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Economic Viability and Institutional Framework of the Rice Seed Value Chain in Telangana, India

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ABSTRACT

Background: Telangana, known as India's seed hub, hosts around 400 seed companies, including multinationals. These companies leverage high processing capacities, extensive storage, strong research networks and a favourable climate for rice seed production, positioning the region as vital for agricultural advancement. Given the importance of rice seed business potential in Telangana, understanding the economic viability and institutional framework within the rice seed value chain is crucial for optimizing production, enhancing seed quality and maximizing stakeholder benefits.

Methods: This study used different sets of data to examine the rice seed value chain in Telangana. Data were collected from 104 seed growers, 60 seed organizers, 10 company representatives and 10 seed distributors, ensuring a comprehensive understanding of value chain dynamics. Additionally, 30 focus group discussions provided qualitative insights into stakeholder roles and perceptions. The research highlighted the essential roles of public and private institutions in varietal development and seed quality, specifically analysing how contractual arrangements among stakeholder's impact yield outcomes and overall productivity. Furthermore, the cost and returns were analysed at each stakeholder level within the rice seed value chain.

Result: Findings indicated that education, cooperative membership and technical assistance positively correlated with rice seed yield, while larger family sizes and excessive irrigation negatively impacted productivity. Seed growers incurred a production cost of `13,910 per tonne and received a gross price of `19,820 per tonne, resulting in a net benefit of `5,910 per tonne. Seed organizers earned `1,200 per tonne, while companies faced total costs of `31,520 per tonne, selling to cultivators at `35,000 per tonne for a net benefit of `3,480 per tonne. Overall, stakeholders in the rice seed chain received total benefits of `15,590 per tonne, with seed growers accruing the largest share (37.91%).

Key words: Contract farming, Institutional arrangements, Public-private interface, Rice seed system, Seed value chain.

INTRODUCTION

Among all vital agricultural inputs, seeds stand out as the only biological input that enhances the efficiency of other inputs, resulting in a considerable improvement in crop yields (Ngo *et al.,* 2019; Hanumanthappa *et al.,* 2018). The combination of seed quality, timely availability in the necessary quantities at a fair price is critical to increase crop productivity (Singh and Agrawal, 2018). A study shown that using quality seeds alone can boost rice yields by 8 to 20 per cent in India (Hossain and Swathi Nayak, 2020). For instance, the average seed replacement rate for rice in India has increased from around 40 per cent in 2011 to 64 per cent in 2017, resulting in a 13.38 per cent improvement in rice yield (Kaviraju *et al.,* 2022).

The consistent replacement of rice seeds, particularly in major rice-growing states in India, has led to a growing demand for high-quality certified seeds. With rice being cultivated on approximately 45 million hectares across diverse ecosystems (MOA, 2021), the private sector has recognized this as a significant opportunity to expand its involvement in the rice seed business. Following the development of rice hybrids in the 1990s, the private sector began playing a more prominent role in the rice seed sector, attracted by the large market potential and high profit margins (Pray and Nagarajan, 2014). In contrast, the public sector has primarily focused on inbred/varietal rice seed

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development, as private companies have shown limited interest due to the bulky nature of these seeds and their lower profit margins (Pal *et al.,* 2000). However, Private sector participation in the distribution of (inbred/varietal) rice seeds has been increasing as farmers prefer purchasing seeds for their genetic purity and timely delivery of clean, high-quality seeds, which is often difficult with farm-saved seeds (Singh and Agrawal, 2018; Prasanna *et al.,* 2018). Additionally, the low cost of (inbred) rice seeds relative to other inputs in rice cultivation has made them more appealing. Consequently, the private sector's share in varietal/inberd rice seed distribution has grown, especially with the rising demand for packaged seeds in varietal rice cultivation (Kolady *et al.,* 2012).

Despite the significant advancements in seed technology and the growing involvement of the private sector in India's rice seed industry (Spielman and Smale, 2017), there remains a lack of comprehensive studies focusing on the institutional and economic dynamics of the rice seed value chain, particularly in states like Telangana that are pivotal to seed production. Existing literature emphasizes the role of quality seeds in boosting productivity and the increasing private-sector participation in hybrid and varietal rice seed distribution. However, there is limited understanding of how these dynamics impact the distribution of economic benefits among stakeholders and the overall sustainability of the rice seed value chain.

