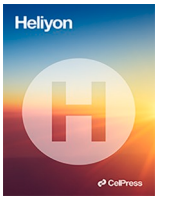
Heliyon 10 (2024) e25110

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon



Research article

Commercial rice seed production and distribution in Indonesia

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ARTICLE INFO

Keywords:
Seed market
Seed system
Farmer knowledge
Capacity production
Food security

ABSTRACT

Rice is a major source of carbohydrates worldwide. As the global population increases, its annual consumption also increases. Using the high-quality seeds, rice productivity can be enhanced. However, increasing seed access and availability is a major concern. This study aimed to map rice seed production and distribution in Indonesia and determine the challenges. It was carried out in 10 provinces in Indonesia from May to December 2022. These provinces are the centers of rice production in Indonesia. Primary (survey, focus group discussion, and key informant interviews) and secondary data collection methods were used. Results showed that producer capacity and production are closely related to institutional type, where legal institutions are more powerful in terms of knowledge, competency, and market. Almost all seed producers produced the extension seed class. The specific locations, agroecology, and rice consumer preferences affected the variety produced. Seeds were produced with good management, as shown by the adequacy of information types and sources. Furthermore, a free market is a sustainable strategy for selling seeds. The main challenges for seed rice production and distribution in Indonesia include encouraging appropriate resource management and planning (human, infrastructure, and financial) in the seed sector and increasing the linkage of seed stakeholders, such as research institutions, seed certification agencies, producers, and the government. A rapid and appropriate response to these challenges can increase seed availability for producers.

1. Introduction

Rice (*Oryza sativa* L.) is an important source of carbohydrates worldwide [1,2], and its consumption increases as the population grows [3,4]. Owing to population increase, more rice needs to be produced to meet the rising demand. The rice productivity in Indonesia must be increased to preserve the nationwide supply; however, the productivity between rice production on Java Island and that on other islands differs. A total of 468 regency/city rice production sites and 176 regencies/cities produce more than 5 ton ha^{-1} of rice, whereas other sites produce less than 5 ton ha^{-1} [5]. The national rice productivity in Indonesia is approximately 5.2 ton ha^{-1} [6], and the rice productivity outside Java, Kalimantan, Sulawesi, and other islands is lower than the national productivity. Using low-quality seeds may be the reason for low rice productivity in Indonesia [7,8]. Low seed quality can reduce crop production [9]. In the last 5 years, the rate of using quality seeds at the farm level has been approximately 60 % [10].

Seeds are a crucial factor affecting plant production [11,12] and are a medium for technology dissemination [13]. New varieties

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https://doi.org/10.1016/j.heliyon.2024.e25110
Received 24 March 2023; Received in revised form 4 December 2023; Accepted 20 January 2024
Available online 26 January 2024

have been a major contributor to global crop production increase over the last 25 years [14]. New crop varieties have been developed to provide farmers with the seeds of cultivars that are adaptable to specific environmental or management conditions to achieve the best yield and quality [15]. Seed is an important input for crop production that offered a bridge the plant genetic potential from breeder. The prompt delivery of seeds is an essential aspect of agricultural success, having a direct impact on seed viability and, as a result, crop yield [16].

Seed availability is crucial to address the sustainability of supply and food security [17]. Seed access is an important factor in crop production [18] and is supported by more complex production factors such as fertilizers and pesticides [19]. Seed producers and distributors make important contributions to seed systems. They play a key role in meeting seed demand and greatly contribute to increasing the seed supply through seed production, diversification of varieties in large quantities, and seed delivery to farmers [20]. According to the Republic of Indonesia, Law No. 22, 2019 "Sustainable Agriculture System," this country has a formal seed system regulated by The Directorate General of Crop Seed, Ministry of Agriculture. This system has four subsystems: research and development for new varieties and technology, seed production and distribution, seed certification and quality control, and supporting subsystems (financial, infrastructure, human resources, institutional, and government regulation).

The seed certification program recognizes four classes of seed in Indonesia: breeder, foundation, stock, and extension seeds. The breeder, foundation, and stock seed classes are the source seeds in Indonesia, whereas the extension seed class includes the commercial seeds. Indonesia has a wide agroecology; thereby requiring a specific variety for cultivation. However, currently, not all high-yielding varieties released can be adopted by seed producers or farmers. The availability of source seeds that were spread could not be determined. Furthermore, seed production and quality control institutions are not optimal, and not all farmers use high-quality or certified seeds. Recently, some seed producers have not accessed source seeds. Hence, this study aimed to map the production and distribution of commercial rice seeds in Indonesia and identify their challenges.

