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EVALUATION OF SEED INDUSTRY: *WAY FORWARD*

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List of Abbreviations

WPADC	West Pakistan Agricultural Development Corporation
IBRD	International Bank for Reconstruction and Development
FSC&RD	Federal Seed Certification and Registration Department
NSC	National Seed Council
MoNFS&R	Ministry of National Food Security and Research
CSTL	Central Seed Testing Lab
ISTA	International Seed Testing Association
VEC	Variety Evaluation Committee
VCU	Value for Cultivation Use
DUS	Distinguish Uniformity, and Stability
IPR	Intellectual Property Rights
NARC	National Agricultural Research Center
PARC	Pakistan Agricultural Research Council
AARI	Ayyub Agricultural Research Institute
R&D	Research and Development
FAO	Food and Agriculture Organization
AMIS	Agricultural Marketing Information System

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Executive Summary

Genetically pure and high-quality seeds are imperative to achieve the objective of high productivity in the agriculture sector. However, the current regulatory processes involve numerous steps and engage multiple government departments, resulting in significant delays and costs. It has badly damaged the growth and potential benefits of both agriculture and the seed sector. Different stakeholders are involved in the development and marketing of seed business considering that the seed sector is over-regulated. Due to over-regulation private sector is reluctant to invest in Research and Development of the seed sector. In the modern marketing system, the reputation of a brand is more valuable than the approvals from Federal Seed Certification and Registration Department (FSC&RD). It is important to note the government is spending more than 800 million per annum on FSC&RD but its certification does not earn any value in the market. Hence, there is a pressing need to liberalize the seed sector by transitioning from a centrally managed variety approval system to establish brands having intellectual property rights (IPRs).

The majority of the certified seed is produced under the supervision of provincial seed corporations. For the marketing and multiplication of seed, the provincial seed corporation hand over these seeds to the private sector. This has impeded the growth of seed sector. Hence, the informal sector remains the predominant source of seed supplier in the agriculture sector. Further, a large number of non-registered firms are involved in selling seed without proper labeling and branding. This has led to spread low quality seeds and are considered one of the major source of low productivity in agriculture sector of Pakistan.

The primary aim of agricultural research and development is to enhance crop productivity and profitability. Despite the introduction of numerous crop varieties in Pakistan, the sector has not fully tapped into its potential. In comparison to global standards, the country notably falls behind in crop productivity. The primary reason of this productivity gap lies in the insufficient availability of quality seeds and the inefficiency in delivering extension services. Bridging this gap necessitates the implementation of policies and interventions geared towards providing small-scale farmers with increased access to quality seeds, technology, training, and financial support. These measures hold the promise of empowering small-scale farmers, enabling them to enhance their crop yields and uplift their livelihoods. Elevating the average farmer's yield to match that of progressive farmers in just five major crops (wheat, rice, maize, cotton, and sugarcane) could yield a cumulative gain of Rs.1722 billion during 2021-22.

Based on all the observations, our recommendations to liberalize the seed sector are:

- Abolish the stringent seed certification to attract private sector investment and to create space for its growth as poorly regulated seed market promotes low quality seeds, affecting agricultural productivity.

- Proposes a transition from a centrally controlled variety approval system to free market mechanism where entry and exit are free without any restriction.

- Brands/companies have to submit a surety bond issued by banks to FSC&RD only to get registered. The FSC&RD should be bound to issue the registration on the same day after receiving the surety bond issued by banks. Banks will issue the surety bond after receiving the amount mentioned in the surety bond in their reserve which will be kept by the bank until the brand/company cancel its registration with FSC&RD.

- The involvement of the public sector in the seed production business and price regulation need to completely abolish.

- In the proposed set up, the role of FSC&RD will be only to keep records of registered firms. Any farmer can launch a complaint if seed do not contain characteristics mentioned in the labeling. In the event of a proven violation, their registration licenses may be revoked, and the bonded amount can be seized. This amount of surety bond can be used to repay the loss of the consumer or can be handed over to government to settle the dispute. If complainant found guilty, he must have to a face a fine equal to the amount covering all the expenses involved during the whole procedure.

- Granting intellectual property rights IPRs system needed to be cleaner and justified, which is only possible with the engagement of the private sector.

- There is a need to establish specialized courts having sufficient knowledge and expertise about biosafety systems, tools, genes, and procedures used in the development of transgenic varieties to decide confrontation on IPRs or the existing courts should seek the technical expertise from the relevant experts.

1 Regulatory Burden: Time and Cost of Seed Certification and Variety Approval in Pakistan

1.1. Seed Sector Development in Pakistan: An Overview

During the initial fourteen years following independence (from 1947 to 1961), Pakistan lacked a formal system for seed production and distribution. To address this, the West Pakistan Agricultural Development Corporation (WPADC) was established in 1961. However, WPADC's performance was less than successful, leading to its dissolution in 1972. Nevertheless, WPADC played a crucial role in raising awareness about the importance of quality seeds by establishing various seed testing laboratories across the country.

Recognizing the significance of seed quality, production, multiplication, and variety registration, the government of Pakistan, with assistance from the Food and Agriculture Organization (FAO) and the International Bank for Reconstruction and Development (IBRD), initiated a seed industry project in 1976. This endeavor laid a solid foundation for the scientific production of quality seeds and received legal backing through the Seed Act of 1976, which facilitated the establishment of the necessary infrastructure. Subsequently, a national seed council was established at the federal level, along with provincial seed councils or departments in each province. Additionally, two separate departments, the National Seed Registration Department (NSRD) and the Federal Seed Certification Department (FSCD), were created. However, due to national austerity measures in 1997, these two departments were merged to form the Federal Seed Certification and Registration Department (FSC&RD)[1].

In this chapter, we will explore the procedures involved in seed certification and variety approval in Pakistan, along with the associated time and costs. We will also examine how seed certification and variety approval are conducted globally and assess whether these regulatory practices effectively support the entire system of seed production and variety approval in Pakistan. If not, we will identify the constraints and propose potential solutions

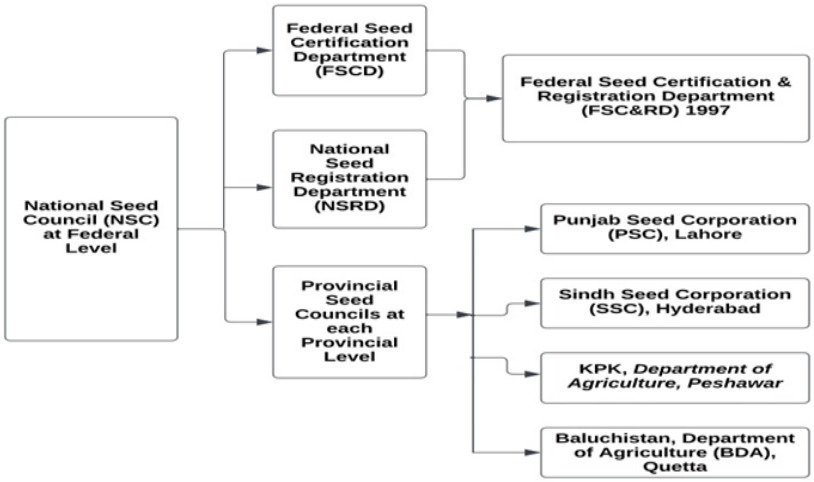
1.2. Seed Production Agencies and Seed Supply in Pakistan

The process of seed production, multiplication, processing, storage, and marketing is a collaborative effort between the public and private sectors in the provinces. The primary public sector seed supply agencies include the Punjab Seed Corporation, Sindh Seed Corporation, and the departments of agriculture in KPK and Baluchistan, as illustrated in Figure 1.1.

Public sector seed agencies primarily acquire pre-basic seeds of various crop varieties from research institutes in their respective provinces. They then multiply these pre-basic seeds to produce basic seeds, which are supplied to private seed suppliers/companies and used for their own sales directly to farmers. The Punjab Seed Corporation has also established

[1] The Seed Industry in Pakistan: file:///C:/Users/Administrator/Downloads/p15738coll2_128882%20(3).pdf

a mechanism for producing breeder's nucleus seed and pre-basic seed at its own farms in collaboration with plant breeders and FSC&RD. Private seed companies acquire basic seeds of different crop varieties from public sector seed agencies, as mandated by statutory requirements. They then multiply and distribute these seeds through their own network as certified seeds.



Source: Authors Creation

Figure 1.1 The Seed Production Agencies in Pakistan

1.3. National Seed Council: Functions and Structure

The National Seed Council (NSC) primarily offers policy direction for the advancement, management, and regulation of provincial seed industries. It also oversees the enforcement of all provisions within the revised Seed Act of 2015. The NSC is responsible for monitoring provincial seed programs and offering directives for maintaining seed quality control. Furthermore, it ensures the safeguarding of investments in the seed industry, including approving and endorsing seed standards and providing guidance on seed imports. The NSC also plays a regulatory role in the movement of seeds between provinces and contributes to the establishment of farms dedicated to producing certified seeds. It coordinates efforts to retain genetic potential, multiply seeds, and ensure the supply of certified seed varieties.