Telangana, a major rice seed hub, supplies 70% of India's hybrid rice and 30% of inbred rice seeds (Seeds Men Association, 2021). However, fragmented rice seed production and distribution systems, along with institutional framework, pose significant challenges that require deeper investigation. There is also insufficient analysis of key economic parameters, including cost structures at various stages of rice seed value chain, pricing mechanisms and profit margins, that can inform policy and investment decisions. This research addresses these gaps by conducting an institutional and economic analysis of the rice seed value chain in Telangana, offering actionable insights to enhance policy frameworks and ensure equitable growth across stakeholders. Therefore, an effort was made to analyse the rice seed value chain with the following objectives.

1. To analyse the institutional framework of the rice seed industry in India, emphasizing the role of the private sector.
2. To assess the distribution of benefits among various stakeholders within the rice seed value chain.

MATERIALS AND METHODS

Telangana is recognized as India's seed hub, hosting around 400 seed companies, including major multinationals. The state's favourable climate supports rice seed production and research during both the kharif and rabi seasons. Given the significant role of rice seed production in Telangana's agricultural economy, this study was conducted in 30 key seed-producing villages across Hanamkonda and Karimnagar districts, which collectively contribute to around 80% of the state's total rice seed production (Janaiah and Xie, 2010).

The sample size for the study was determined to ensure comprehensive coverage of the rice seed value chain while maintaining representativeness. This paper draws from the author's doctoral research, which involved a total sample of 300 rice seed growers from 30 seed villages (10 growers per village). Of these, 196 were hybrid rice seed growers and 104 were inbred/varietal rice seed growers, selected through purposive sampling to focus on experienced growers directly involved in seed production. However, this paper specifically presents the data collected from the 104 inbred rice seed growers. Further, the inclusion of 60 seed organizers (2 from each of the 30 selected villages) helped in capturing the diversity of experiences and practices within the seed multiplication process. Additionally, 10 seed company representatives, 10 seed distributors and 10 seed dealers were selected to provide a balanced view of the supply chain, from production to distribution. The sample sizes for these groups were determined to balance practical constraints with the need for sufficient data to represent the dynamics of the rice seed industry in Telangana. This approach ensures the data collected is both relevant and representative, allowing for meaningful analysis of the value chain's economic and institutional framework. Additionally, 30 focus group discussions (FGDs) with local experts, farmers and other stakeholders offered valuable insights into the dynamics of rice seed production by capturing shared experiences and perspectives. These FGDs were instrumental in capturing shared experiences, concerns and suggestions, enhancing the depth of the study.

A structured schedule was used for interviews with seed growers and organizers to ensure consistency in data collection, while a semi-structured schedule was employed with company representatives, distributors and dealers to allow flexibility in capturing detailed insights into their roles within the value chain. Both instruments were validated through a pilot test involving a small subset of participants, enabling refinement of questions for clarity and relevance. This approach ensured the reliability of data collection and facilitated replicability of the study.

This study utilized both primary and secondary data. Four sets of primary data were gathered from various sources, including farm-level data from focus group discussions and inputs from seed growers, organizers, distributors and dealers. The secondary data collected through expert consultations with public and private sector stakeholders and seed industry associations. Primary data were collected during the 2021-22 *Rabi* season, while secondary data covered the years 2020 and 2021. The data were analysed using descriptive statistical methods to explore the rice seed value chain.

The multiple regression model was employed to examine the relationship between rice seed yield and various explanatory variables, making it an ideal choice for agricultural studies where yields are influenced by multiple factors. The analysis considered a range of independent variables, including age, education, family size, percentage of irrigated area, machinery and labour costs, fertilizer usage, labour man-days, cooperative membership (coded as 1 for members and 0 for non-members) and training (coded as 1 for trained growers and 0 for untrained growers). By incorporating these diverse factors, the model provided a robust framework for understanding their combined impact on rice seed yield.

