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CGIAR Standing Panel on Impact Assessment

MONASH University

The Dynamics of Agricultural Innovation in North India

Shortlisting CGIAR-related Innovations in North India: Criteria, Evidence and Process

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Shortlisting CGIAR-related Innovations in North India: Criteria, Evidence and Process

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Introduction

The Foundation for Agrarian Studies (FAS), India, Monash University, Australia, and the Indian Council of Agricultural Research-National Bureau of Plant Genetic Resources (ICAR-NBPGR), India, jointly undertook a research project titled *The Dynamics of Agricultural Innovation in North India*, funded by the CGIAR-Standing Panel on Impact Assessment (SPIA). The project aims to document CGIAR-related innovations in North India since 2000[1] comprehensively, and study the reach and adoption of selected innovations that have achieved scale. In this study, we define North India as comprising six states: Punjab, Haryana, Uttar Pradesh, Bihar, West Bengal, and Odisha.

We have documented CGIAR-related innovations in North India through a systematic stocktake exercise (process explained in the working paper on 'Stocktake Process: Building the Longlist of CGIAR-related Innovations in North India'). The project also aims to prepare a shortlist of innovations to study their reach and adoption. This note, in particular, outlines the process and criteria used to prepare the shortlist from the longlist.

Shortlisting Criteria

Through a systematic approach and defined criteria, we derived a shortlist of 29 innovations from the longlist of 102. The shortlisting process considered the availability of survey-based and other published data sources, alongside the diversity of agricultural contexts across the study regions in North India. The shortlisting process did not rely on a single evidence source. Instead, innovations were assessed using a combination of estimated adoption scale, area coverage, regional spread and innovation presence, strength and reliability of the sources of the evidence, published documentation, and expert validation.

Broadly, two criteria were formulated and adopted to derive the shortlist:

i) Scale of adoption: innovations with evidence of scale and reach at the regional and state levels based on data from survey and non-survey datasets, published studies and expert opinions.

ii) Contextual significance: innovations that are particularly significant within a specific regional or socio-economic context, even where their geographical reach or overall scale of adoption may be limited.

Figure 1 shows the criteria followed for the screening process. The innovations that did not meet the criteria were excluded from the shortlist.

[1] An innovation or technology that was developed, introduced or disseminated after 2000.

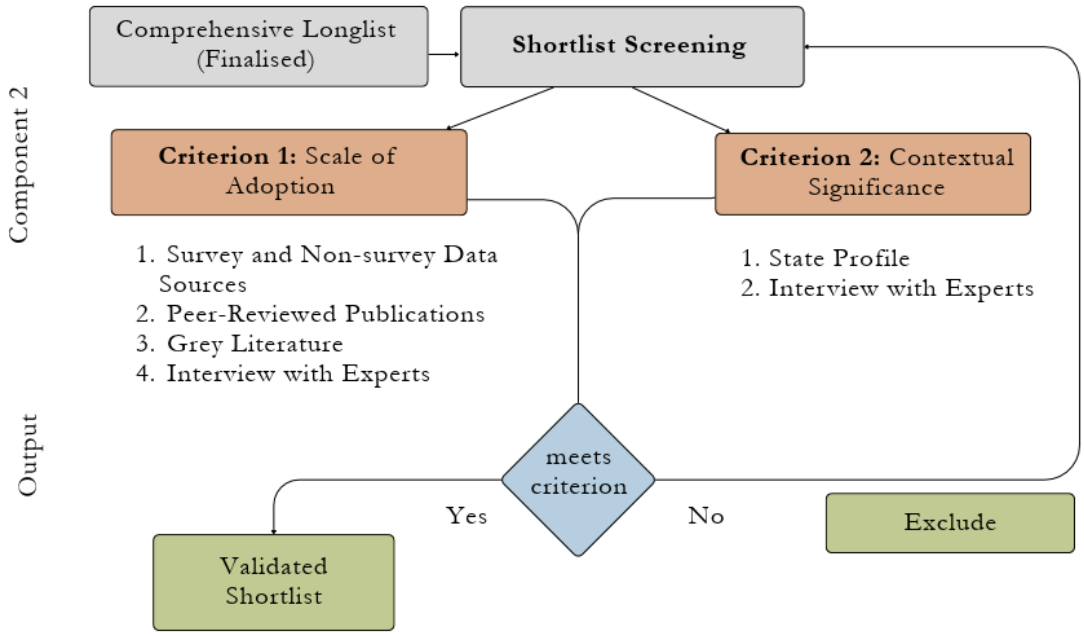


Figure 1. Shortlist Screening Process

The following section describes how we defined the scale of adoption and provides a detailed account of the four major sources of evidence used to assess it.

1. Scale of Adoption

Scale of adoption refers to the extent to which farmers or other end-users have adopted a CGIAR-related innovation. It considers the number or proportion of farm households adopting the innovation, the total area (in hectares) cultivated under new varieties, and the uptake of new methods and technologies, including mechanised farming practices, nutrient management and advisory tools, and improved agronomic practices in the field. It also considers the geographical distribution of adoption, particularly the extent to which an innovation has been scaled up in the specific states or regions and its uptake in areas exposed to particular stresses, such as floods, crop diseases, and other agro-ecological challenges.

To assess and estimate the scale of adoption, four sources were used:

- Survey and Non-survey Data Sources: data collected and compiled by government departments and public institutions.
- Peer-reviewed Publications: articles, book chapters, research papers, and academic dissertations
- Grey Literature: resources published by CGIAR centres, such as annual reports, compendia, policy briefs, and newsletters.
- Expert Interviews: interviews with experts from CGIAR, the Indian Council of Agricultural Research - National Agricultural Research and Education System (ICAR-NARES) system, State Agricultural Universities (SAUs) and Central and State Agricultural Departments.

Table 1 provides an overview of the specific sources used to estimate the scale of adoption for different categories.

