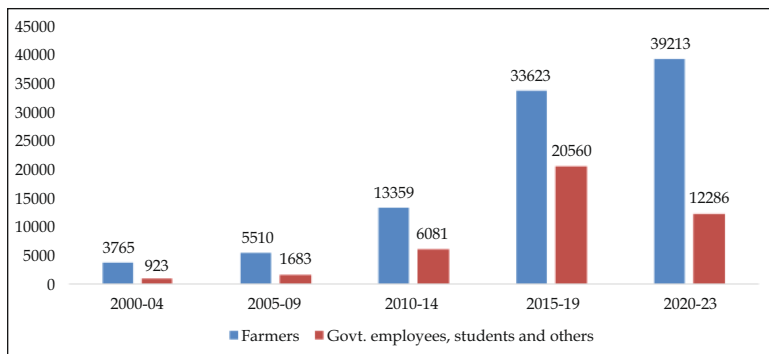


Fig. 15: Total beneficiaries from IGFRI technological support across the periods

Literature on the impact of outreach programs reveals significant benefits from the adoption of improved forage practices by farmers in the Bundelkhand region. According to Sharma *et al.* (2021), these practices led to a substantial increase in annual milk production, with an average rise of over 950 liters, and daily milk yield increased from 1.15 to 2.04 liters. Additionally, farmers experienced a reduction in feeding time by approximately 2 hours during the zaid season and around 1 hour during the *kharif* season. In another study, Choudhary *et al.* (2022) found that the adoption of forage technology promoted by IGFRI resulted in a 22% improvement in the technical efficiency of dairy farmers in Bundelkhand. Moreover, Choudhary *et al.* (2023) investigated the impact of the SCSP program by IGFRI in Jhansi district, Uttar Pradesh, and reported that technological interventions enhanced farm income by 45-51% and increased asset possession for SC farmers by 23-27%. While these regional studies provide valuable insights, a comprehensive pan-India impact assessment of IGFRI technologies would offer a broader perspective on their effectiveness.

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