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6 X_6 + b_7X_7 + b_8X_8 + b_9X_9 + b_{10}X_{10} + b_{11}X_{11} + b_{12}X_{12} \ldots\ldots\ldots + b_n X_n + e$$

Where,

Y = Yield of inbred rice seed variety.

b_0 = Intercept.

b_1 to b_{12} = Beta coefficients.

X_1 = Age (years).

X_2 = Number of educational years.

X_3 = Family size (number).

X_4 = Size of farm (acres).

X_5 = Percent of area under irrigation (acres).

X_6 = Machine labour cost (Rs./acre).

X_7 = Quantity of fertilizer (Kg/acre).

X_8 = Labour man days (acre).

X_9 = Number of technical staff visits.

X_{10} = Cooperatives (Cooperatives 1, otherwise 0).

X_{11} = Training (Trained 1, Otherwise 0).

Following the materials and methods, this article is presented under different sub sections in results and discussion chapter, that deepen the understanding of the rice seed value chain.

RESULTS AND DISCUSSION

Institutional framework in rice seed sector

The institutional framework of the rice seed sector in Telangana involves both public and private institutions that manage seed production, distribution and quality control. Insights from focus group discussions (FGDs) with rice farmers, seed growers and seed industry experts highlighted the roles of key institutions, the challenges in accessing quality breeder seeds and the regulatory oversight of public agencies. This section examines these institutional dynamics and their impact on the rice seed sector in Telangana.

Rice varietal development in India is primarily led by state agricultural universities (SAUs) and national institutes, with financial support and coordination from the Indian Council of Agricultural Research (ICAR) (ICAR, 2023). In recent years, private companies have also entered into this space by developing proprietary selections of notified varieties within the open-pollinated variety (OPV) segment (Singh *et al.*, 2008). This session explores the evolving dynamics of rice seed development in India with special

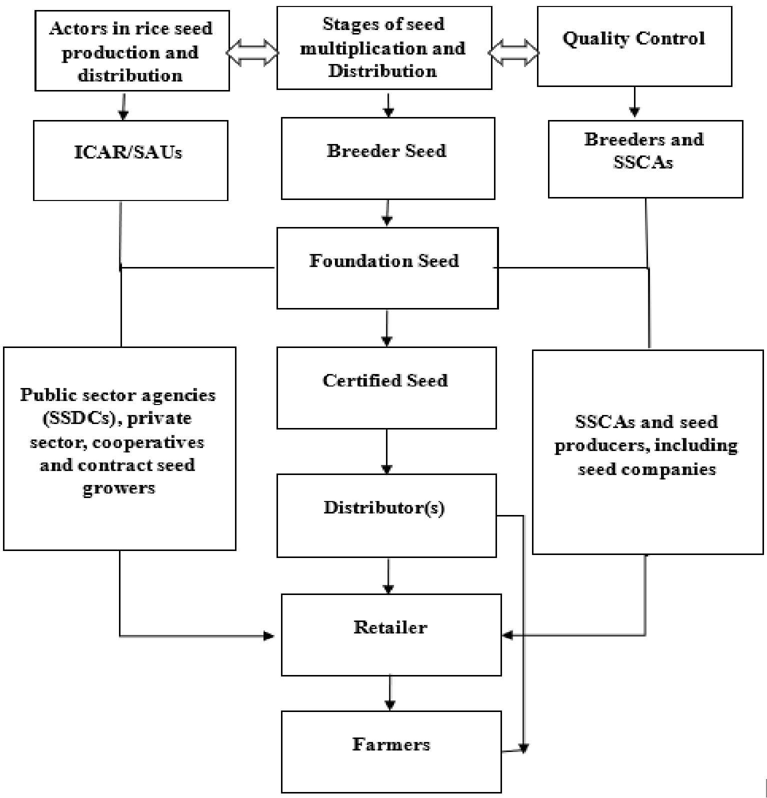

Fig 1: Institutional framework of rice seed sector.

focus on Telangana state, examining the roles of public and private institutions and assessing the impact of these changes on the rice seed industry and its stakeholders, particularly in terms of innovation and seed quality.