Table 1. Overview of Scale of Adoption Criterion for the Shortlisting Process

Innovation Category/Source of evidence	Crop Improvement	Digital Advisory Tools	Machinery and Agronomic Practices	Policy/Institution Building
Survey and Non-survey Data Sources	a) Seed Rolling Plan; b) Breeder Seed Indent; c) Availability of Certified Seeds; d) Seed Distribution Data; e) Crop survey reports	App download statistics	a) Agriculture Input Survey, India; State and Central government records	Parliamentary records; Government dashboards; Government of India policy briefs
Peer-Reviewed Publications	Research Articles; Book Chapters			
Grey Literature	CGSpace; CGIAR Results Dashboard; MEL platform; CGIAR-IAES evaluation reports	CGIAR centre platform reports; Digital tool evaluation briefs	CGIAR evidence reports; various CGIAR Research Programme (CRP) reports	CGIAR-IAES evaluation reports; Government of India policy documents; CGSpace
Interview with Experts	ICAR scientists; SAUs scientists; State agriculture department officials; CGIAR scientists			

Note: Survey-based data included the Agricultural Input Survey and other sample surveys, while non-survey data comprised administrative records maintained by different authorities and data on app downloads.

1.1 Survey and Non-survey Data Sources

In this study, officially published survey-based and non-survey data were used as key sources of evidence across all three categories of innovation: crop improvement, digital advisory tools, and machinery and agronomic practices.

For innovation related to crop improvement, five datasets were used: (a) Seed Rolling Plan, (b) Breeder Seed Indent Data, (c) Availability of Certified Seeds, (d) Seed Distribution Data, and (e) Crop Survey Reports. Similarly, we used official data from the Agriculture Input Survey for machinery and agronomic practices. We also included data published in government reports for our analysis. For digital advisory tools, application download statistics were used as an indicator of the scale of outreach and potential reach of these tools.

Crop improvement accounts for the largest share of innovations in the shortlist, reflecting the scale of CGIAR's contribution in Indian agriculture.

1.1.1 Crop Improvement

Crop improvement constitutes a major focus area of CGIAR institutes, under which extensive germplasm supply and collaborative breeding efforts[2] have been undertaken across CGIAR mandate crops in India, which include rice, maize, wheat, potato, sweet potato, barley, grasspea, lentil, chickpea, groundnut, pearl millet, pigeonpea, cassava, and sorghum. Varieties developed through such germplasm contributions and collaborative efforts are referred to as *CGIAR-related varieties*.

These innovations include those that advance crop productivity, resilience, and tolerance to biotic and abiotic stress. We adopted a trait-based approach to classify these innovations; for instance, disease-

[2] Collaborative breeding efforts refer to the sharing of genetic resources, and these collaborative efforts include projects undertaken that advance further work on trait development, including activities such as the use of donor lines, molecular breeding, and field evaluation.

resistant rice or biofortified wheat. Such innovation encompasses multiple varieties exhibiting the specified trait. To verify the list and trait-specific information, information on germplasm was confirmed through various sources, such as All India Coordinated Research Projects (AICRP) reports[3], scientific publications, and materials from respective CGIAR centres or through the analysis of pedigree/parentage data.[4]

As the available data on crop improvement are generated and maintained within the institutional framework of the Indian seed system, a brief overview of the functioning of this system is provided below

Seed System in India

The Indian seed system consists of a formal and informal system (Figure 2). The formal seed system involves an organised regulatory framework for production, processing, distribution and sale of seeds of released and notified varieties[5]. It comprises public sector institutions such as National and State Seed Corporations, Public Sector Undertakings, ICAR research institutes, and Central and State Agricultural Universities, along with private sector companies, including Indian and multinational seed companies (NAAS 2018).

In India, seed quality is regulated under the Seed Act (1966)[6]; which requires compulsory labelling[7] for seeds, while seed certification remains voluntary[8]. Under this regulatory framework, the formal seed system produces two major categories of seeds: certified seeds (ensure labelling and certification) and truthfully labelled (TL) seeds (ensure labelling without certification).

Certified seeds are quality seeds produced under an official seed certification system. In this system, seed production is supervised and inspected by authorised certification agencies to ensure seed quality at different stages, including production, processing, and marketing. Certified seeds include centrally released and notified varieties, state-released and notified varieties, and notified varieties developed by private seed companies. The certification tag attached to the seed packet acts as a guarantee of seed quality and authenticity for farmers. Truthfully labelled (TL)seeds, on the other hand, are quality seeds that are produced and sold without the seed certification process. Here, the responsibility to ensure seed quality is with the producer, who declares the seed quality details on the label. TL seeds include varieties released at the central or state level, which may be produced either by the concerned developing institution itself, or by agencies authorised through licensing arrangements (varieties produced and marketed by companies through MoUs with seed developing institutes). They also include varieties

[3] All India Coordinated Research Projects (AICRP) is a network of projects launched by the ICAR for the development, testing, and identification of technologies through multi-location trials. It is a nationally coordinated research mechanism through which ICAR institutes and SAUs conduct trials under diverse agro-climatic conditions across India together. The AICRP reports are a compilation of annual or periodic research findings, experimental data, and technological advancements.

[4] Pedigree and parentage data refer to a breeding method that maintains detailed records of the ancestry, parentage and important traits of plants. Pedigree analysis is a systematic method to trace the ancestry and genetic relationships among different crop lines, including parental lines, intermediate derivatives, and released cultivars, enabling an understanding of how specific traits are transmitted across generations.

[5] Released and notified varieties are crop varieties that have been officially approved for cultivation by Central or State Variety Release Committees after evaluation for performance and suitability in multiple locations. After release, these varieties are notified under the Seeds Act, 1966 to bring their seed production, certification, quality control, and marketing under legal regulation.

[6] Primary legislation in India enacted to regulate the quality of seeds during production and marketing.

[7] The mandatory requirement that every container of seed of any notified kind or variety offered for sale shall bear, in the prescribed manner, an accurate and conspicuous label containing particulars such as the name of the variety, germination percentage, purity, date of testing, and other prescribed standards, irrespective of whether the seed has been certified or not.