2. Materials and methods

2.1. Site study

The research was conducted from May to December 2022 in across various locations strategically chosen to represent clusters characterized by differing levels of agricultural advancement. These clusters were determined based on key indicators encompassing planting area, harvest area, seed production planting area, seed needs, and seed production data from the year 2019. Based on the results of the regional cluster (Fig. 1), 10 provinces were identified: West Java, Central Java, and East Java (Cluster 1); Lampung, South Sulawesi, and South Sumatera (Cluster 2); and West Sumatra, Yogyakarta, Banten, and West Nusa Tenggara (Cluster 3).

2.2. Data collection

This study used primary and secondary data. Primary data were collected through surveys, focus group discussions (FGD), and key informant interviews (KII), whereas secondary data were collected from the Ministry of Agriculture of the Republic of Indonesia, Provincial/District/City Agricultural Offices, Institute for Agricultural Technology Studies (IATS), Indonesian Center for Rice Research (ICRR), and seed certification agencies (SCAs).

2.2.1. Pretested questionnaires

The seed producers and distributors were surveyed using a pretested questionnaire that was designed to capture information related to the producer and distributor profiles, seed sources and varieties, production capacity, seed prices, adoption of new and improved varieties, market types, and challenges in seed production.

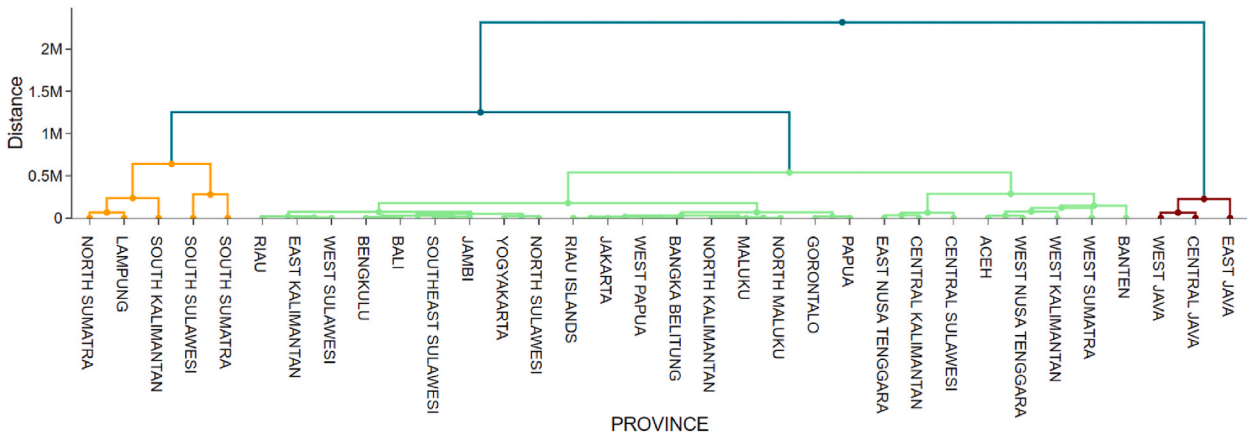

Fig. 1. Cluster determination of regions based on agricultural progress.

2.2.2. Focus group discussion and respondent

FGDs were conducted in research provinces involving farmers, seed producers and traders, Provincial/District/City Agricultural Offices, IATS, ICRR, SCA, and farmer groups. The selection of respondents and the number of respondents interviewed in the survey were based on the results of FGD conducted in each province in the research area. Table 1 summarizes the details of the number and area of respondents interviewed, and Fig. 2 shows a map of the survey area.

2.2.3. Key informant interviews for in-depth interviews

In-depth interviews were unstructured interviews designed to gather information about the experience, interpretations, understanding, and reactions to a particular phenomenon in seed system stakeholders in Indonesia. It is usually open ended, inviting stakeholders to discuss seed systems in Indonesia. Stakeholders included research institutions, seed producers and distributors, SCAs, and seed regulation officers. Table 1 summarizes the details of KII for the in-depth interviews.