In Telangana, the majority of rice varieties used for seed production are publicly bred, following a three-stage multiplication process: Breeder Seed (BS) to Foundation Seed (FS) to Certified Seed (CS) (Fig 1). Both public and private seed companies depend on a consistent supply of breeder seed produced by public sector research organizations. Each year, agencies such as private seed companies, State Seed Development Corporations (SSDCs), the National Seed Corporation (NSC) and seed cooperatives request (Indent) breeder seeds from the State Department of Agriculture and Cooperation (DAC). The DAC compiles these requests and forwards them to the crop project coordinator at ICAR, which assigns BS production responsibilities to relevant SAUs or ICAR institutions (Janaiah and Behura, 2017). In Telangana, the responsibility for breeder seed production lies with Professor Jayashankar Telangana State Agricultural University (PJTSAU) and other ICAR institutions. Consequently, both public and private seed companies acquire breeder seed from above said institutions (PJTSAU and ICAR) through the public indent system (Fig 1). This seed is used to produce FS, which is then multiplied into CS over a process that takes at least two years.

BS multiplication into FS is conducted by public and private seed agencies on their farms. FS is then multiplied into CS with the assistance of contract seed growers, who are essential stakeholders in the rice seed value chain. This process involves contractual agreements outlining procurement prices, quality standards and operational timelines. The seed organizer plays a crucial role in these arrangements by facilitating interactions between seed companies and growers. Typically, seed companies choose a progressive farmer with significant experience in rice seed production as the seed organizer. He ensures timely activities are completed by the growers and provides essential technical advice. Seed companies compensate organizers based on the quantity of seed produced (Fig 1).

Both the public and private seed companies procure seeds from growers through organizers and oversee seed processing, packaging and distribution to farmers, supported by seed distributors (wholesalers) and seed dealers (retailers) (Fig 1). The Telangana State Seed and Organic Certification Agency (TSSOCA) ensures quality control from breeder to certified seed multiplication (Fig 1). In 2019-20, TSSOCA certified a total of 940 metric tonnes of rice seed, with 57 per cent produced by private companies and 38 per cent by TSSDC (Annual Report, TSSOCA-2019). However, as per the FGD data it was observed that most private companies marketed the majority of their rice seeds as Truthfully Labelled (TL). The widespread reliance on TL seeds in the private sector is largely due to the short certification window for rabi-produced seeds sold in the subsequent kharif season. This limited timeframe often leads companies to prefer self-certification through TL labels.

Key players in rice seed production: Contractual arrangements and yield implications

The rice seed varieties grown on the sample seed farms, along with their average yields and procurement prices from various agencies, are detailed in Table 1. During the *rabi* 2021-22 season, the total area allocated for inbred rice seed production by sample seed growers was 601.3 acres, involving more than 20 private seed companies and two cooperatives. Notably, the participation of multinational companies (MNCs) in this rice seed was minimal. The majority of rice seed varieties cultivated were publicly bred,

Table 1: Summary of rice seed companies, varieties grown, acreage, yield and price paid to seed growers.

Company	Varieties	Area (acres)	Yield (tonnes/ acre)	Price paid to seed growers (`/tonnes)
Mulkanoor cooperative rural credit and marketing society ltd.	RNR-15048, MTU-1010, JGL-24423, MTU-1153, KNM-113, BPT-5204, MTU-1156	142 (23.62)	2.48	18900
Dharmarajupalli paddy seed growers' cooperative society	MTU-1010, BPT-5204, MTU-1156,61 KNM-118, JGL-24423	61 (10.14)	2.60	19200
Kaveri seeds pvt ltd.	Kaveri-715, MTU-1010, BPT-5204	60 (9.98)	2.48	19720
Rasi seeds pvt ltd.	BPT-5204, RNR-15048, MTU-1010	44.5 (7.40)	2.45	19500
Nath seeds pvt ltd.	IR-64, BPT-5204	31 (5.16)	2.65	21750
Paturu seeds pvt ltd.	MTU-1010	30 (4.99)	2.40	20120
Mahyco pvt ltd.	BPT-5204, MTU-1010	28 (4.66)	2.60	20000
Nuziveedu seeds ltd.	BPT-5204	26 (4.32)	2.55	21000
Yashoda hybrid seeds Pvt Ltd.	MTU-1010, BPT-5204.	26 (4.32)	2.35	19200
Annadatha seeds Pvt Ltd.	MTU-1010	18.4 (3.06)	2.50	19160
Others	AMANI, MTU-1010, BPT-5204	134.4 (22.35)	2.45	19500
Total		601.3 (100)	2.50	19820