[8] Voluntary seed certification is the optional official certification of seed quality under Section 9 of the Seeds Act, 1966, whereby a seed producer or seller may apply to the Seed Certification Agency for certification of seed that meets the prescribed standards.

developed by private seed companies. These private sector varieties may be either notified varieties, which come under seed law regulations, or non-notified varieties that are marked without formal notification.

In contrast, the informal seed sector is primarily a farmer-managed system, where seeds, known as farm-saved seeds, are produced, saved, exchanged, and accessed through farmers' own harvests and social networks such as friends, neighbours, and relatives (Pal *et al.* 2022).

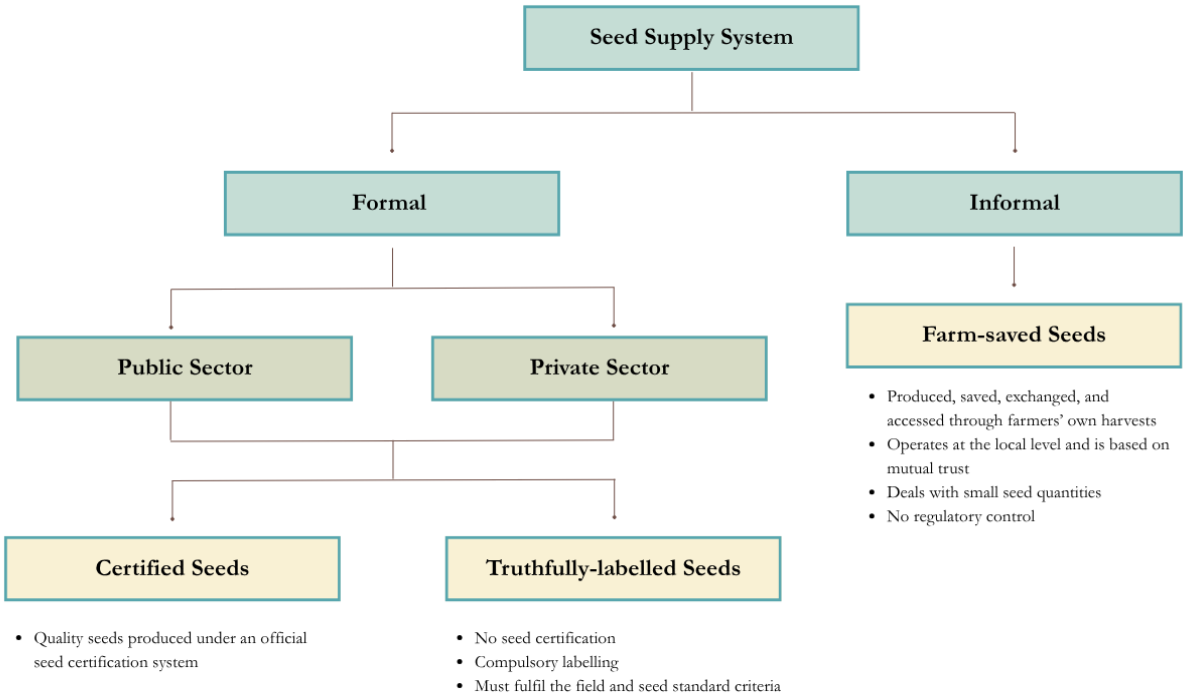


Figure 2. Seed Supply System in India

Contribution of formal and informal seed systems in India:

Within the seed supply system, seed distribution functions through both the formal and informal channels. Their relative contribution varies by crop and state. This variation is important for understanding the extent of data available and accessible for this exercise. The survey and non-survey datasets used are primarily of the formal system.

According to the State of Indian Agriculture (2015-16) Report (Government of India, 2016), the formal sector accounts for about 30-35 per cent of the total seeds distributed in the country and the remaining share (65-70 per cent) is supplied through the informal seed system.

This variation can also be observed among the CGIAR mandate crops cultivated in India. In paddy, the formal seed sector contributes about 88.6 per cent, and the informal sector only 11.4 per cent. In pulse crops, the informal sector contributes 73 per cent in chickpea and 81 per cent in lentils, whereas the formal sector contributes only 27 per cent and 19 per cent, respectively. In pigeonpea, the formal sector contributes 55.5 per cent and the informal sector 44.5 per cent. Similarly, in groundnut, the formal sector accounts for 33.7 per cent, while the informal sector contributes 66.3 per cent. However, in wheat, the gap is considerably narrower, with the formal system contributing 49.5 per cent and the informal system 50.5 per cent (Pal *et al.* 2022).

Similarly, within the formal seed system, the share of public and private sectors varies considerably across the crops. For instance, Pal *et al.* (2022) reported the dominance of the private sector for seed production and distribution in maize, pearl millet, and sorghum. Within the wheat seed system as well, the public sector accounts for nearly 30 per cent and the private sector for approximately 70 per cent of seed distribution (Vijayaraghavan *et al.* 2018).

Importance of using this data:

The datasets used represent different stages of varietal progression within the formal seed system, beginning with variety development, seed production, seed multiplication and extending to seed availability and distribution to farmers (Figure 3). These datasets do not uniformly provide direct evidence of varietal cultivation in farmers' fields; rather, they capture different points along the pathway through which improved varieties become available to farmers.

Moreover, these datasets are generated through established government and institutional processes and reflect decisions made by central/state governments, public and private seed agencies, and seed producers regarding the multiplication and dissemination of specific varieties. No single dataset independently provides a complete measure of adoption; however, their combined use (subject to availability) offers useful evidence regarding the extent to which *CGIAR-related varieties* have entered, progressed through, and persisted within the formal seed system.

Among the available datasets, breeder seed indent data is particularly important because its availability across multiple years and broad geographical coverage enables the assessment of temporal trends and comparison of varietal patterns across states. Moreover, where crop survey data and variety-wise area estimates are available alongside breeder seed data, they provide stronger and more direct evidence of varietal cultivation in farmers' fields, thereby enabling validation of patterns inferred from seed-system datasets.

Therefore, these datasets are important for understanding the spread of CGIAR-related crop improvement innovations through the formal seed system. However, they should not be interpreted as evidence of the actual on-the-ground reach or adoption of these innovations. Rather, they provide an indication of their potential reach.