The NSC primarily operates within the framework of the Ministry of National Food Security and Research (MoNFS&R). Consequently, the chairman of the NSC is the federal minister, and the vice chairman is the federal minister of state. Other members of the council include the chairman of PARC, the provincial secretaries of the Department of Agriculture from all provinces, the director general of FSC&RD, the managing directors of seed corporations, the managing director of the Agriculture Development Authority, one representative from each of the seed growers in Punjab, Sindh, KPK, and Baluchistan, and one representative from each of the progressive growers in each province. Additionally, the council comprises four representatives, two from local seed processing and trading companies and two from multinational companies in the private sector, as well as a representative from the Agricultural Development Commission/Additional Secretary.

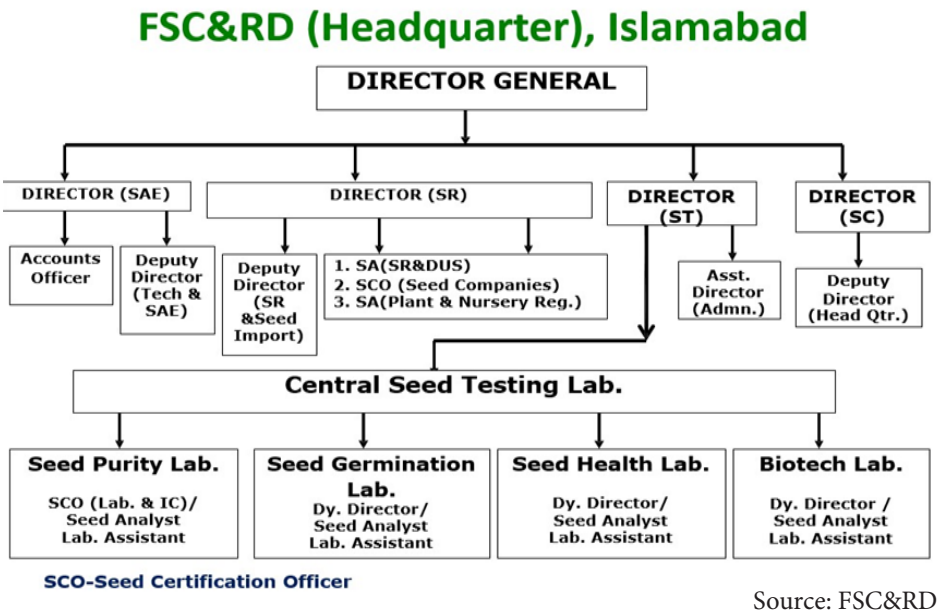
1.4. The FSC&RD: Structure and International Liaison

The FSC&RD operates as the executive arm of the NSC and provides independent professional counsel regarding national seed policies. Additionally, it functions as an

independent third-party regulator, overseeing the progress and development of seed businesses throughout the country. However, the primary responsibilities of the FSC&RD are to grant approval of varieties and monitoring seed quality. Before granting seed certification, the FSC&RD conducts field inspections of registered and released varieties intended for sale as basic seed or certified seed. It also conducts sampling and testing of seed lots designated for sale to verify their purity, viability, germination capacity, and health status, adhering to specified procedures. Ultimately, the FSC&RD publishes a list of registered seed varieties.

The FSC&RD comprises four key directorates: Seed Act enforcement, seed registration, seed testing, and seed certification. The Director of Seed Testing primarily oversees a research division responsible for managing the Central Seed Testing Lab (CSTL), as illustrated in Figure 1.2. This lab conducts all the essential experiments and tests necessary for the approval and release of any seed variety. These tests encompass seed purity, seed germination, seed health, and biotechnology assessments. For this purpose, the FSC&RD operates 27 regional offices across the country, with 14 in Punjab, 6 in Sindh, 4 in KPK, 2 in Baluchistan, and 1 in Gilgit. These regional offices play a crucial role in conducting zonal trials for all candidate varieties received.

The CSTL is a proud member of the International Seed Testing Association (ISTA), which means that its accreditation and testing procedures meet global standards. As a result, CSTL's accreditation opens up opportunities for seed exports on an international



Source: FSC&RD

Figure 1.2 The Structure of FSC&RD

scale. Additionally, the Seed Amendment Act of 2015 has made CSTL accreditation a requirement to facilitate the creation of accrediting laboratories in the private sector.

1.5. The Procedure for Crop Variety Approval

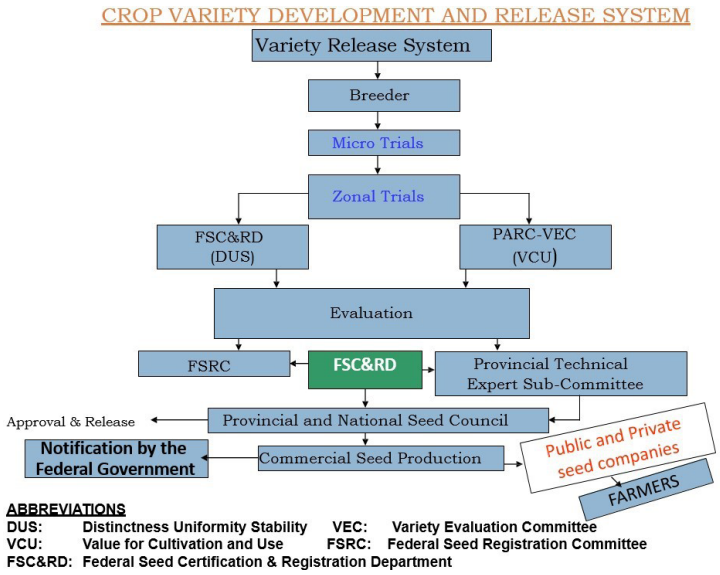
Seeds serve as the carrier of genetic potential, a fundamental factor that ultimately influences crop performance. Genetically pure and high-quality seeds are thus of paramount importance for achieving improved agriculture outcomes. Consequently,

the approval of a seed variety involves a series of extensive experiments aimed at ensuring stable yield potential and the ability to withstand both biotic and abiotic challenges. These criteria are rigorously assessed through a varietal release mechanism, which we will discuss in detail in the following sections, illustrating the comprehensive procedure carried out by the FSC&RD, as depicted in Figure 1.3.

The FSC&RD initiates the variety approval process by receiving the breeder nucleus seed (BNS) of the candidate variety. In the follow up process, micro-trials are conducted, and the best strain or seed is selected for zonal trials. Zonal trials encompass two types of assessments: Value for Cultivation Use (VCU) and Distinguish Uniformity, and Stability (DUS) tests. In the case of VCU tests, all varieties are referred to the Variety Evaluation Committee (VEC) of PARC, except for cotton, which is forwarded to the Pakistan Central Cotton Committee (PCCC). For DUS tests, all varieties are directed to the DUS section of FSC&RD.

The VCU test primarily evaluates the candidate variety's yield potential, while the DUS test determines whether the variety is distinguishable from all other existing varieties of the same crop. Additionally, the new variety must exhibit reasonable uniformity within its stand, allowing for the identification of individual plants. It must also remain true to its description during the reproduction stage. The entire process of conducting VCU and DUS tests spans a period of 2 years and 6 months. After completing all the assessments, the results are forwarded to the federal seed registration committee and provincial technical expert committee for final evaluation before approval. Following their assessments, these committees recommend the variety to the PSC, and it subsequently goes to the NSC. Ultimately, the variety is approved through a notification issued by the federal government. Subsequently, the commercial seed production phase commences under the supervision of provincial seed corporations. From there, the seeds are made available to both public and private seed companies, tasked with the distribution of seeds to farmers for cultivation.

It is worth noting that there appear to be some redundant steps in the variety approval process. Ideally, if the variety is deemed suitable by the relevant experts, they should be authorized to



Source: Source: FSC&RD

Figure 1.3 The Process of Crop Variety Development and Approval

issue the release notification. The current process, involving approval from the federal cabinet, often results in unnecessary time delays.

1.6. Regulatory Procedure for Imported Seeds

The imported seeds must also undergo adaptation testing and trials, a process overseen by the Variety Evaluation Committee (VEC). Research institutes or companies conduct two years of adaptability trials or multi-location trials. Upon successful completion of these trials, they receive authorization for commercial importation. Once granted permission, commercially imported seeds undergo an additional evaluation procedure. Initially, the import documents and labeling requirements are scrutinized for compliance. Subsequently, an FSC&RD inspector collects a 10 kg sample for quality analysis, a process that typically takes around 10 days. Following the quality assessment, release orders are issued by the FSC&RD.