Note: Figures in the parenthesis are per cent to total area under inbred rice seed production.

developed by public sector research organizations, with MTU-1010, BPT-5204, RNR-15048, KNM-118 and JGL-24423 occupying the largest share of the total planted area. A few private companies have established their own research wings to conduct adaptive research for identifying rice varieties suited to specific production environments, marketing these as “research seed” under commercial names such as Kaveri-715, Amani and Jaisriram. The Mulkanoor Cooperative Rural Credit and Marketing Society members cultivated the largest area (23.6%), followed by the Dharmarajupalli Paddy Seed Growers’ Cooperative Society at 10.14%. The average yield for all varieties ranged from 2.3 to 2.7 tonnes per acre, with Yashoda Hybrid Seed Private Limited reporting the lowest yield and Nath Seeds the highest. The procurement prices for inbred rice seed varied slightly among agencies, ranging from `18900 to `21700 per tonne (Table 1).

A transparent and vibrant contractual system in seed production encourages seed growers to invest more resources and care into their crops, leading to higher yields. These contracts provide price assurance and buyback guarantees, which can be crucial for growers. To analyse the impact of contractual arrangements on inbred rice seed yield, a yield response function was estimated using a multiple regression model that included various explanatory variables, as shown in Table 2. The model explained approximately 58.5% of the variation in rice seed yield, as indicated by the coefficient of multiple determination (R^2), while the remaining 41.5% may be attributed to external factors such as weather, variety characteristics and soil fertility. The analysis revealed that labour man-days had a negative impact on yields; specifically, each additional labour unit decreased yield by -0.216 units at the 1% significance level. The negative impact of labour man-days on rice seed yield indicates that excessive or inefficient labour use, often linked to field issues or quality control efforts, can reduce yield. This highlights the need for skilled and optimized labour rather than higher labour input. Further, larger family sizes reduced yield by -0.258 units at the 10% significance level. This could be due to the financial strain of supporting more family members, which limits investment in quality inputs. Additionally, increased irrigation was associated with a yield reduction of -0.041 units, significant at the 5% level, likely due to waterlogging.

Table 2: Regression results of rice seed yield function.

Variables	Coefficient (b)	Standard error (SE)	t-value
Intercept	17.75702***	3.99	4.45
Age (years)	0.02295	0.02	1.15
Number of educational years	0.03629	0.04	0.81
Family size (number)	-0.25769*	0.16	-1.62
Farm size (acres)	0.099813***	0.03	3.30
Percent of area under irrigation	-0.04126**	0.02	-2.30
Number technical staff visits	0.42568**	0.17	2.56
Machine labour cost (Rs./acre)	0.000649***	0.00	2.68
Quantity of fertilizer used (Kg/acre)	0.047483***	0.01	4.67
Labour man days (acre)	-0.21597***	0.04	-5.14
Cooperatives (Cooperative 1, others 0)	1.165629**	0.50	2.32
Training (Trained 1, others 0)	0.796931**	0.51	1.57
R^2		58.48	
Adjusted R^2		53.52	
F		11.77	

Note: *** significant at 1 per cent level, ** significant at 5 per cent level.

Table 3: Detailed cost analysis of various inputs in rice production (per acre).

Various input costs	Quantity	Cost (Rs.)	% To total cost
Seed cost (`/acre)	24	1050	3.01
Organic manure (tonnes)	1	3420	9.80
Chemical fertilisers (kg)	180	3130	8.90
Plant protection chemicals (L)	3.25	4102	11.81
Machine labour	-	7488	21.49
Labour (man days)			
Normal farm operations	28	12780	36.70
Additional farm operations	6	2866	8.20
Total	34	15646	44.90
Total cost		34836	100.00

Conversely, positive influences on yield were linked to factors such as age (0.023 units), education (0.036 units), farm size (0.099 units), technical staff visits (0.426 units), fertilizer use (0.047 units), cooperative membership (1.166 units) and training (0.797 units). The support provided by cooperatives significantly enhanced yields, reinforcing the importance of cooperative involvement in agricultural productivity.