2.3. Data analysis

Data were processed and analyzed using descriptive and correlational analyses. We used descriptive analysis to describe the distribution of each research variable, including producer characteristics, variety diversity, new variety adoption, access to seed sources, marketing type, and seed production planning. The relationships between variables were defined through correlation analysis using SAS OnDemand for Academics (https://www.sas.com/en_id/software/on-demand-for-academics.html).

3. Results and discussions

3.1. Institutional, capacity, and production

In several rice production centers in Indonesia, a survey was conducted on 33 seed producers/distributors with different numbers of producers/distributors (Table 2). The business entities of the seed producers/distributors were mostly individuals (48.5 %), limited companies (39.4 %), farmer groups (6.1 %), and government agencies (6.1 %). A high percentage of individual seed producers indicate that the seed business process runs well at the farm level. Production capacity owned by producers based on production facilities in the form of owned land ranges from 6 to 8000 tons/year. Production capacity positively correlated with production realization (data not shown). The production realization of each producer highly depends on market control and capital, ranging from 4 to 7000 tons/year.

The capacity of seed producers can be seen in terms of technical, organizational, and management capacities [21]. One of the most important factors affecting production capacity is the size of the production land. Land size can influence seed production and is closely related to a person's innovative nature [22]. Producers with large landholdings are more responsive to innovations. Responsiveness to innovation leads to increased capacity and production. The distribution of the capacity and production of rice seed producers was divided into five scales (Table 3). Rice seed producers with a capacity of >250 tons/year accounted for 56 % and production of >250 tons/year accounted for 44 %. We also found seed producers with a production of <10 tons/year, approximately 18 % of the total producers.

The rice seed producers in Indonesia produced stock seed and extension seed classes (Table 3). They mostly produced the stock seed class (65 %), but approximately 12 % of them produced two seed classes simultaneously. Extension seeds were produced from the stock seed class, and according to the seed system regulation, rice production for consumption was recommended for use in the extension seed class [23]. Unusually, farmers have recently used the higher seed class for rice production for consumption, likely the stock seed class. This phenomenon has been reported in Ref. [24], where the notation that a higher seed class produces a higher grain yield, as was the commodity believed by farmers and other stakeholders, was incorrect.

3.2. Variety diversity and modern variety adoption

The varieties produced by producers in each region are very diverse. A total of 33 varieties were produced (Table 4), with various adaptation types, including irrigation, upland, and swamp (Table 5). Some varieties produced by >50 % of the seed producers were Inpari 32 (87.5 %), Ciherang (65.6 %), Inpari 42 (56.3 %), and Mekongga (59.4 %). Inpari 32 and Inpari 42 are two irrigated rice

Table 1
Details of key informant interviews for the in-depth interview.

No	Key Informant Interview	Issues
1	Research Institution	a. Strategy to develop a new variety b. Strategy to maintain the breeder seed
2	Seed producer and distributor	a. Source seed price b. Seed production planning c. Seed production facility
3	Seed certification agency	a. Human resource eligibility and capacity b. Seed testing infrastructure and quality
4	Seed regulation officer	a. Seed class b. Seed subsidies