1.7. Time and Steps Involved in Different Procedures

Regulatory procedures involve a number of steps and several departments which results in significant delays and costs, that eventually pose many disincentives for the seed sector. In addition to this, stringent laws and high test requirements result in a limited number of improved cultivars that may be registered and put into production. This provides a strong rationale to ease the time, effort, and cost burdens linked to regulatory standards. For example; someone needs 170 days to register a seed business and the registration process undergoes 6 different steps. Why one hundred and seventy days are required for just registration of a seed business? The registration of the crop seed processing unit requires 105 days and the process undergoes 4 different steps. Similarly, registration of a fruit plant nursery needs 80 days and the process undergoes 4 different steps, while enlisting of plant varieties or hybrids needs 120 days and this process undergoes 4 different steps. The time and steps involved in different procedures are shown in Table 1.1.

Table 1.1 Time and Steps Involved in the different Procedures

Procedures	No. of Steps Involved	Required Time
Registration of Plant Varieties	7	2 years 6 months
Certification of Seeds	9	One crop season
Enlisting of Plant Varieties or hybrids	4	4 months
Seed Quality Analysis of imported seed consignments for issuace of relese order	3-4	10 days
Registration of Fruit Plant Nusrseries	4	2 months 20 days
Registration of seed suppliers/companies	6	5 months 20 days
Registration of seed processing units	4	3 month 15 days

Source: FSC&RD

1.8. The Price for Different Procedures

We've already mentioned the significant time and effort involved in the approval process, but it's essential to consider the associated costs as well. Each of the three steps—DUS testing of a new variety, plant variety registration, and variety enlistment—incur separate costs of Rs. 10,000 each. Seed processing units must pay an annual fee of Rs. 10,000 for registration. Local company registration carries a cost of Rs. 50,000, while seed importers are required to pay Rs. 75,000 for a one-year permit. The renewal costs for the following year are Rs. 25,000 for local seed producers and Rs. 40,000 for importers, respectively. You can find detailed cost breakdowns in Table 1.2.

It's worth noting that despite these costs, the total revenue generated by FSC&RD was only 22.45 million during the 2017-18 fiscal year, which is a relatively small amount compared to their annual budget. According to the budget performance report for the fiscal year 2022, the total budget allocated to FSC&RD is 818 million[2]. However, the total budget utilized, including both operational and employee-related expenses (for over 400 employees), is 549 million. Therefore, the entire process of various certifications and registrations incurs costs of more than 500 million.

Table 1.2 The Cost of Different Procedures

Application for	Rate for different activities (in Rs.)
DUS trial of a New Plant Variety	10,000
Registration of a Plant Variety	10,000
Enlisting of Plant Varieties	10,000
Registration of Seed Processing Unit	10,000/annum
Issuance of Certificate to do Seed Business	For Seed Importer Rs. 75,000 For Local Seed Producer Rs. 50,000
Issuance of Certificate for the Renewal of permission to do Seed Business	For Seed Importer Rs. 40,000 For Local Seed Producer Rs. 25,000

Source: Source: FSC&RD

1.9 Summary of Legal Development in the Seed Sector

The presence of appropriate legislation regarding intellectual property rights (IPR) and biosafety system indicate the strength of a country that allows the firms and breeders to protect genes or gene sequences, tools, and procedures used in the transgenic crops development. Here we try to understand the historical efforts in this regard and current legal development in Pakistan as described in Figure 1.4. We observed a number of legal developments in the past decade.

To provide legal cover or support to the research and development of varieties in Pakistan's seed sector, the First Seed Act was introduced in 1976. Subsequently, in 1987, regulations governing seed registration were implemented. Seed (truth in labeling) guidelines and procedures were implemented in 1991, along with seed standards and procedures that were approved in 1988. In 1998, additional regulations for fruit plant certification were enacted. Recognizing the need for revising the Seed Act, a modified Seed Act was introduced in 2015[3]. The key revisions that are made in the Seed Act of 2015 are summarized as follows.

[2] https://www.finance.gov.pk/budget/Budget_2023_24/Performance_Monitoring_2021_22.pdf

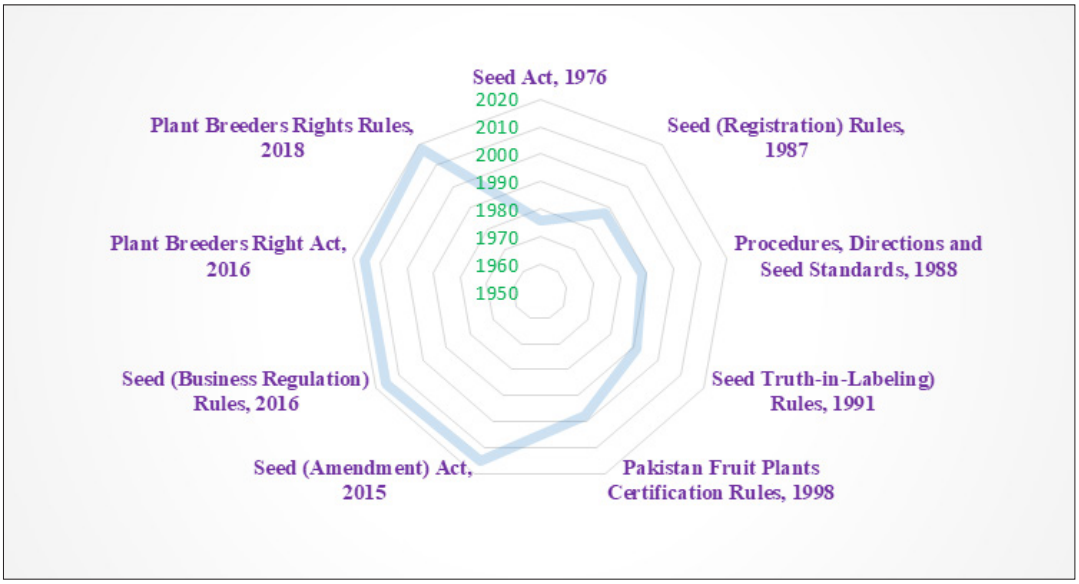
- **Certification was kept mandatory for the strategic crops only.** Strategic crops include wheat, cotton, maize, rice, pulses (OPV) and potato.

- All minor crops namely vegetables, oilseeds, fodder/forages, ornamental, and only hybrids of strategic crops (wheat, cotton, maize, and rice) are linked with **truth in labeling but the** certification requirement is relaxed.

- Private sector seed companies are allowed to produce seeds for all crops and permitted to multiply the same.

- Private sector seed companies are allowed to establish their own **Accredited Seed Testing Laboratories** to test the seed and also allowed to sell the seed of enlisted verities with FSC&RD

To ensure the protection of plant varieties and intellectual property, plant breeders' rights[4] and rules[5] are made and enacted. These rights can be established through patents, and an effective sui-generis system, allowing private corporations to set up their own labs and develop new varieties in accordance with international norms. Considering the traditional farming practices and socio-economic conditions of our farming community, a Sui-generis system is opted as the most suitable approach to introduce IPR for plant varieties. This system aims to safeguard the rights of plant breeders while accounting for the unique context of the agricultural landscape in the country. Further, a new registry was established in FSC&RD with the name of Plant Breeders' Rights Registry. The main purpose was to provide protection to new plant varieties, by following newly introduced criteria for protection, DUS which is carried out by FSC&RD through lab analysis and field testing.



Source: Authors Creation

Figure 1.4 The Legal Developments for the Seed Sector in Pakistan

[3] http://www.federalseed.gov.pk/Detail/NzhjNThkMWMtNDYzOS00OWM2LWE1NmYtZjJmYTQwMDM5YmI
[4] http://www.federalseed.gov.pk/Detail/YzljYzEwNTYtN2UwMi00ZjVjLWFiZTAtNjQyMWI0MjQ4Yzcx
[5] http://www.federalseed.gov.pk/Detail/ZjdlZTFhMTMtZWI1MC00MWI1LWExZjctMGMwNmYwYmViNTkw

Seed Act in Pakistan primarily regulates the development and distribution of seed under the umbrella of the public sector but the private sector has a limited role in the marketing of seed. The role of the private sector has been limited to seed multiplication subject to registration by FSC&RD. Similarly, the Act restricts the sale of notified seed varieties only but does not oversee the production, storage, or farmers' practices of saving seeds for non-notified varieties. Unfortunately, The Seed Act of 1976, its accompanying regulations, and the 2015 amendment underscore a minor role for the private sector in seed-related activities. It also imposes intricate and bureaucratic procedures for variety approval, elevating the risk of seed piracy for breeders. The lax enforcement of these strict laws has given rise to an informal sector, where numerous companies and breeders promote new varieties without proper registration. Moreover, farmers are unaware of the quality of these seeds because it is being supplied by non-branded and unregistered firms[6].

1.10. Seed Regulatory Models in the World and Pakistan

There are two distinct models for seed industry regulation in the world, one followed by the US and the other by the EU. In practice, most countries around the globe adopt one of these two models[7], as shown in Table 1.3. EU model is somewhat restrictive having compulsory and mandatory conditions of seed certification, variety approval, and registration of a seed business. Whereas, the US model is almost opposite to the EU model. The US follows voluntary procedures for seed certification, variety approval, and registration of a seed company. Pakistan is following the restrictive regulatory model of the EU with slight changes. However, by adhering to this strict approach, we are still able to offer 37% of the required certified seed in the country[8]. Confronting a significant market fraud with seeds, too. Poor quality seed, counterfeit seed, and unethical business practices appear as big issues in Pakistan like in many other developing countries[9].