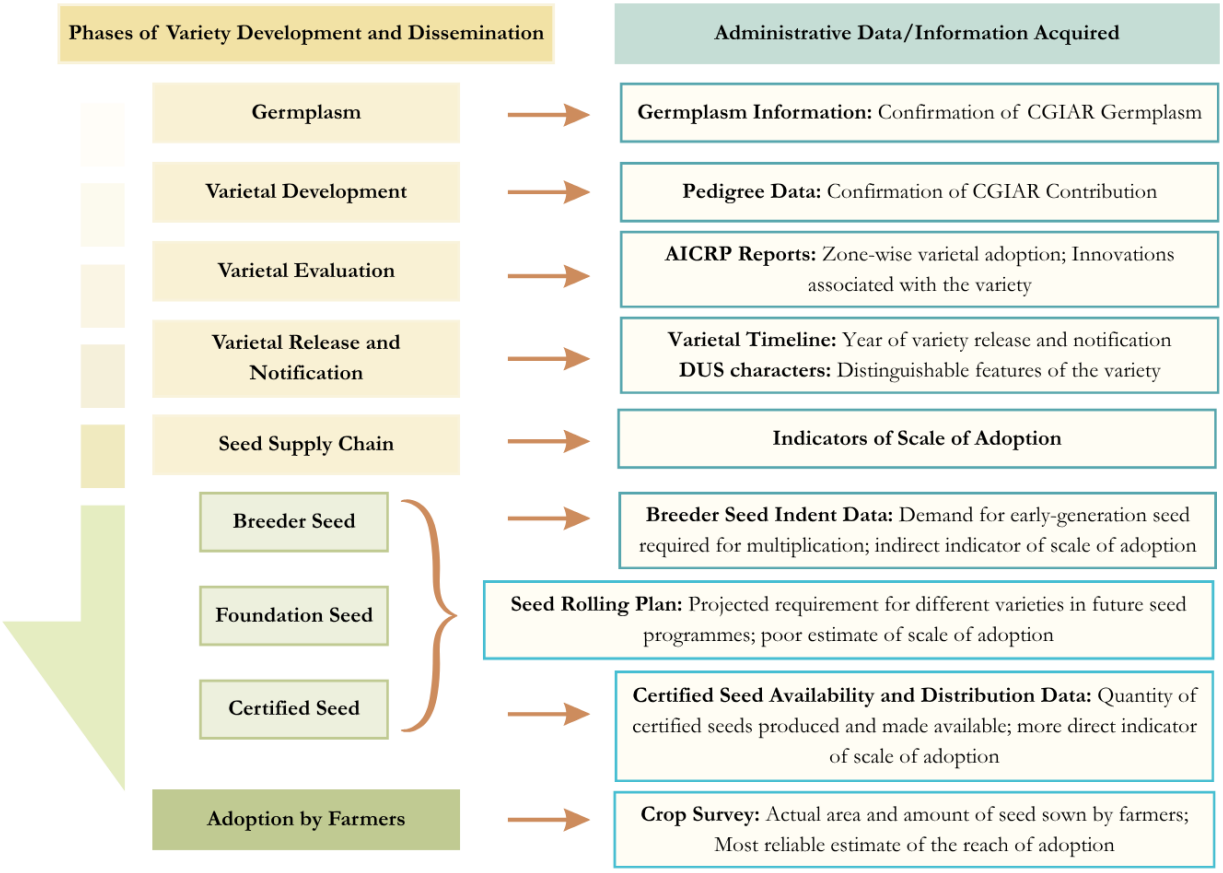


Figure 3. Schematic Illustration of the Survey and Non-survey Datasets Used Across Different Stages of Crop Variety Development, Seed Production, and Dissemination.

Note: The formal seed supply in India goes through three phases. Breeder seed is first multiplied into foundation seed, which is further multiplied to get certified seed. Breeder seed is the purest form of seed held by the institution, which is used to develop a specific variety. Foundation seed is the progeny of breeder seed produced by recognised seed-producing agencies (both private and public). Certified seed is produced from foundation seed by registered seed growers and is the final class of seed that is grown in farmers' fields.

To estimate the scale of adoption, we collected and analysed seed officially published data for CGIAR mandate crops from multiple sources. These data capture four aspects of the seed supply chain: requirement, allocation, distribution and adoption of seeds, only within the formal seed system.

These datasets include: Seed rolling plan, breeder seed indent data, availability of certified seeds, seed distribution data, and crop survey reports.

Each dataset captures a particular stage of the variety's development trajectory through the formal seed chain and provides indirect but important evidence of varietal adoption by monitoring a variety's demand, multiplication, production, and distribution over time. Together, these data reflect adoption within public institutions and provide a comprehensive understanding of how crop improvement innovations move through the formal seed system, from planning and production stages to their eventual uptake by farmers.

Prior to data analysis, we consolidated the *CGIAR-related varieties* associated with crop improvement innovations from respective CGIAR centres and ICAR institutes. We then matched the identified varieties in each innovation with the listed ones in the respective datasets, and extracted and compiled information pertaining to the matched varieties, such as estimated area under cultivation, breeder seed demand, seed distribution, and seed availability.

We subsequently aggregated the information at the state level for each innovation. To assess the extent of an innovation's reach, we estimated the share of each innovation in the total allocation for the corresponding crop within each state. Depending on the dataset, we estimated the proportion of total cultivated area occupied by the varieties under a specific innovation, their share in breeder seed indent, seed distribution, or seed availability.

A detailed description of each dataset is provided in the sub-sections below:

(a) Seed Rolling Plan

The Seed Rolling Plan is a three-year planning document submitted to the Department of Agriculture and Farmers Welfare (DAC&FW), under the Ministry of Agriculture and Farmers' Welfare (MoA&FW), Government of India, by all state governments. It assesses the state-wise seed requirement of different crops/varieties for *kharif* and *rabi* seasons as per the prescribed seed rate, the area under crop/variety, and the seed replacement rate. For instance, the seed rolling plan for the financial year 2027-28 was prepared and submitted in early 2025. This provides the crop- and variety-wise seed requirement for the sowing of *kharif* 2028 and *rabi* 2028-29 crops, along with agency-wise seed production targets assigned in *kharif* 2027 and *rabi* 2027-28 to meet that requirement. The presence of a variety in the seed rolling plan may indicate that it is being cultivated by the farmers in that particular State.