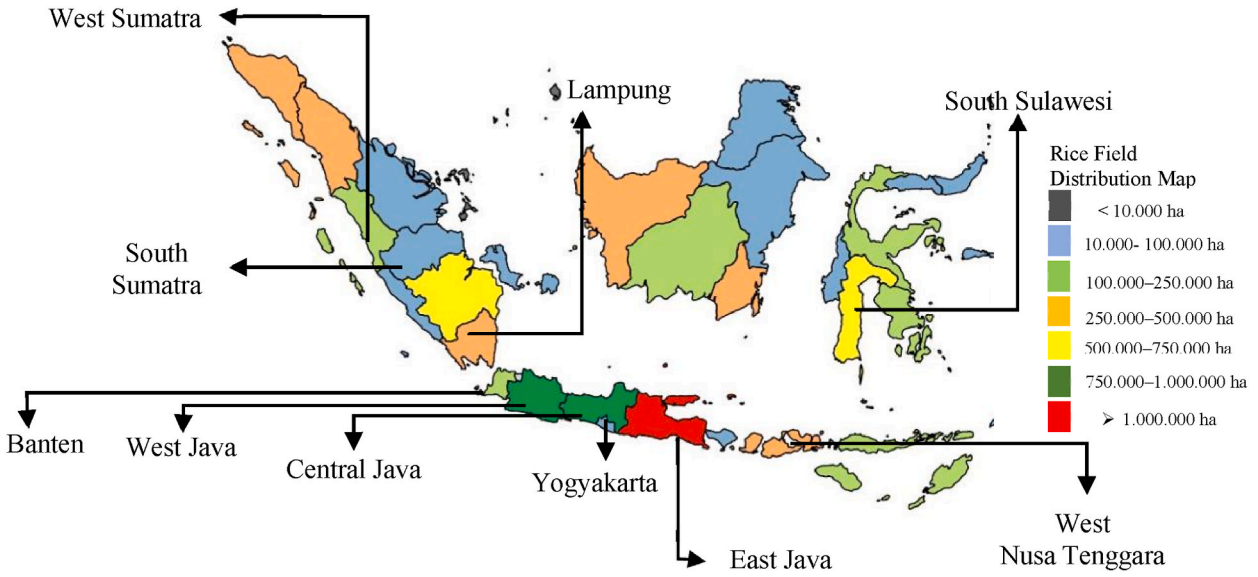

Fig. 2. Distribution of research locations.

Table 2
Seed producer respondents.

Location	No.	Company name	Business form	Production capacity (ton)	Real production (ton)
Lampung	1	PT. Andall Hasa Prima	Limited Companies	500	500
	2	CV Yubim Mulya Abadi	Limited Companies	1000	600
	3	CV. Benthany Mulia Indah	Limited Companies	8000	7000
Banten	4	Sinar Bahagia	farmer groups	300	240
	5	Unnamed	individuals	250	175
	6	Unnamed	individuals	7	5
	7	Unnamed	individuals	6	4
	8	Unnamed	individuals	100	70
Yogyakarta	9	(PB Usaha Tani Group)	Limited Companies	300	250
Central Java	10	PP Kerja	Limited Companies	5000	4000
	11	PB. Prima Tani	individuals	200	150
	12	Unnamed	individuals	6	4
	13	Kesambisari	individuals	10	8
West Java	14	Unnamed	individuals	300	200
	15	CV. Fiona Benih Mandiri	Limited Companies	3000	2000
East Java	16	UD. Sri Ayu	Limited Companies	500	300
	17	UD. Himalaya	Limited Companies	100	70
	18	PB. Tani Bahagia	Limited Companies	300	280
South	19	PT. Harmoni Mega	Limited Companies	1000	500
Sulawesi	20	Instalasi Kebun Benih Maros	Government	30	20
	21	PT. Harmoni Mega	Limited Companies	1000	600
West Nusa Tenggara	22	Unnamed	individuals	400	400
	23	Unnamed	individuals	500	300
	24	Unnamed	individuals	450	300
West Sumatra	25	Institute for Agricultural Technology Studies (IATS)	Government	100	70
South Sumatra	26	Unnamed	individuals	300	100
	27	Swak Teriti	individuals	7	5
	28	Unnamed	individuals	1000	500
	29	Tunas Baru	farmer groups	60	40
	30	Unnamed	Individuals	70	40
	31	CV Dua Putra	Limited Companies	100	30
	32	PT. SHS Sumsel	Limited Companies	1000	600
	33	Unnamed	Individuals	20	0

*Unnamed: Individual registered as the seed producers without company.

varieties released less than 10 years ago, while Mekongga and Ciherang are older varieties released more than 20 years ago (Table 5).

Rice farmers' satisfaction with new superior varieties can be influenced by factors such as productivity, rice flavor, plant age, lodging resistance, pest and disease resistance, milled dry grain price, seed price, availability of seeds in the market, and crop

Table 3
Capacity, production, and seed classes produced.

Production (ton)	Distribution (%)	
	Capacity	Real
<10	12.5	18.7
10–100	15.6	18.8
100–250	15.6	18.7
250–500	31.3	21.9
>500	25	21.9
Seed classes	%	
SS	65.6	
ES	21.9	
ES–SS	12.5	

Notes: SS, stock seed; ES, extension seed.