Table 1.3 Seed Regulatory Models in the World

Model	Seed Certification	Variety Registration	Registration of Seed Companies
US Model	The owner of the variety can get seed certification voluntarily but it is not mandatory.	Registration is on voluntarily basis	Registration is not required but some individual states may have compulsory requirement
EU Model	Mandatory for all major crops Voluntarily for vegetables	Registration is mandatory 2 years VCU & DUS Tests for field crops One year of DUS tests for vegetables.	Registration is required based on Minimum Criteria

A prosperous and growing seed sector demands very quick procedures and less involvement of Govt. as the poor performance is typically attributed with over dominance of state. So, what is the way out? Asking Govt. for step back and just keep its focus on creating a favorable environment and opt for complete deregulation or we can suggest improving the capacity of regulatory agencies for better and faster testing procedures including the ease in regulation standards for varieties and their notification/listings. Revisit all kinds of constraints like taxes and tariffs and make them

[6] file:///C:/Users/Administrator/Downloads/The-State-of-PakistansAgriculture_Pakistan_Agricultiural_Coalition.pdf
[7] https://agrilinks.org/sites/default/files/resource/files/State_of_the%20Evidence_in_Seed_Policy_Reform.pdf

flexible to attract high investment in imported seeds. The most convincing model is of USA, model. They have deregulated all the systems and just keep an eye on the whole value chain through a strong surveillance system, and not compromise on counterfeit or poor quality seed. Finally, to curb fraudulent seeds in the market, and also to enhance the farmer's trust, a piercing surveillance system is proposed.

1.11. Summary, Conclusions, and Recommendations

Bureaucratic and lengthy procedures for variety approval are observed which is not only slowing down the seed business but also promoting the lemon market in seeds. Further, regulations governing the seed registration process, variety release, and seed certification are adding unnecessary time and cost to the production and sale of certified seed. Hence, a shift from a centrally managed variety approval system is the need of the time. Further, if certification is kept mandatory then it creates sludge and increases the cost of doing business which leads to discouraging the investment. Moreover, firms will transfer the certification cost to the end user (i.e. Farmer).

The private sector is ready to take the lead or actively participate in the process of variety development, but it is reluctant to share or hand over germplasm to the government authorities to get its approval. Because FSC&RD is using the services of the National Agricultural Research Center (NARC) for conducting trials of new varieties submitted for approval. On the other hand, NARC itself is involved in developing new varieties of different crops. It creates a conflict of interest and thus private sector is reluctant to make heavy investments in the development of new varieties. Because seeking approval for new varieties, seed has to pass through its competitors which is not logical and makes the investment of the private sector highly risky. Moreover, the private sector believes that time-consuming procedures of seed testing at FSC&RD add no value to the seed business ultimately. Therefore, several companies have started releasing varieties directly into the market without getting any approval from FSC&RD. The private sector argues that they are operating in an over-regulating environment. Further, they believe, it is a brand name, not a tag of approval issued by the FSC&RD that carries weight in the market. Hence, they believe that the complete process of FSC&RD is intrusive, time-consuming, and unnecessary. Hence, the private sector believes that a long seed certification process is of little value. As a result, unregistered verities started to grow at a faster rate in the market, making the need for certification less relevant. Hence, the stringent condition of seed certification needs to be abolished to create more space for the private sector. This will not only attract private sector investment in R&D but also in seed production and marketing. The poorly regulated seed market is promoting poor quality seed, affecting agricultural productivity and affecting the welfare of producers and consumers.

This provides sufficient evidence of the inefficiencies existing in the seed sector. Hence, it emphasizes exploring alternatives to enhance the efficiency of the seed sector. An alternative mechanism to liberalize the seed sector could be that seed companies have to deposit surety bonds (the amount of which can be decided mutually depending on the size of the business) in the bank to get involved in the development of new

[8] https://www.finance.gov.pk/survey/chapters_23/02_Agriculture.pdf
[9] https://seepnetwork.org/files/galleries/SEED_pakistan.pdf

seeds and their marketing. Each seed company should get registered as a brand with FSC&RD just by presenting a surety bond deposited in the bank. FSC&RD should be bound to issue the registration on the same day without any fee after receiving the surety bond issued by banks. Each brand is bound to produce and supply seeds with proper labeling which can be verified by anyone in any certified laboratory. The provision to establish a certified laboratory already exists and certification can also be obtained from international laboratories. If any seed company is found guilty of labeling their seeds wrongly to attract a larger share of the market, then the surety bond of that company will be transferred to the court which can use that money to compensate the sufferer or can hand it over to the government by black listing the company/brand.

Conclusion

Variety Approval Procedure and Seed Regulations highlight the following key issues:

- Bureaucratic and lengthy procedures are observed.
- The procedures slow down seed business and promote low-quality seeds.
- Regulations add unnecessary time and cost to seed production and sale.
- Mandatory certification causes disadvantages to consumers because firms transfer seed certification costs to farmers.
- The private sector is ready to lead the process of variety development but hesitant to share germplasm for government approval due to conflict of interest.
- The private sector views seed testing at FSC&RD as time-consuming and having no value in the market.

Recommendations

Based on the observations mentioned earlier, our recommendations are as follows:

- Abolish the stringent seed certification to attract private sector investment and to create space for its growth as a poorly regulated seed market promotes low-quality seeds, affecting agricultural productivity.
- Proposes a transition from a centrally controlled variety approval system to a free market mechanism where entry and exit are free without any restriction.
- Companies, have to submit the surety bond issued by banks to get register their brands with FSC&RD.

2 Low-Quality Seed Supply Hampering Productivity in Pakistan: Way Forward

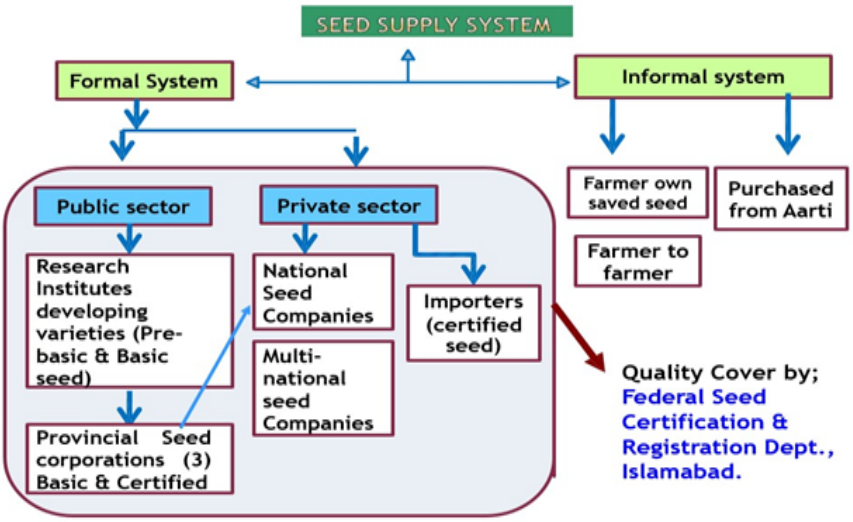
2.1. Background

Although a large number of varieties have been developed in recent years and seed-producing companies have also increased by 76 percent in the last 15 years, only 37 percent of the total seed available to the farmers is certified. Non-certified and low-quality seed is being sold to the farmers by packing in different companies' bags, which has created a lemon market that has damaged the farmer's trust in certified seed eventually. Under these circumstances, the regulator has to take very stringent measures to build back the trust of farmers in certified seed, implying that the whole supply chain of seed needs to be re-visited. The unavailability of good-quality seeds is one of the major impediments to substantial improvement in agricultural productivity in Pakistan. The existence of a large number of informal (without having any registration) seed suppliers, points out that the regulator fails to perform its role in providing high-quality (certified) seed to the farmers. This chapter has multiple objectives. The primary objective is to offer a comprehensive examination of the seed supply system and its historical performance in the light of formal and informal seed markets. Moreover, we aim to quantify the factors that lead to the trust loss of farmers on certified seed-supplied by the private sector. Based on these insights, the study outlines prospective pathways for the future.