For our analysis, we examined the seed rolling plan data for 2017-21 and 2024-25 to determine the reach of adoption of each crop improvement innovation. For instance, 28 IRRI-related rice varieties released after 2000 were identified as drought-tolerant varieties. These varieties were matched with the rice varieties listed in the Government of Bihar's seed rolling plan. Based on the estimated area under these varieties, the scale of adoption of drought-tolerant rice varieties in Bihar was estimated at 16 per cent in 2017-18, 18 per cent in 2018-19, 19 per cent in 2019-20, 19 per cent in 2020-21, and 31 per cent in 2024-25.

Although the seed rolling plan provides variety-wise area estimates, there is ambiguity regarding how these are derived. The state governments did not clearly document the methodology used for estimating the area under each variety. Moreover, since the data are projected in advance, they may not accurately reflect actual ground-level adoption. Given these limitations, we found the inferences drawn from the Seed Rolling Plan data to be unusable for the current exercise.

(b) Breeder Seed Indent Data

The Breeder Seed Indent data are reported by the MoA&FW, Government of India, and were sourced for eight years, spanning from 2017-18 to 2024-25, from the Seed Net Portal[9]. Breeder seed indent is the demand placed on DAC&FW, Government of India, by state agricultural departments and institutions such as the National Seed Association of India (NSAI), Indian Farmers Fertiliser Cooperative Limited (IFFCO), and Krishak Bharati Cooperative Limited (KRIBHCO), among others, within the formal public seed system for a particular variety. The data provides the indents for varieties across different

[9] The SeedNet India Portal is a centralised digital platform maintained by the Department of Agriculture and Farmers Welfare, Government of India, for collecting, managing, and disseminating information related to seed production, distribution, certification, and variety development within the formal seed sector. Website link: https://seednet.gov.in. Since the introduction of the SATHI Portal (https://seedtrace.gov.in) in 2023, many of the functions and datasets previously managed through the SeedNet India Portal have been migrated to the new platform.

crops, including the quantity of breeder seed required to produce an estimated quantity of certified seed that each state expects to use in the successive cropping season. The presence of a variety in breeder seed indent indicates that it is being actively multiplied and disseminated through formal channels, and serves as evidence that the variety has been adopted on the ground.

For example, since 2000, more than 50 biofortified wheat varieties developed using CIMMYT germplasm have been released for North India. To assess their adoption, we matched these varieties with the varieties appearing in breeder seed indent data from 2017-18 onwards. In Bihar, the combined share of the identified biofortified wheat varieties increased from 0.96 per cent in 2018-19 to 30 per cent in 2023-24. In other words, nearly one-third of the wheat breeder seed allocated to Bihar in 2023-24 comprised biofortified CGIAR-related biofortified wheat varieties.

However, these data have certain limitations in capturing ground-level adoption.

1. Share of private sector: The relative contribution of public and private sectors varies across crop seed systems. For instance, the share of the public sector is higher in rice, whereas the private sector contributes significantly to the maize seed systems. The breeder seed indent data does not capture the varieties across crops whose seeds are produced, multiplied and distributed as truthfully labelled seeds by the private sector.
2. Absence of State-level data: Breeder seed indents from institutions, such as NSAI, IFFCO, KRIBHCO, among others, represent the aggregated indents received across all states. The data does not report separate indents from each state.
3. Mismatch in indent and production: Breeder seed reaches farmers through multiple stages of multiplication, during which non-lifting, overestimation, and attrition frequently occur, causing a mismatch between the breeder seed indent and actual breeder seed production of the concerned variety. Seed sources exist outside the formal seed supply channels as well, including farm-saved seeds, truthfully labelled seeds, and seeds from licensed varieties, which are not captured in breeder seed indent data.

(c) Availability of Certified Seeds

Certified seeds are produced from foundation seeds and undergo official field inspections and testing. This is the last stage of seed production and is sold to farmers for cultivation.

We retrieved the availability of certified seeds of different varieties (in quintals) for *kharif* 2025 from the State Agricultural Department's 'Contingency Plan 2025' report. All state governments publish this report, which also includes mitigation plans for weather irregularities and recommendations for alternative crop planning, water management practices, etc. It documents the quantity of certified seeds available to farmers for rice, maize, pigeonpea, groundnut, sorghum, and pearl millet in the state.

For instance, the latest Odisha Agricultural Department's 'Contingency Plan 2025' reported that submergence-tolerant rice varieties (*BINA Dhan 11, CR Dhan 801, CR Dhan 802, Swarna Sub-1, CR Dhan 1009 Sub-1, Varsha Dhan*) constituted 9.5 per cent of the total available certified rice seeds for the *kharif* season 2025.

A limitation of this dataset is that it reports the availability of certified seeds, not their actual distribution. Thus, the quantity available can only serve as a proxy for estimating seed distribution, which may not accurately reflect the volume of seeds reaching farmers.

(d) Seed Distribution Data

Seed distribution data captures the actual volume of certified seeds distributed to farmers through the public sector channels such as State Seed Corporations, State Agricultural Departments, etc. Unlike the

breeder seed indent and the seed rolling plan, the seed distribution data depicts the actual quantity of seeds distributed.

In India, seeds are distributed through several channels, such as departmental outlets at the block and village level, cooperatives, outlets of seed corporations, and private dealers, among others. The state governments are primarily responsible for the production and distribution of quality/certified seeds through State Seed Corporations, Departmental Agricultural Farms, Cooperatives, etc. For instance, the Odisha Agricultural Department documented the variety-wise quantity of seeds distributed in the state. The Activity Report of 2015 documented the variety-wise quantity of seeds distributed in the state during *kharif* 2014 and *rabi* 2014-15 for paddy, wheat and maize. For example, 13207 quintals of *Sahbhagi Dhan* were distributed, accounting for 2.2 per cent of the total rice seeds distributed in the state during the period.