Table 4
Type and scale of rice seed varieties produced.

No.	Varieties	N	n	%	No.	Varieties	N	n	%
1	Inpari 4	33	3	9.4	18	Cilamaya Muncul	33	4	12.5
2	Inpari 7		1	3.1	19	Ciherang		21	65.6
3	Inpari 16		1	3.1	20	Mekongga		19	59.4
4	Inpari 19		1	3.1	21	Situbagendit		5	15.6
5	Inpari 30		4	12.5	22	Sintanur		2	6.3
6	Inpari 32		28	87.5	23	Sunggal		3	9.4
7	Inpari 33		5	15.6	24	Gilirang		1	3.1
8	Inpari 39		1	3.1	25	Cakrabuana		4	12.5
9	Inpari 42		18	56.3	26	Bromo		1	3.1
10	Inpari 43		3	9.4	27	Padjajaran		2	6.3
11	Inpari 45		2	6.3	28	Way Apo Buru		2	6.3
12	Inpari 46 (Nutrizinc)		1	3.1	29	Sidenuk		1	3.1
13	Inpara 2		1	3.1	30	Cigeulis		3	9.4
14	Inpago 8		1	3.1	31	Sikumpai		1	3.1
15	IR 64		10	31.3	32	PB 42		1	3.1
16	Ciliwung		8	25.0	33	IPB 3S		1	3.1
17	Bestari		1	3.1					

Notes: N, total number of seed producers; n, number of producers that produced a specific variety.

marketing [25]. Varieties that are adaptive and have high yield potential and quality according to farmer and consumer preferences are easy for farmers to adopt [26]. Their preferences for rice quality differ according to the characteristics of each region [27]; however, in Indonesia, most farmers prefer the taste of fluffy rice [28]. The varieties Ciherang and Mekongga are maintained because of their superiority. Both varieties are characterized by resistance to pests and diseases, early maturity, and high productivity [29]; they are old varieties that remain popular in the community [30].

The varieties grown by farmers are largely determined by the agroecological conditions and taste preferences. Table 6 presents the number and types of varieties produced on each island and province. Approximately 23 varieties were produced by seed producers on Sumatra Island, 18 varieties on Java Island, and 10 varieties on Sulawesi Island. The number of varieties produced positively correlated with the production capacity and the actual production (data not shown). The varieties Inpari 32 and Inpari 42 are always available at all locations for seed producers. Mekongga and IR 64 are also available on all islands, but they are not available or produced in the Yogyakarta or South Sumatra provinces. The ubiquitousness of the Inpari 32 and Inpari 42 seeds may be explained by their high demand from farmers.

Owing to their superiority in several aspects, these two varieties are the most widely planted by farmers [31]. For example, Inpari 32 has a high production, long and full grain and rice shape, medium fluffy rice flavor, and resistance to leaf blight [27]. Inpari 42 has a resistance to lodging, thereby suitable for rice fields in Indonesia that are easily submerged; additionally, its leaves are higher than the panicle, thereby preventing bird pests before harvest [31].

Almost all seed producers can access information on new superior varieties obtained from government agencies, universities, social media, and fellow breeders (Table 7). Government agencies such as agricultural offices, ICRR, and IATS are the main sources of information for seed producers in addition to social media. Therefore, the government was the main source of seeds and information in the study area. The role of the government is indeed significant, given that it is the main source of access to seeds, new superior varieties, and information [32,33].

3.3. Source seed access

Government seed production has been developed to deliver as many seeds as possible to farmers [34]. Producer seed production is

Table 5
Adaptation, release, and breeding institution of rice varieties.