2.2. Seed Supply System and "Lemon Market"

The seed supply system in Pakistan comprises both formal and informal sectors. The formal seed system encompasses public and private institutions engaged in the development of new varieties through research, multiplication of seeds of new varieties, and distribution of certified seeds. The registration and certification of seeds being developed in the public sector institutions are strictly monitored and without getting approval from the Federal Seed Certification and Registration Department (FSC&RD), these seeds can't be released to the farmers. In contrast, the informal system means non-certified seeds primarily involve farmers' home-produced seeds or obtaining them from fellow farmers, landowners, or local seed dealers. Many local seed developers in the private sector are developing, multiplying, and selling seed to the farmers without getting approval or certification from FSC&RD and earning millions of Rupees from the seed business. Many large farmers are engaged in the illegal seed business, especially in the seed multiplication process to harness the opportunity of high profitability. Because of their vested interest, these large farmers do not allow the government to implement the law of intellectual property rights. Hence, low-quality and noncertified seeds are being sold by these large farmers by labeling these are good-quality certified seeds. Moreover, it is difficult for FSC&RD to crack down against these farmers because these small suppliers are not registered and they are not supplying seed with registered brands or addresses on labels. Moreover, the monitoring capacity of FSC&RD is not sufficient to stop such supply in the market. In such an environment international and genuine local firms fail to compete with these unregistered

firms. Finally, it is leading to the development of a "lemon market". The functioning of the formal and informal seed systems in Pakistan is depicted in the diagram shown in Figure 2.1.



Source: PARC

Figure 2.1 Seed Supply System in Pakistan

2.3. The Role of Public Sector Institutions in Variety Development

Roughly there are 200 agricultural research institutes in the country, out of which nearly 57 are specifically dedicated to seed research and the development of varieties, catering to the needs of both arid and irrigated regions. Notably, the Ayyub Agricultural Research Institute (AARI) in Faisalabad, which operates under the Punjab provincial government, stands out as the largest institution in this category. AARI has several specialized sub-research institutes that concentrate on specific crops. Among these most prominent are, the Wheat Research Institute in Faisalabad, the Mango Research Institute in Multan, and the Rice Research Institute in Kala Shah Kaku. In addition to this, Pakistan has seven key universities as well as 46 degree-granting institutions for agricultural research.

An overlapping or duplication of roles of different research stations is also observed, particularly in terms of their objectives and achievements. A prominent example of this redundancy is evident in the case of the Pakistan Central Cotton Committee (PCCC) and the Cotton Research Institute (CRI) in Multan, both dedicated to plant breeding and variety development specifically in the context of cotton. The PCCC operates at the federal level under the umbrella of the Ministry of National Food Security and Research (MNFSR), while the CRI functions as a provincial research institute. These two institutions coexist as separate entities and have limited communication to achieve the objective of high-yielding varieties[10]. In addition to this, NIBGE also works on the development of new cotton varieties. Similarly, Kala Shah Kakoo and a unit of NARC are working on the development of Rice varieties without having close coordination. Moreover, many other examples exist.

2.4. The Contributions of the Formal Seed Sector in Research

A large number of research and development (R&D) institutions developed a total number of 1183 varieties for different crops. The province-wise R&D contributions are shown in Table 2.1.

[10] The Seed Industry in Pakistan: https://seepnetwork.org/files/galleries/SEED_pakistan.pdf

Notably, researchers from the Punjab province have made a significant contribution, given that Punjab is the primary agricultural hub in Pakistan. As of 2022, this includes a total of 191 wheat varieties, 68 paddy varieties, 66 maize varieties, 56 sugarcane varieties, 220 cotton varieties, 17 barley varieties, and 59 fodder varieties. R&D programs in Pakistan focus on developing improved seed varieties for various crops. These efforts aim to enhance crop yields, pest and disease resistance, drought tolerance, and other desirable traits. However, these new varieties did not contribute to enhancing productivity significantly because, in the majority of the crops, our yield is below the world average. This implies that either there is a problem in the approval mechanism which could not decide about the right parameters for the approval of new varieties or these varieties are not marketed properly. In either case, it is a failure of government institutions. Hence, variety approval, multiplication, and distribution of seed should take place under the umbrella of the private sector.

Table 2.1 Registered and Released Varieties

Crop	Punjab	Sindh	KPK	Baluchistan	Gilgit Baltistan	Islamabad	PVT	Pakistan
Wheat	81	27	67	8		7	1	191
Barley	10		3	4				17
Maize	30		29				7	66
Rice	40	18	8				2	68
Cotton	147	41	2				30	220
Sugarcane	22	13	20				1	56
Pulses	64	4	38	1		5		112
Oil Seeds	45	7	28			8	5	93
Fodders	48		8	1			2	59

Data Source: FSC&RD, 2022-23

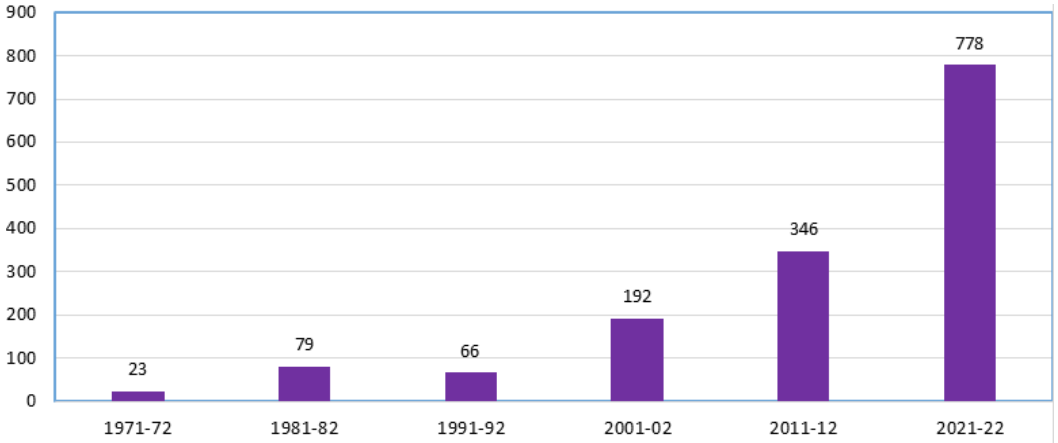
2.5. The Role of the Formal Sector in Seed Supply

Although, substantial progress in the availability of certified seeds has been observed over the past five decades in Pakistan, as illustrated in Figure 2.2, but majority of the farmers are still using non-certified seeds. In 1976, a seed industry project was launched with collaboration and support from the Food and Agriculture Organization (FAO) and the International Bank for Reconstruction and Development (IBRD), which played an essential role in expanding certified seed availability in Pakistan[11]. Although this initiative led to an increase in certified seed availability, but progress was relatively slow. However, in the early years of the twenty-first century, there was a remarkable surge in the availability of certified seeds. Specifically, the data shown in Figure 2.2 indicate that the amount of certified seed supply has increased from 192 metric tons in 2001-02 to 778 metric tons in 2021-22.

Despite a large increase in certified seed production, we are able to provide only 37% of the required certified seeds for all crops (Figure 2.3)[12]. The development and dissemination of new technology (seed development and its dissemination) have been one of the most limiting factors in enhancing Pakistan's agricultural productivity over the past two decades.

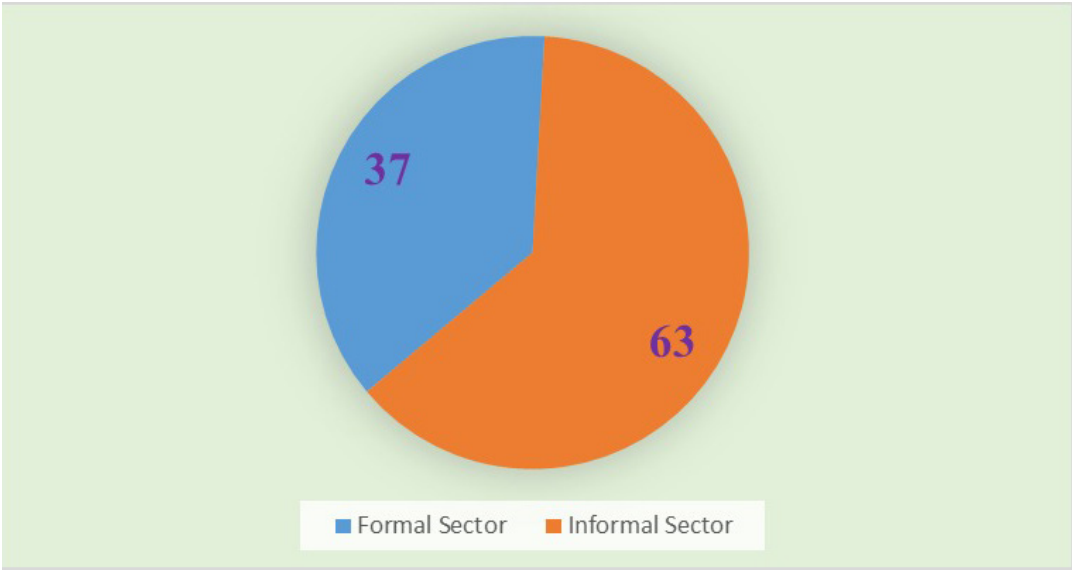
[11] The Seed Industry in Pakistan: file:///C:/Users/Administrator/Downloads/p15738coll2_128882%20(3).pdf
[12] The Economic Survey of Pakistan. https://www.finance.gov.pk/survey/chapters_23/02_Agriculture.pdf

However, maize was the only exception where imported hybrid seed played an important role in boosting maize productivity. Another concerning issue is the prevalence of contaminated seeds in the market, falsely labeled as "certified seeds", since farmers can't distinguish between genuine and fake certified seeds because both are labeled and well-packed. This erodes farmers' trust in genuine certified seeds. This is leading to promote the lemon market of seed in Pakistan. Currently, seed supplied by informal sources is 63 percent, implying that a major share of seed supplied is non-certified. This implies that radical changes need to be introduced at different modes of the value chain (development, production, and distribution) to improve the seed sector in Pakistan.