Though the seed distribution data are reliable, there are some discrepancies between the quantity of seeds distributed and the actual quantity sown in the field. Moreover, this data only captures the seeds distributed through the public sector channels. The absence of district-level distribution data of crop varieties also limits a comprehensive understanding of seed distribution in a specific area.

(e) Crop Survey Reports

ICAR conducts and coordinates several agricultural surveys carried out by AICRP, SAUs and state agricultural departments. This is a large-scale survey that aims to identify the widely adopted varieties in a particular region. The survey also collects a range of other information on various aspects of crop cultivation, such as climatic conditions, varietal profile, consumption patterns, inputs and their availability, biotic and abiotic challenges, area under cultivation, and more.

For instance, for rice, Production Oriented Survey (POS) is conducted every year by ICAR-Indian Institute of Rice Research (IIRR) across major rice-growing states (the number and set of states vary each year). The survey adopted an eyeball method (visual field observation of crops at specific growth stages) and a questionnaire survey with the farmers. Additionally, the district and state agricultural departments provided district-specific data, like total area under rice, area under high-yielding varieties (HYVs), area under hybrids, area under basmati, seed replacement rates, etc. We referred to the publicly available POS reports, 2011 and 2017-2023, to analyse the evidence of adoption.

For evidence of adoption, we collected the total area under specific varieties (wherever available). For instance, according to the POS report (2019), in West Bengal, *Swarna Sub-1* was cultivated on 40,766 ha in Jalpaiguri, which roughly constituted 0.32 per cent of the total area under rice in that district.

1.1.2 Digital Advisory Tools

Digital advisory tools include new or improved digital tools, services, platforms, and data-driven approaches that address challenges in crop production and farm management. These tools deliver a range of services, including field-specific advisory information on crop and nutrient management, insect pest and disease diagnostics, details of inputs, and feed solutions, and real-time climate- and weather-based advisories disseminated to farmers in the form of alerts and notifications.

We shortlisted digital advisory tools using app download statistics, published reports and evaluation briefs on the usage of the apps and other digital tools at scale. For instance, the downloads of Plantix exceed ten million in India (CGIAR, n.d.; ICRISAT, 2022).

The exact adoption of the tools is difficult to capture online and can only be measured through their usage and app download statistics.

1.1.3 Machinery and Agronomic Practices

Machinery and Agronomic Practices include agricultural machinery and equipment designed to perform specific farming operations, alongside agronomic practices that improve crop yield, maintain soil health, and promote environmentally sustainable agricultural systems.

These practices have been integrated with machinery and introduced to farmers as a bundled package. For instance, crop residue management is an established post-harvest practice; however, its integration with zero tillage (a technique that involves no-tillage of soil before sowing) with machines like Happy Seeders could enhance the practice. This bundled approach demonstrates that the incorporation of appropriate mechanisation into existing agronomic practices may yield greater benefits.

Within this innovation category, Laser Land Leveller and zero-tillage technologies were shortlisted based on evidence from the Agriculture Input Survey, India (2016-17), state and central government records, and peer-reviewed publications, including research articles and book chapters.

The following sub-section briefly describes the data derived from the Agriculture Input Survey.

(a) Agriculture Input Survey

The Agriculture Input Survey is a quinquennial follow-up to the Agricultural Census conducted by the DAC&FW, which provides state-wise data on the consumption and use of agricultural inputs across different categories of operational holdings. It captures information on ownership and use of agricultural machinery, fertilizers, seeds, pesticides, livestock, agricultural credits, among others. The most recent data available are for the year 2016-17.

To assess the reach of the CGIAR-related mechanisation innovations, we consolidated the total number of specific machines in each state from Agricultural Input Survey data. For instance, the estimated number of Happy Seeders used was 2377 in Bihar, 40601 in Haryana, 30131 in Punjab, 4588 in Uttar Pradesh and 2588 in Odisha in 2017. Similarly, for laser land levellers and other machines, this data provides an overall picture.

Since the available survey data were old, more recent information (2024) presented by the concerned ministry in the Parliament of India[10] was also utilised. These data provided official estimates of the deployment of different agricultural machinery and equipment under various government schemes, thereby offering updated insights into the dissemination and adoption of mechanisation technologies. In particular, the data reported the number of Happy Seeders and Super Seeders distributed between 2018-19 and 2024-25. It provides a recent indication of the adoption and spread of these machines across North India.

1.2 Peer-Reviewed Publications

In addition to survey and non-survey data sources, peer-reviewed publications are the second source used to estimate the scale of adoption. These publications include articles, book chapters, research papers and academic dissertations published in indexed journals and volumes. We identified them using the following approaches: keyword searches centred on specific innovations, and review of scholarly publications by CGIAR researchers, NARES scientists, and independent researchers. We referred to publications on field surveys, adoption studies and data to derive adoption figures. However, we excluded field trial data and experimental study results to understand the real adoption at the ground level.

[10] Government of India, Ministry of Environment, Forest and Climate Change. (2024). Unstarred question no. 1974: [how effective GRAP has been considering the present pollution levels in Delhi]. Rajya Sabha. Answered on 12 December 2024.

For example, Dar *et al.* (2020) reported that 60 per cent and 64 per cent of sampled households adopted the *Sahbhagi Dhan* rice variety (Drought Tolerant Rice) in Odisha and West Bengal, respectively. Raghu *et. al.* (2022) estimated that 8.9 per cent of 4744 sampled households across West Bengal, Odisha and Assam adopted the *Swarna Sub-1* rice variety. Similarly, for machinery and agronomic practices, Jat et al. (2004) reported that 1000 farmers adopted the Laser Land Leveller (LLL) in India, covering 10000 acres across western Uttar Pradesh and Haryana. More recently, Surendran-Padmaja *et. al.* (2025) reported that around 72 per cent of farmers in Punjab (out of 1021) and 74 per cent in western Uttar Pradesh (out of 640) have used laser land levelling at least once.