Table 4: Profitability of rice seed production on sample seed farms.

Cost / returns	Per acre
Yield (tonne/acre)	2.50
Procurement price (`/tonne)	19820.00
By product (`/acre)	1695.00
Gross returns (`/acre)	51324.00
Total costs (`/acre)	34836.00
Net returns (`/acre)	16488.00
Cost of production (`/tonne)	13910.00
Net returns (`/tonne)	5910.00

Cost and returns profile in rice seed production at seed grower level

The costs on various inputs in rice seed production were computed and presented in Table 3. The total costs on various inputs used in rice seed production were `34,836 per acre. Among all cost components, the cost on labour alone accounted for about 45 per cent of the total input cost. After the labour cost, the charges for machinery used were found to be higher, accounting for nearly 21.5 per cent of the total costs. Further, all other costs accounted for 33.5 per cent of the total costs (Table 3).

The average seed yield and returns from inbred rice seed production on sample seed farms are presented in (Table 4). The average yield of rice seed was reported as 2.5 tonnes/acre (2504 kg/acre). The average procurement price offered by various seed companies for the sale of (inbred) rice seed by seed growers was `19,820/tonne. The total gross returns from the inbred rice seed production by sample seed growers was estimated at

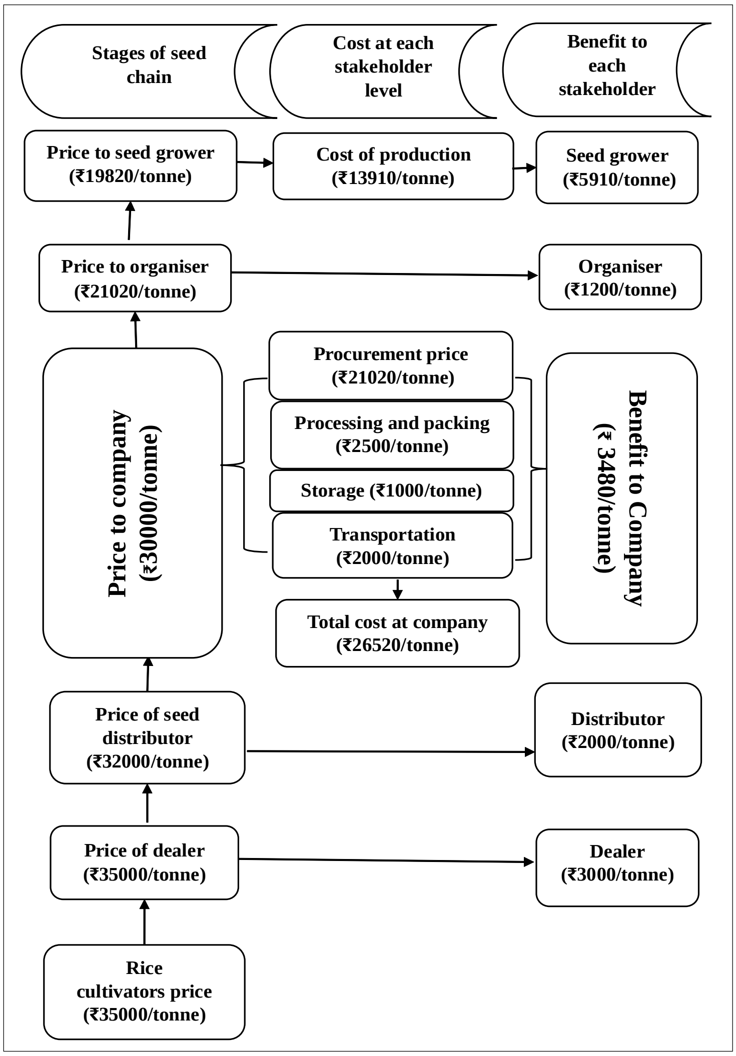

Fig 2: Cost and return analysis at different levels of the rice seed value chain.