Data Source: Multiple Economic Surveys of Pakistan

Figure 2.2 An Overview of Certified Seed Distributed (MT)



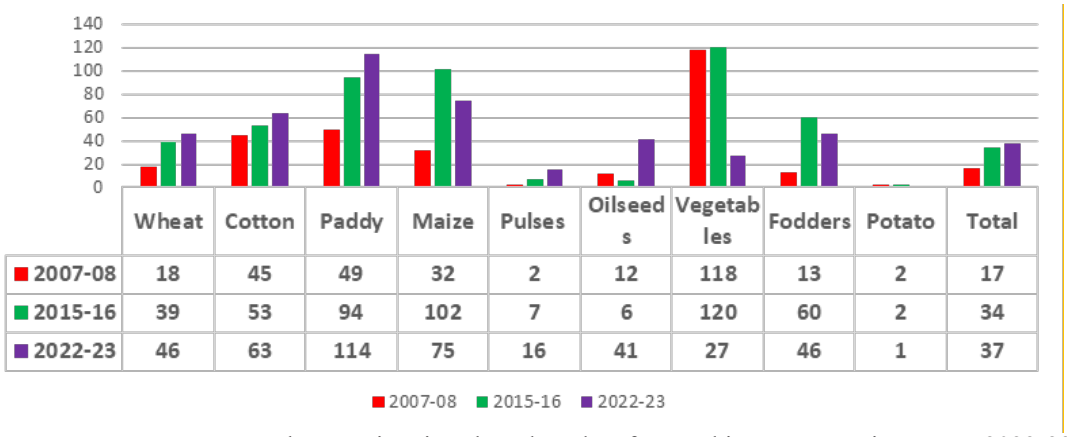
Data Source: Pakistan Economic Survey 2022-23

Figure 2.3 Size of Formal and Informal Seed Sector

2.6. The Certified Seed Availability for Different Crops

We attempted to explore the supply of certified seeds for different crops over the past 15 years. Between, 2007-08 and 2015-16, it is observed that in the case of many crops, the supply of certified

seeds is almost doubled (Wheat, Paddy, Maize, Pulses, and Fodder) except for cotton, oilseeds, vegetables, and potatoes (Figure 2.4). However, during 2015-16 and 2022-23, for some crops (wheat, cotton, paddy, pulses, and oilseeds) the supply of certified seed has increased slightly, and for some other crops like maize, fodder, and vegetables the supply of certified has declined, demonstrating that either there is a problem of strict regulation in the approval of new varieties or there is a capacity problem of provincial seed corporation (such as Punjab seed corporation) to multiply seeds of different crops or over-regulated seed market by the provincial corporations could be possible reasons of this decline. In either case, government footprints are required to be reduced drastically to improve the efficiency of the seed sector. It is a matter of worry that the supply of vegetables certified seeds has drastically decreased from 120 percent in 2015-16 to 27 percent in 2022-23, which also indicates that uncertified seeds have captured a large share of the market. This will affect the vegetable production significantly in the country. A detailed study is required to investigate why the supply of certified seeds has not increased sharply during the last 8 years and why it has declined drastically in the case of vegetables. This stresses the need for solicitous engagements of the private sector to address this issue. We believe that the certification of seeds is not so important because farmers are not giving much value to the certification while purchasing seeds of different crops. Hence, a major focus should be placed on true labeling so that farmers can decide for themselves based on good brands that deliver high-yielding varieties.

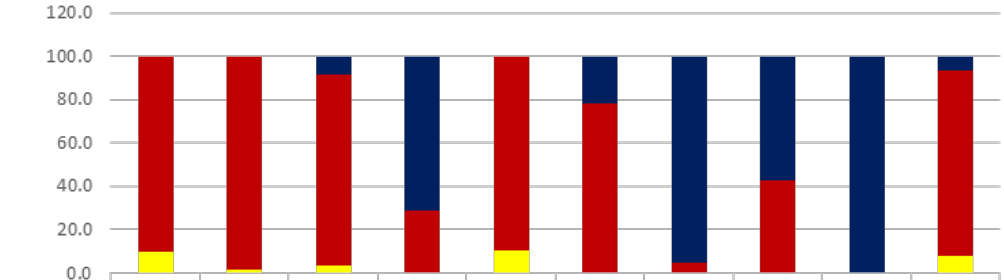


	Wheat	Cotton	Paddy	Maize	Pulses	Oilseeds	Vegetables	Fodders	Potato	Total
2007-08	18	45	49	32	2	12	118	13	2	17
2015-16	39	53	94	102	7	6	120	60	2	34
2022-23	46	63	114	75	16	41	27	46	1	37

Source: Authors' estimations based on data from Pakistan Economic Survey, 2022-23

Figure 2.4 Certified Seed Availability during different Time Intervals

Among the most common sources of supply of certified seed are the public sector, private sector, and imported seed. The role of the private sector in the supply of certified seed is getting prominent, especially in the case of wheat, cotton, rice, pulses, and oil seed but in the case of vegetables, fodder, and potatoes major sources of supply of certified seed is import (Figure 2.5). This implies that still Pakistan is heavily dependent on imported seeds particularly for vegetables, fodder, and potatoes in the case of certified seeds, indicating less focus on R&D is the key reason that informal seed use for these crops holds a large share in the market. Hence, R&D should specifically focus on developing local high-quality seeds of vegetables, fodder, and potatoes. This will save foreign exchange reserves too. Moreover, it is important to note that the private sector is also involved in supplying low-quality seeds by claiming that it is certified seed. In this way, the private sector deceives the farmers, and the seed market moves towards the lemon market for seeds. This also nurtures the need for a strong surveillance system to eradicate the lemon market.



	Wheat	Cotton	Paddy	Maize	Pulses	Oilseeds	Vegetables	Fodders	Potato	Total
Imported	0.0	0.0	8.5	71.0	0.0	21.8	95.5	57.5	100.0	6.6
Private	90.4	98.5	87.7	28.9	89.8	77.6	3.9	42.5	0.0	85.4
Public	9.6	1.5	3.7	0.0	10.2	0.5	0.6	0.0	0.0	8.0

Source: Authors' estimations based on data from Pakistan Economic Survey, 2022-23

Figure 2.5 The Sources of Certified Seed Supply in Pakistan

2.7. The Status of Registered Seed Companies

As documented earlier, only 37 percent of the total seed supply is certified. This demonstrates the substantial potential for growth that can be exploited by supplying high-yielding varieties. Although, the number of private companies has increased from 672 in 2008 to 938 in 2022, indicating a high growth of more than 70 percent. It is worth noting that a significant number of seed company licenses have been canceled (Table 2.2) but still, there are a number of issues related to fake seeds and poor-quality seeds, which underscores the importance of implementing a more robust surveillance system. Moreover, there is no change in the multinational companies, implying that the foreign private sector is reluctant to invest in the seed sector mainly because the sector is heavily regulated. Hence, in order to attract private sector investment and international investment in the seed sector, Pakistan needs to decrease government footprints. Most importantly certification requirement under FSC&RD needs to be abolished because it takes about 3 years and the private sector can't wait so long. In such a long time market dynamics changed and the investment of the private sector failed to pay back the profits. That is why there is no real increase in the registration of international seed companies because companies don't feel it is an attractive avenue for their investment.