1.3 Grey Literature

Grey literature forms the third source to estimate the scale of adoption. It refers to a wide range of materials produced by CGIAR centres that are not subject to independent editorial review but contain detailed and up-to-date evidence of relevance, dissemination and adoption of innovations. These include annual reports, datasets, posters, pamphlets, policy briefs, brochures, handbooks, newsletter bulletins, and study reports.

Key sources used include CGIAR's open-access platforms such as CGSpace[11], CGIAR centre-specific repositories[12] and official institutional websites, CGIAR Results Dashboard (2017-2024), CGIAR Monitoring, Evaluation, and Learning (MEL) platform, and evaluation reports from the CGIAR-Independent Advisory and Evaluation Service (IAES). We also gathered information on announcements of CGIAR-related projects, programmes, and interventions from social media platforms such as X, LinkedIn, Facebook, and YouTube of CGIAR and its respective centres. We collected internal reports directly from CGIAR centres during visits and expert consultations which were not publicly available.

Documents published or relevant since the year 2000 were compiled for this exercise. We systematically organised the collected materials by year of publication and thematic subject areas, and further categorised them into peer-reviewed publications and grey literature. This also helped us form a centre-specific repository and a foundational archive for the subsequent tasks of the stocktake process.

For instance, a CIMMYT-CCAFS (2014) report documents the adoption of zero-tillage practice across Climate-Smart Villages in Nilokheri, Gharaunda, Indri, and Nissing in Haryana, covering a total of 898 households and 2492 ha. Grey literature sources also provide evidence on digital innovations; CGIAR (n.d.) reported that the Plantix application was downloaded by more than 7 million users, with 80 per cent of users from India. In a policy context, WorldFish (2022) reports that through the "*Inclusion of Small Fish in Supplementary Nutrition Programme (SNP) in Odisha and Assam*" policy, around 8000 packets of dried fish powder were provided to 1208 children aged 3-6 years, 2,820 packets to 470 pregnant/lactating women, and 1974 packets to 329 adolescent girls in Odisha.

1.4 Interview with Experts

Expert interviews form the fourth and final source used to gauge the scale of adoption. These were critical sources of evidence, given the limitations of official statistics in capturing ground-level adoption. Experts were identified through two approaches: authors of relevant publications (peer-reviewed and grey literature) for specific innovations and snowball referral during ICAR/NARES institutes and CGIAR institutes visits, whereby scientists recommended additional informants with specialist knowledge in each innovation or region. The key objectives were to validate the listed innovations in the target states, solicit comments on the scale of adoption (at the regional and state levels), and collect relevant data. During the stocktake process, we prepared a database of current and former personnel in leadership

[11] CGSpace is a repository and a collection of CGIAR and partner research reports and outputs.

[12] All CGIAR centres have their own repositories. This is CIMMYT's repository: https://repository.cimmyt.org/home

positions from CGIAR, ICAR-NARES, and central and state agricultural departments. Thereafter, we scheduled visits and in-depth interviews with senior scientists, plant breeders, seed officials, and senior officials. We also conducted a stakeholder consultation to review and discuss the longlist of innovations, which saw the participation of personnel from the above-mentioned institutes.

At the national level, we conducted interviews with scientists and researchers from CGIAR centres and ICAR-NARES institutes. These experts provided information on the scale and adoption of innovation dissemination, as well as CGIAR attribution. For instance, CG representatives provided data on dissemination and information not publicly available. Similarly, the scientists at ICAR-Central Rice Research Institute (CRRI) provided information on the major varieties grown in the state and the estimated adoption in terms of area. According to the director of CRRI, *Sahbhagi Dhan*, a drought-tolerant rice variety, has been adopted in around 31 per cent of the rice cultivated in the states where it has been released.

At the regional level, we conducted interviews with faculty and scientists from SAUs, extension workers from State Agriculture Departments and Krishi Vigyan Kendras (KVKs) personnel. These provided a grassroots perspective on local seed adoption, varietal performance, and diffusion constraints. For instance, the scientists at Punjab Agricultural University (PAU) provided the adoption estimates of specific wheat varieties in Punjab and Haryana. *PBW 826*, a disease-resistant wheat variety, was reportedly cultivated on approximately 10.4 lakh ha in Punjab during 2024-25, accounting for nearly 40 per cent of total wheat area.

Altogether, 36 scientists were interviewed from the following institutes: ICAR, New Delhi; ICAR-National Bureau of Plant Genetic Resources (NBPGR), New Delhi; ICAR-Indian Agricultural Research Institute (IARI), New Delhi; ICAR-Central Rice Research Institute (CRRI), Odisha; ICAR-Central Institute for Women in Agriculture (CIWA), Odisha; ICAR- Indian Institute of Maize Research (IIMR), New Delhi; Punjab Agricultural University (PAU), Punjab; and Odisha University of Agriculture and Technology (OUAT), Odisha.

These expert interviews also serve as cross-verification of the existing attributions made based on survey and non-survey data sources, peer-reviewed publications and grey literature. Following the comments received from expert meetings, we systematically reviewed all innovations, identified gaps, and documented them in a standardised format. These expert assessments are, by their nature, mostly informed personal views, and the level of accuracy was interpreted accordingly.

The four evidence sources (officially published survey and non-survey data sources, peer-reviewed publications, grey literature, and interviews with experts), used to assess the scale of adoption, provided a comprehensive understanding of the reach, scale, area coverage, regional spread, and prevalence of CGIAR-related innovations. While survey and non-survey data sources offered a more quantifiable assessment of the trajectory and extent of these CGIAR-related innovations, peer-reviewed literature and grey literature provided evidence from field-level studies, evaluations, and other documented experiences. Expert interviews further complemented these sources by providing contextual insights and helping address gaps in the available documentary evidence.

Accordingly, the scale of adoption of each innovation was assessed by triangulating evidence across all four sources. We argue that these sources are complementary and that their combined use provides a more robust and reasonably comprehensive basis for assessing the significance and scale of adoption of CGIAR-related innovations. This approach provided a basis for shortlisting innovations for further study.

The following section discusses the second criterion used, contextual significance.