`51,324/acre. Further, the operational production cost of inbred rice seed was reported as about `13,910/tonne and net profit estimated as `5,910/tonne (Table 4).

Distribution of benefits among various stakeholders in the rice seed chain

The cost and return analysis at each stage of the rice seed value chain, as depicted in Fig 2, provided a comprehensive overview of the economic flows across stakeholders. At the seed grower level, the total cost of producing rice seed was estimated at `13,910 per tonne. Upon sale, the seed grower received a price of `19,820 per tonne from seed organiser, yielding a net benefit of `5,910 per tonne, which represented the seed grower's margin. This net benefit was seen as the residual income after accounting for the direct costs of seed production, which included expenses related to land preparation, source seed, labour, irrigation and crop protection.

Moving up the value chain, the seed organizer played a crucial role in the aggregation and coordination of seed procurement from the grower. The organizer's procurement cost was `19,820 per tonne, which matched the price paid to the grower. However, the organizer received an additional service charge of `1,200 per tonne from the seed company for facilitating the procurement process. This service fee represented the organizer's contribution to the value chain without incurring significant additional costs, resulting in a net benefit of `1,200 per tonne. Thus, the procurement cost of the seed to the company rose to `21,020 per tonne (price paid to seed grower `19,820 and organiser service charge `1,200).

At the company level, the costs of procurement, processing, packaging, storage and transportation were accounted. The procurement cost to seed company was estimated at `21,020 per tonne. Additional costs at seed company level included `2,500 per tonne for processing and packaging, `1,000 per tonne for storage and `2,000 per tonne for transportation this included transportation costs from seed villages to processing units and from processing units to distribution centres. These costs reflected the company's operations, which involved transforming raw seed into market-ready products, ensuring storage capacity for maintaining seed quality and managing logistics for distribution. As result, the total cost incurred by the company in producing and processing the rice seed was `26,520 per tonne. Due to the lack of reliable data, costs associated with research, advertisements and infrastructure development were excluded from this calculation. These expenses are considered one-time or capital investments rather than recurring operational costs, making it challenging to accurately allocate them to the cost per tonne of seed production and processing. Finally, through the slae of rice seed, the seed company received `30,000 per tonne from subsequent stakeholder (Distributor). As a result, the seed company was realised net benefit of `3,480 per tonne.

In the rice seed value chain, marketing begins at the onset of the kharif season, when seed companies supply rice seed to distributors and dealers. Distributors act as wholesale traders, handling bulk quantities and supplying them to retailers. Retailers, being closest to farmers, sell smaller quantities directly to cultivators. Farmers paid a final sale price of `35,000 per tonne, from which marketing intermediaries deducted their margins. The total marketing margin was `5,000 per tonne, with distributors earning `2,000 and dealers `3,000 per tonne as commissions.

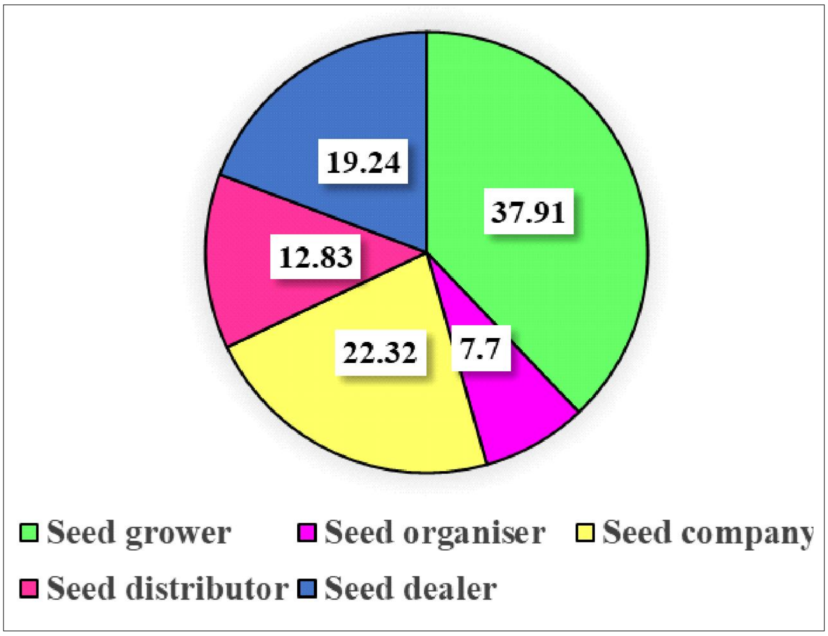

Fig 3: Share of various stakeholders in total benefits of rice seed chain.