Novelty range	Variety	Type	Year released	Institution
New (<5 years; 2017–2022)	Inpari 45	Irrigation	2019	ICRR
	Inpari 46 (Nutrizinc)	Irrigation	2019	ICRR
	Padjajaran	Irrigation	2018	ICRR
	Cakrabuana	Irrigation	2018	ICRR
Quite New (5–10 years; 2012–2016)	Inpari 30	Irrigation	2012	ICRR
	Inpari 32	Irrigation	2013	ICRR
	Inpari 33	Irrigation	2013	ICRR
	Inpari 39	Irrigation	2015	ICRR
	Inpari 42	Irrigation	2016	ICRR
	Inpari 43	Irrigation	2016	ICRR
	IPB 3S	Irrigation	2012	IPBU
Quite Old (10–20 years; 2002–2011)	Inpari 4	Irrigation	2008	ICRR
	Inpari 7	Irrigation	2009	ICRR
	Inpari 16	Irrigation	2011	ICRR
	Inpari 19	Irrigation	2011	ICRR
	Inpara 2	Swamp	2009	ICRR
	Inpago 8	Upland	2011	ICRR
	Bestari	Irrigation	2008	NNEA
	Mekongga	Irrigation	2004	ICRR
	Situbagendit	Irrigation	2003	ICRR
	Sunggal	Irrigation	2002	ICRR
	Gilirang	Irrigation	2002	ICRR
	Way Apo Buru	Irrigation	2002	ICRR
	Cigeulis	Irrigation	2002	ICRR
	Sidenuk	Irrigation	2011	ICRR
Very Old (>20 years; <2002)	IR 64	Irrigation	1986	ICRR
	Ciliwung	Irrigation	1988	ICRR
	Cilamaya Muncul	Irrigation	1996	ICRR
	Ciherang	Irrigation	2000	ICRR
	Sintanur	Swamp	2001	ICRR
	Bromo	Irrigation	Unrecord	Community
	Sikumpai	Irrigation	Unrecord	Community
	PB 42	Irrigation	1980	ICRR

NNEA, National Nuclear Energy Agency; ICRR, Indonesian Center for Rice Research; IPBU, Institut Pertanian Bogor University.

Table 6
Availability of rice variety seed by island and province.

The Island (No. of Varieties)	Province	Varieties	
		Total	Type
Sumatra (23)	Lampung	15	Inpari 30, Inpari 32, Inpari 33, Inpari 39, Inpari 42, Inpari 46, Inpara 2, Inpago 8, IR 64, Ciliwung, Bestari, Cilamaya muncul, Ciherang, Mekongga, Situbagendit
	South Sumatra	8	Inpari 30, Inpari 32, Inpari 33, Inpari 42, Inpari 43, Ciliwung, Ciherang, Mekongga,
	West Sumatra	7	Junjuang, Banang Pulau, Batang Piaman, Anak Daro, Cisokan, PB 42, Inpari 13, Lampai Siranah
Java (18)	Banten	5	Inpari 32, Inpari 42, IR 64, Ciherang, Mekongga,
	West Java	8	Inpari 32, Inpari 42, IR 64, Cilamaya muncul, Ciherang, Mekongga, Sintanur, Sidenuk
	Central Java	10	Inpari 32, Inpari 33, Inpari 42, IR 64, Ciherang, Sunggal, Cakrabuana, Bromo, Padjajaran, Way Apo Buru
	Yogyakarta	7	Inpari 16, Inpari 32, Inpari 42, Inpari 43, Sintanur, Sunggal, Gilirang,
	East Java	14	Inpari 32, Inpari 42, Inpari 43, Inpari 45, IR 64, Ciherang, Mekongga, Situbagendit, Sunggal, Cakrabuana, Padjajaran, Way Apo Buru, IPB 3S
Sulawesi (10)	South Sulawesi	10	Inpari 4, Inpari 30, Inpari 32, Inpari 42, Ciliwung, Ciherang, Mekongga, Situbagendit, Cigeulis, Sikumpai

Numbers in brackets is a number of rice varieties in this island.

determined by the availability of source seeds, including quantity, price, and accessibility. Seeds are deemed accessible if the user can access quality seeds from both formal and informal sources. Quality seeds may be available in the community but not affordable by all, either because of supply side constraints when priced highly or demand-side barriers, such as when farmers lack purchasing power [35].

Source seeds are used to produce lower seed classes, and their affordability can be measured by the adequacy of quantity, ease of acquisition, and price [36]. Producers can easily access source seeds, as evidenced by 84 % of producers saying that the source seed quantity was sufficient and 88 % saying that such seed is easy to obtain (Fig. 3). The price of source seeds purchased by producers varied widely, from IDR 10,000/kg to 17,000/kg, but most producers (60 %) wanted the price to be no more than IDR 14,000/kg.

Table 7
Affordability and sources of information on new improved varieties.