2. Contextual Significance

Contextual significance refers to the importance of an innovation within a particular agro-ecological, regional, or socio-economic context, as well as its historical significance during the period under consideration, irrespective of its current scale of adoption. CGIAR centres, in collaboration with NARES partners, have developed and disseminated several innovations that are significant in these contexts. These innovations can be broadly classified into three categories: (i) those developed to address specific agro-ecological conditions; (ii) those designed to address the specific needs of particular population groups; and (iii) those that achieved substantial adoption and impact during some period between 2000 and 2023 but whose adoption has subsequently declined due to factors such as the introduction of new technologies, improved varieties, changes in farming conditions, or shifts in farmers' preferences and production practices.

Thus, unlike scale of adoption, this criterion allowed us to recognise and include innovations that were significant within particular regional, agro-ecological, or socio-economic contexts, and were historically salient, despite declining adoption.

2.1 Agro-ecological Stress

Innovations in this category are developed and deployed to address specific biophysical constraints, particularly abiotic stresses such as salinity, drought, and flooding. The nature and severity of these stresses vary across agro-ecological zones, influencing crop choices, cropping patterns, and agricultural practices. Consequently, the relevance and adoption of such innovations are often geographically concentrated in areas where the corresponding stresses are prevalent.

For instance, salt-tolerant rice varieties are particularly relevant in coastal areas of Odisha, where soil salinity poses a major constraint to rice cultivation. The *Saltol* quantitative trait locus (QTL), which confers salinity tolerance during the seedling stage, was introduced into several Indian rice varieties, including *CR Dhan 405*. These varieties are particularly relevant to areas affected by salinity and illustrate how the agro-ecological suitability of an innovation can be an important consideration, irrespective of its wider geographical spread.

2.2 Innovations Addressing the Needs of Population Groups

Innovations under this category are not necessarily confined to specific agro-ecological regions but are designed to address the particular needs of population groups facing nutritional vulnerabilities or other forms of socio-economic disadvantage, especially women and children. Biofortified crop varieties enriched with nutrients, such as protein, zinc, iron, and vitamin A, have been developed and disseminated across different parts of India to address nutritional deficiencies. For instance, in some parts of Odisha, biofortified sweet potato varieties are being cultivated. Similarly, gender-inclusive seed production programmes in Odisha, although limited in their geographical reach, have considerable importance in terms of their relevance to and potential benefits for participating women.

2.3 Historically Time-Specific Innovations

This category includes innovations that achieved substantial adoption and impact at particular points during the period 2000-2023 but have subsequently become less prominent. Their declining adoption may be associated with the introduction of improved varieties, changes in farming systems and cropping patterns, or the emergence of alternative technologies and practices, including digital tools. Despite their declining prevalence, these innovations are considered for inclusion because of their historical contribution to agricultural development during the period under consideration. Evidence of their past adoption and impact is drawn primarily from published reports, evaluation studies, and expert consultations. Tropical Potato Seed (TPS) technology, for instance, involves the development of hybrid

seed from a cross between two tetraploid potato plants. In Tripura, TPS technology was used to produce hybrid varieties (Baruah and Ghosh, 2024).

Conclusion

The shortlisting exercise followed a two-step, criteria-based approach to systematically narrow down the longlist of CGIAR-related innovations to a final shortlist. The first criterion, scale of adoption, focused on identifying innovations with measurable adoption and assessing their geographical reach, extent, and prevalence. We drew evidence from four complementary sources: survey and non-survey data, peer-reviewed literature, grey literature, and expert interviews. These sources enabled the triangulation of evidence, providing a more comprehensive and robust assessment of the scale and reach of each innovation. The second criterion, contextual significance, sought to identify innovations that may not have achieved widespread adoption but were nevertheless important within specific regional, agro-ecological, or socio-economic contexts, and those that had achieved significant adoption in an earlier period but had subsequently declined in prominence.

Together, these two criteria ensured that the shortlisting process considered not only the extent of adoption but also the significance of innovations across specific regional, agro-ecological, and socio-economic contexts and over time. Through this systematic, evidence-based process, we identified 29 innovations for further study to assess their reach and extent of adoption across six states in North India. The category-wise bifurcation and count of the shortlisted innovations are provided in Table 2.

Table 2. Number of Shortlisted Innovations, by Category

S. No.	Innovation Category	Count
1	Crop Improvement	17
2	Seed Production Technique	1
3	Digital Advisory Tools	2
4	Machinery and Agronomic Practices	2
5	Policy/Institution Building	7
	Total	**29**

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Abbreviations

BGRI	Borlaug Global Rust Initiative
CCAFS	Climate Change, Agriculture and Food Security
CIMMYT	International Maize and Wheat Improvement Center
CIP	International Potato Center
CIWA	Central Institute for Women in Agriculture
CRRI	Central Rice Research Institute
DAC&FW	Department of Agriculture and Farmers Welfare
DUS	Distinctness, Uniformity, and Stability
FAO	Food and Agriculture Organisation
FAS	Foundation for Agrarian Studies
MoA&FW	Ministry of Agriculture and Farmers' Welfare
HYV	High-Yielding Varieties
IAES	Independent Advisory and Evaluation Service
IARI	Indian Agricultural Research Institute
ICAR	Indian Council of Agricultural Research
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFFCO	Indian Farmers Fertiliser Cooperative Limited
IIMR	Indian Institute of Maize Research
IRRI	International Rice Research Institute
KRIBHCO	Krishak Bharati Cooperative Limited
KVK	Krishi Vigyan Kendras
LLL	Laser Land Leveller
MEL	Monitoring, Evaluation, and Learning
NAAS	National Academy of Agricultural Sciences
NARES	National Agricultural Research and Education System
NBPGR	National Bureau of Plant Genetic Resources
NSAI	National Seed Association of India
OUAT	Odisha University of Agriculture and Technology
PAU	Punjab Agricultural University
POS	Production Oriented Survey
SAU	State Agricultural University
SPIA	Standing Panel on Impact Assessment
TL	Truthfully labelled
TPS	True Potato Seed