These margins represented their net benefits, as the seed company bore all transportation costs from processing units to distribution centres.

Economically, the marketing margins, which include the distributor and dealer commissions, provide insights into the cost structure within the downstream segments of the value chain. These margins reflect the roles and economic incentives of the intermediaries in facilitating the distribution of rice seed. The company's net benefit, in contrast to the marketing margins, is a function of both its ability to control costs and the price it can command from cultivators in the market. The distribution of these margins underscores the interdependencies within the rice seed value chain, with both the intermediary stakeholders (distributors and dealers) and the company itself playing critical roles in determining the final price spread.

It is appropriate to find the distribution of benefits at each stakeholder level in the rice seed chain to assess the impact of seed production on seed growers, organisers, seed companies and marketing middlemen. Furthermore, it provided a clear picture of price dynamics among various stakeholders and the position of each stakeholder in the rice seed chain. Keeping this in view, an attempt was made to estimate costs and benefits at each stakeholder level in the rice seed chain (Fig 2). The total cost at various stakeholders' levels in the rice seed chain was estimated at `19,410/tonne. Likewise, the sum of benefits at various stages of the rice seed chain were estimated as `15,590/tonne. The sale price of rice seed available for rice cultivators was reported as `35,000/tonne (Fig 2).

Furthermore, the per cent share of each stakeholder in the total benefits of the rice seed chain was also estimated and presented in Fig 3. The total benefits received by all stakeholders in the inbred rice seed chain were estimated at `15,590/tonne, in which the majority share (37.91%) went to the inbred rice seed grower, followed by the seed company (22.32%), seed dealer (19.24%), seed distributor (12.83%) and organiser (7.7%) (Fig 3).

CONCLUSION

This study provides a detailed analysis of the rice seed value chain, examining production practices, cost structures, benefit distribution and yield determinants. Publicly bred rice seed varieties dominate the market, supported by cooperatives that play a vital role in achieving better yields and profitability for seed growers. While multinational companies have limited involvement, private players with adaptive research capacities contribute by marketing specific varieties as research seed. Transparent contractual arrangements, including price assurances and buyback guarantees, were found to motivate farmers to allocate resources more efficiently, thereby improving productivity. Cooperative membership and technical staff visits emerged as critical drivers of higher yields, emphasizing the need for robust cooperative systems and targeted farmer training.

The distribution of benefits across stakeholders in the rice seed chain reveals an uneven allocation, with seed growers retaining the largest share (37.91%) due to their labour and resource intensive role. However, operational challenges such as high labour costs and irrigation inefficiencies, coupled with pricing dynamics, affect overall profitability. The marketing margins, particularly the commissions of distributors and dealers, provided insight into the downstream cost structure. To lower seed prices, addressing these inefficiencies and optimizing the value chain is crucial. Enhancing policy support, strengthening cooperative frameworks and integrating technological advancements can help alleviate constraints, improve labour efficiency and ensure more equitable benefit distribution. These steps will not only reduce the price spread but also promote sustainability and equity, ultimately benefiting all stakeholders and enhancing the resilience of the rice seed industry.

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Disclaimers

The views and conclusions presented in this article are solely those of the authors and do not necessarily reflect the opinions of their affiliated institutions. While the authors strive for accuracy and completeness in the information provided, they do not accept any liability for direct or indirect losses resulting from the use of this content.

Informed consent

All animal procedures for experiments were approved by the Committee of Experimental Animal Care and Handling Techniques were approved by the University of Animal Care Committee.

Conflict of interest

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