New Variety Information	N	N	%
Access			
- Yes	33	32	97.0
-No		1	3.0
Sources			
- Agricultural Offices	33	14	26.4
- ICRR		16	30.2
- IATS		11	20.8
- Producers		1	1.9
- Social Media		10	18.9
- University		1	1.9

Notes: N, total number of seed producers; n, number of producers that produced a specific variety.

3.4. Seed production planning

Seed producers must understand the demand for seed production. Over- or underproduction can lead to serious financial consequences for seed producers. Hence, the fulfillment of seed demand information in seed production planning is crucial for them. For seed production planning, they should acquire information on planting area, planting season, seed demand (variety, quantity, location, and time) in previous and upcoming years, and government programs (Table 8). They can obtain this information from various sources, including personal searches, agricultural offices, agricultural shops, SCAs (i.e., Badan Pengawasan dan Sertifikasi Benih [Bureau of Seed Control and Certification]), and seed centers.

3.5. Seed market

Seed producers often lack access to profit- and value-added markets [37]. While producers are faced with accessibility to seed market information and infrastructure, seeds need to reach farmers at the right time, place, quantity, and price [38]. Producers sell their seeds in two market types: captive and free (Fig. 4). The captive market is carried out by producers as partners in providing seeds for government programs [39]. The free market is used by all producers to market the seeds produced, although at the same time, approximately 66 % of producers also engage in captive market. Producers do not use the captive market as their main marketing channel because the risk is very high. The risk pertains to the sustainability of market control, which is at risk of being lost, along with the dependence on government seed subsidy programs.

Marketing coverage greatly affects the level of production carried out; therefore, wide marketing coverage needs to be supported by bringing production centers closer to the location of demand. Most seed producers have a market that is relatively close to the main production centers, causing them to produce seeds in one production center (Fig. 5). This single-center marketing range must be overcome by recruiting new breeders in production centers and maximizing the role of government seed companies and state-owned enterprises, or the private sector. As a result, local producers may be empowered to improve their capacity and production facilities.

3.6. Challenges for seed production and distribution

The supply flow (production and distribution) of rice seeds in Indonesia involves multiple stakeholders, including research institutions, seed producers, SCAs, and governments. Seed producers were the last actors, highly depending on the three other actors. The government is the main actor in regulating and planning rice seed production and distribution. The other actors, namely, research institutions and SCAs, operate according to government regulations. Table 9 lists the challenges faced by multiple stakeholders in rice seed production and distribution.

In a formal seed system, several strategic steps are required to increase seed production and distribution. Some of these steps are as follows: developing seeds on specific locations, increasing human resources at research institutions, increasing supply–demand integration, and implementing policies that encourage profitable commercial seed businesses. In developing countries, formal or commercial seed provision plays a limited role, supplying a very small proportion of what farmers grow (often measuring well below 10 %) [40]. Resource costs for crop seed production and distribution are also an issue in formal seed systems in Africa, supplying less than 20 % of the total [41]. Overall, a combination of challenges, ranging from agronomic to socioeconomic factors, affects seed production and distribution [42]. Key challenges in the seed production and distribution value chain are the lack of clear national policies to improve seed production activities and seed producers' income; the lack of facilitation of functional linkages between different seed actors, low productivity, and limited access to business development services; and the lack of linkages to external markets [43].

4. Conclusion

Seed producers' capacity and production are closely related to their institutional forms. The producers of legal entities are relatively knowledgeable, competent, and able to market. The seed classes produced were mostly extension seeds with wide-ranging

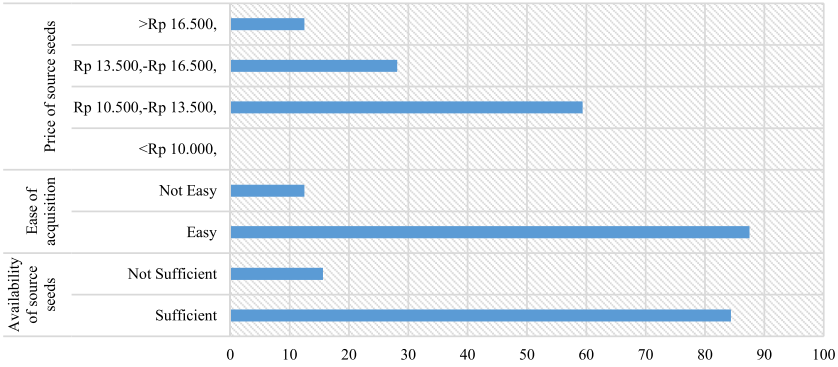

Fig. 3. Affordability of source seeds.