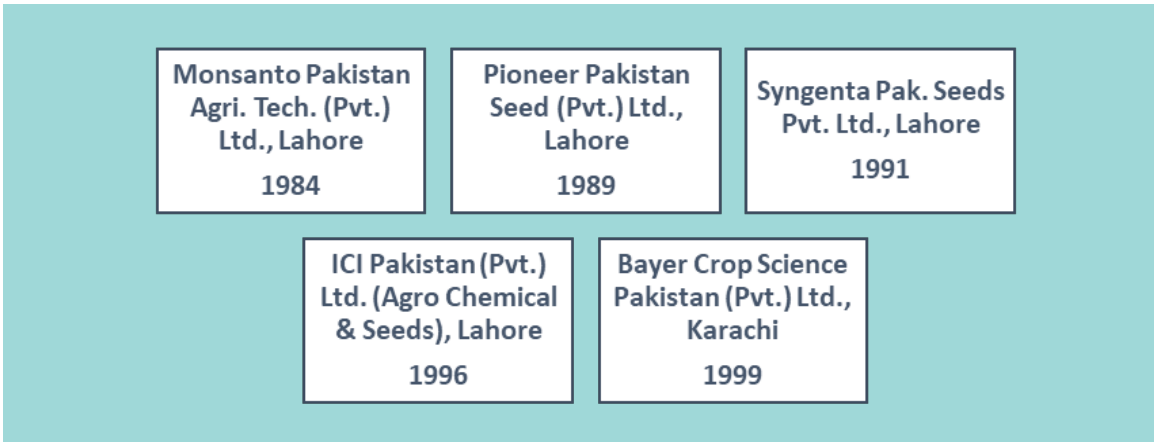
Table 2.2. The Status of Registered Seed Companies in Pakistan

Status			Punjab	Sindh	KPK	Bal.	G.B	ISB	Total
Active	Public	2008	1	1	1	1	0		4
		2022	1	1	1	1	0		4
	Private National	2008	588	65	15	3	1		672
		2022	772	122	34	6	2	2	938
	Private Multinational	2008	4	1	0	0	0		5
		2022	4	1	0	0	0		5
	Total	2008	593	66	16	4	1		681
		2022	**777**	**124**	**35**	**7**	**2**	**2**	**947**
Cancelled			**203**	**37**	**5**	**3**			**248**

Source: FSC&RD

2.8. Role of Multinational Companies in the Seed Business

The agriculture sector in Pakistan has experienced substantial benefits from the involvement of multinational corporations in the seed business. The most popular multinational companies that remain engaged in the seed business in Pakistan are reported in Figure 2.6. Multinational companies not only help to bring new germplasm and hybrids into the country but also help to train human resources which are directly contributing to improving agriculture productivity. In the 1990s, both Pioneer and Monsanto made substantial investments in the development of high-yielding varieties, particularly for important crops like wheat, rice, and cotton. These companies produced seeds not only for the domestic market but also for export to neighboring countries like Afghanistan. However, they eventually withdrew from seed production due to concerns related to germplasm safety, ultimately discontinuing their seed business in 2002-03. The seed of open-pollinated varieties can be easily stolen and re-produced in the absence of intellectual property rights and the government failed to provide required protection to multinational companies. Pakistan approved its first amended seed act in 2015, Plant Breeders Rights Act 2016, and Plant Breeders Rights and Rules 2018, defining the intellectual property right of germplasm and prohibiting others not to producing it without priori permission and the objective was to protect the varieties. However, it will take time for the multinational companies to trust the local market. Further, still there are many complexities and over-regulations that restrict multinational companies from entering into R&D, multiplication, and marketing of seeds[13]. That is why no new multinational companies have entered the seed business of Pakistan over the past two decades.



Source: FSC&RD

Figure 2.6 The Multinational Seed Companies in Pakistan

On a smaller scale, Bayer and Syngenta also dabbled in the seed business, but their primary focus remained the agrochemical industry. Nevertheless, multinational corporations played a pivotal role in the introduction of hybrid seeds in Pakistan. For instance, ICI introduced canola hybrid seeds, while Monsanto and Pioneer were instrumental in bringing hybrid maize and sorghum seeds to the market. This adoption of hybrid seeds led to progressive increases in crop yields, with Pakistan now competing favorably with leading producers, particularly in the case of maize. The success story of maize in Pakistan heavily depends on the engagement of international companies and the private sector. Multinational companies have refrained from transferring their research and development infrastructure to Pakistan too, which has further weakened the domestic seed supply system. Their

[13] https://www.sbp.org.pk/publications/staff-notes/Investigating-Pakistans-Seed-Industry-Dynamics.pdf

current involvement in the market is primarily centered on screening and testing imported seeds before their introduction, rather than investing in local R&D initiatives. One positive aspect of this situation is the multinational companies' interest in doing business with genetically modified (GM) seeds. As a result, these companies are closely monitoring developments related to the commercialization of GM crops in Pakistan. However, the Ministry of National Food Security and Research (MNFS&R) has banned GM crops in Pakistan, implying that multinational companies' hope to produce GM seeds will not come true. Hence, without liberalizing the seed market, it is difficult to attract investment from the private sector multinational companies.

2.9. The Issue of Informal Seed Market

Farmers use saved seed for a variety of reasons, such as low cost, familiarity, performance under local conditions, and preferred attributes other than yield. Usually, farmers will purchase new seed from the market if they want to replace their variety or the seed stock has deteriorated as a result of contamination, etc[14, 15].

The informal sector has drawn attention to the system's distribution of uncertified seeds. In Pakistan, the informal sector continues to be the primary provider of seed, providing 63 percent of the country's total supply, usually sold without proper address or labeling therefore no guarantee is available for the seed quality. This is happening due to weak enforcement of seed quality rules and regulations; the case of BT cotton is instructive in this regard.

On the supply side, local private seed companies, including input dealers, have started selling uncertified seeds in company packaging as a way to bypass the seed certification procedures. They argue that they are operating in an overly regulated environment. The cumbersome and protracted procedures for variety approval, coupled with the regulations governing variety release, and seed certification, have introduced unnecessary delays and costs into the production and sale of certified seeds. Consequently, some companies have chosen to release varieties directly into the market without seeking approval from the FSC&RD, leading to the growth of a sizable informal seed sector. This leads to a lemon market in seeds because each supplier is enlisting good characteristics of seed which do not exist practically and suppliers can also offer lower prices compared to the companies/brands having seed with good characteristics. Additionally, certain unethical practices within public research institutes have been observed, where uncertified seeds of non-registered varieties are supplied to the market to generate extra income, taking advantage of the relatively unregulated seed prices. Under a situation where buyers can't distinguish between good quality and bad quality certified seeds because non-certified seeds are also being labeled as certified, why does he/she need to spend more on certified seeds? **On the demand side**, economic, social, and behavioral factors are largely responsible for the low demand for certified seeds[16].

[14] Architecture of the Pakistani Seed System: A Case of Market-Regulation Dissonance. International Conference of Agricultural Economists. Milan: Universita Degli Studi Di Milano.

[15] Quality seed in SAARC countries. SAARC Agriculture Center, Dhaka, Bangladesh.

Conclusion Recommendations

The involvement of the public sector in the seed production business and price regulation should be minimized, allowing the private market to operate efficiently. Implying that the role of Punjab seed corporation and seed regulation authorities in other provinces need to be abolished. The private sector has come to dominate the provision of certified seeds in the market, surpassing public-sector seed corporations. This suggests that the private sector will likely become the dominant player in the seed market in the future. Recognizing the expanding role of the private sector presents a valuable opportunity for the government to transition to a market-driven approach, discontinue the operation of seed corporations, and allocate the saved administrative costs toward other initiatives.

The role of local private sector and multinational companies should not be limited to the distribution and marketing of certified seed. Rather, there is a need to extend their role to R&D which is only possible if FSC&RD will relax the certification condition of seed. Hence, the role of FSC&RD will change from regulating the certification to keep records of registration based on surety bonds. This will not only help to attract private investment in the R&D of the seed sector but also help to improve agriculture productivity. Moreover, the private sector will also engage in providing extension services to capture a bigger share of the market. In the light of above discussion, the specific recommendations to bring a revolution in the seed industry are summarized below;

- The role of FSC&RD needs to change from approving varieties to ensuring that all available seeds in the market are true in their specifications. However, for the assessment of the quality of seeds in the market, a third party can be engaged to take samples randomly of different varieties developed by different brands for verification. But we are recommending a free market, where a complaint can be filed by the consumer directly in the court, if the seeds sold to him are not true in their specifications. Hence there is no need to engage a third party too. In the event of a proven violation, their registration licenses may be revoked, and the bonded amount can be seized. This amount can be used to repay the loss of the consumer or can be handed over to government to settle the dispute. If complainant found guilty, he must have to a face a hefty fine covering all the expenses involved during the whole procedure.

- Granting intellectual property rights IPRs system needed to be cleaner and justified, which is only possible with the engagement of the private sector. It should be done under the umbrella of FSC&RD at the recommendation/approval of the private sector (third party/laboratory responsible for testing and approval of a variety).

- There is a need to establish specialized courts having sufficient knowledge and expertise about biosafety systems, tools, genes, and procedures used in the development of transgenic varieties to decide confrontation on IPRs or the existing courts should seek the technical expertise from the relevant experts.

[16] www.sbp.org.pk/publications/staff-notes/Investigating-Pakistans-Seed-Industry-Dynamics.pdf

3 Evaluation of Research and Development in the Agriculture Sector: A Growth Analysis

3.1. Introduction

Research and Development (R&D) plays a crucial role in enhancing crop productivity by driving innovation, introducing new technologies, and improving agricultural practices. The primary focus of R&D initiatives revolves around the development of crop varieties with desirable traits, such as higher yield, resistance to pests and diseases, tolerance to environmental stress (e.g. drought or salinity), and improved nutritional contents. The ultimate objective of all these efforts is to enhance the crop productivity and profitability of farmers. Pakistan has successfully developed, registered, and released a total of 1183 new crop varieties, despite receiving relatively modest annual allocations of budget (which is only 0.12% of agriculture GDP) for R&D. But, the provision of certified seed is far below the target and there remains a substantial gap between the required and available quantities of seeds for most of the crops. Probably, this is one of the most important reasons why the benefits of R&D have not been realized by the agriculture sector of Pakistan, despite the fact, a large number of varieties have been approved and released. It could have multiple reasons, either the varieties developed have no potential at the farm level as claimed by research institutions and scientists, and therefore, farmers rejected to opt for or there is a problem in the marketing of these varieties due to which these latest varieties are not reaching to the farmers in its pure shape, thereby failing to bring about substantial change at the farm level. Resultantly, Pakistan was left behind the rest of the world in terms of crop productivity.