Table 8
Seed production planning strategies implemented.

Information Requires for Production Plan	Type/Source of Information
Information needed to plan seed production	Previous year's seed demand Government market information (government program) Planting area Planting season
Seed requirement information (variety, quantity, location, and time)	Seeking independent information Agricultural Offices Agricultural store Seed Certification Agency and Seed Research Institute

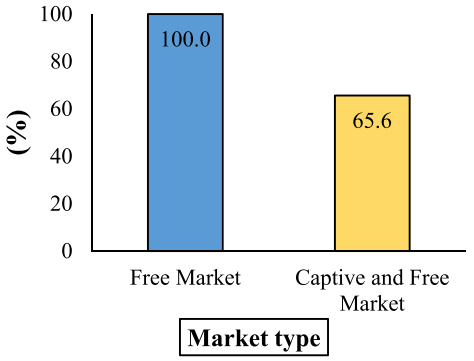

Fig. 4. Types of seed marketing by seed producers.

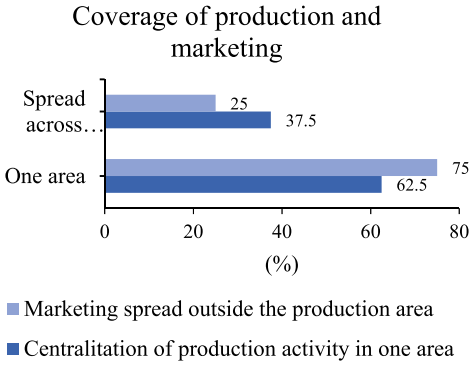

Fig. 5. Production and market coverage.

Table 9
Challenges for rice seed production and distribution.

Research Institution	**Seed Producer**
- Limited human resources	- Limited supply of sources of high-quality seeds
- Variety development is not yet based on farmers' needs and challenges	- Limited information on national seed supply and demand
- Uncertain dynamics of the new variety dissemination mechanism	- Weak linkage of seed stakeholders
	- Price rationalization
Seed Certification Agency	**Government**
- Limited resources (e.g., human, budget, and infrastructure)	- Seed supply budgeting
- Wide coverage area	- Low coordination of seed stakeholders
- Changes of institutional roles in the Indonesian seed system	- Provision of seed producers near the rice production area
	- Encouragement of private sector roles in the seed market.

varieties, according to location-specific needs. Producers plan seed production by using sufficient and close sources of information. To maintain a sustainable market for seeds, they chose a free market. The challenges of rice seed production and distribution may be solved, starting by promoting inter-institutional coordination and networking research to test and release a new variety, increasing farmer involvement in varietal evaluation activities, and strengthening the production of breeder seeds' infrastructure (modern processing and storage, and more labor) to satisfy the rising demand. Additionally, breeders should be given financial incentives to encourage BS production. The authority over seed pricing needs to be relaxed to provide everyone sufficient incentives, and the market should be allowed to set the incentive prices for various players in the system.

Funding

This research was funded by The Endowment Funds for Education (LPDP), Indonesia through the National Research Priority Project for Rice Seed Supply Model in 2020–2021.

Data availability statement

Data included in article.

CRediT authorship contribution statement

Abdul Qadir: Writing – review & editing, Writing – original draft, Supervision, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Mohamad Rahmad Suhartanto:** Writing – review & editing, Supervision, Methodology, Investigation, Data curation, Conceptualization. **Eny Widajati:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Data curation, Conceptualization. **Candra Budiman:** Writing – original draft, Visualization, Validation, Software, Project administration, Investigation, Funding acquisition, Formal analysis, Data curation. **Ahmad Zamzami:** Writing – original draft, Software, Resources, Formal analysis, Data curation. **Astryani Rosyad:** Writing – original draft, Visualization, Software, Resources, Project administration, Formal analysis. **Ridwan Diaguna:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:Abdul Qadir reports financial support was provided by The Indonesia Endowment Funds for Education (LPDP). If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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