The central objective of this brief chapter is to provide empirical evidence of the integrated poor performance of R&D and public extension services during the last forty-two years. We attempted to analyze historical trends in terms of area, production, and yield growth within the agriculture sector. This will help to evaluate the contribution of R&D and the role of public extension services at the farm level. Furthermore, it will investigate the potential benefits that can be derived if the current production levels are elevated to those achieved by progressive farmers.

3.2. Pakistan's Production and Productivity Status in the World

Pakistan occupies a significant position in the global agricultural landscape, consistently ranking among the top ten producers in various crops. For instance, it stands 3rd in chickpeas, 4th in sugarcane, 5th in cotton, mangoes, and guava, 6th in onions, dates, and chilies, 7th in wheat, 9th in tobacco and spinach, 13th in rice, 15th in citrus, and 16th in maize production, as shown in Figure 3.1. However, Pakistan has not fully realized its competencies as far as the potential is concerned. When examining productivity levels, it becomes evident that they fall far behind those of many other nations. Specifically, Pakistan ranks 54th in rice yield, 62nd in wheat yield, 33rd in cotton yield, 22nd in corn yield, and 17th in sugarcane yield, highlighting a significant room for improvement.

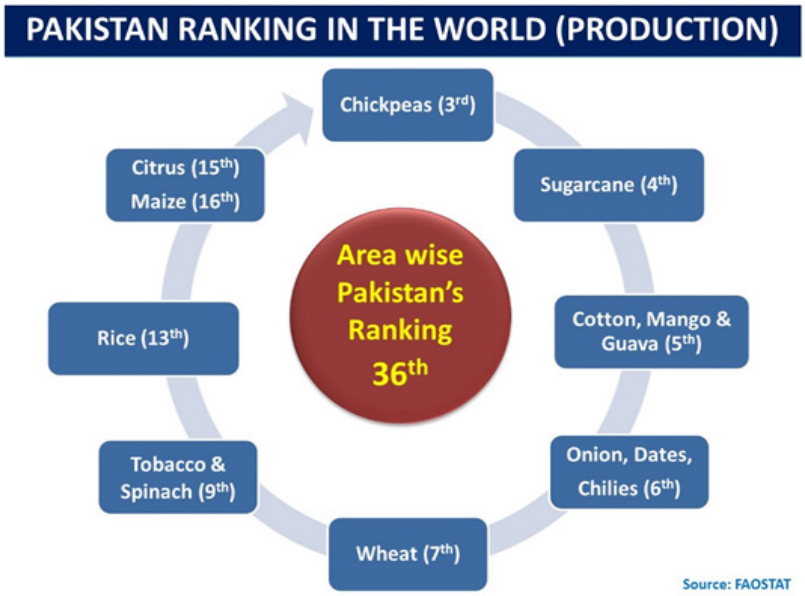
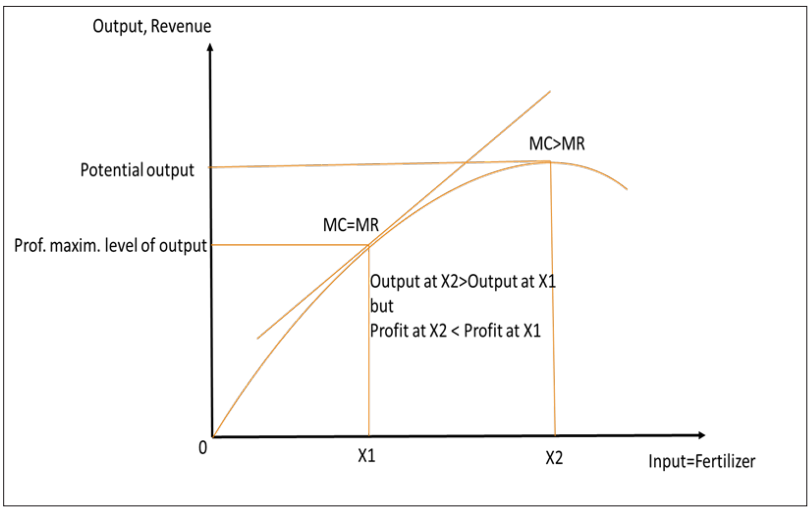


Figure 3.1 Pakistan Ranking in the World Production

3.3. Understanding the Scientific Production and Achievable Production

To explore the core question of why Pakistan's average crop productivity consistently falls below the world average, it's crucial to understand the difference between scientific potential (experimental optimal level of input use) and the profit maximization level of input use because experimental optimal is an unattainable at the farm level because of farmer's nature of profit maximization while the scientists goal is to achieve the maximum yield. At the experimental station, scientists attempt to maximize the yield by using different level of inputs. For example, maximum yield takes place at the X2 level of input but scientists did not incorporate the cost factor while the farmer's profit maximization level takes place at the X1 because the farmers have to pay for each unit of input (Figure 2). Hence, farmers compare marginal revenue with marginal cost to maximize their profit which takes place at the X1 level of input (Figure 3.2). New varieties in Pakistan are approved based on the criteria of the yield at their experimental potential if it is higher than the yield of the existing varieties it is approved, by knowing that these experimental (or potential) yields are not achievable at the farm level. Hence, new varieties failed to make a real change to the farmers' field by shifting the production frontier. Most probably, this is the reason why new varieties failed to achieve its objectives to enhance the yield of different crops in Pakistan at the farm level and the average yield of most of the crops in Pakistan are still below the world average. Moreover, crop production at the experimental stations takes place in controlled environments, affording researchers access to ideal conditions, unlimited resources of inputs such as fertilizers and pesticides, advanced mechanization techniques, and optimized farm management practices. In these controlled settings, researchers can achieve remarkably high yields for specific crop varieties. Consequently, when comparing crop production in controlled experimental settings to that of even the most advanced and progressive growers, the former consistently yields significantly higher results.



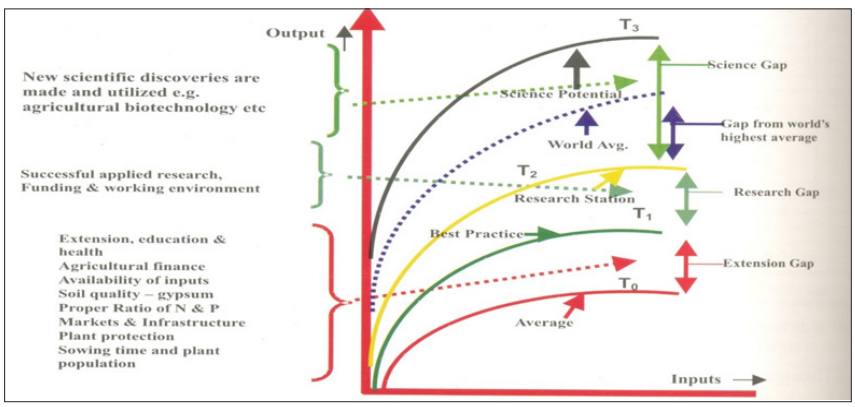
Source: Authors creation

Figure 3.2. Difference between Experimental (or Scientific) and Farm Level Potential

However, the real world is characterized by diverse landholdings and associated problems, particularly among small-scale farmers, as is typical in Pakistan's agricultural landscape. So, achieving such elevated levels of productivity becomes a formidable challenge.

The production gaps are usually divided in three main categories, extension gap, research gap and science gap as indicated in Figure 3.3. The extension gap is the gap between average farmers yield and progressive farmers yield. This gap can be bridged by improving the delivery of extension services, better access to finance and inputs, better access to markets etc. Bridging this yield gap often necessitates the implementation of policies and interventions aimed at providing small farmers with enhanced access to resources, technology, training, and financial support. These measures have the potential to empower small farmers to enhance their crop yields and improve their overall livelihoods.

Another crucial aspect that requires careful consideration is our research dynamics, which currently lag behind the global average production. This indicates that our scientific potential is below the world average, resulting in a significant disparity between global scientific potential and that of Pakistan. Therefore, it is imperative to reevaluate our entire research and development (R&D) system, especially the process of approval of varieties that need to liberalize.



Source: PIDE, 2004[17]

Figure 3.3 The Research Dynamics of Production

3.4. Evaluating the Contribution of R&D in Agricultural Growth

The impact of research and development initiatives is manifested in the overall productivity of the crops. To offer a comprehensive assessment of the impact of R&D on crop performance, a detailed examination of the growth in area, yield, and production growth has been conducted. This involved collecting and analyzing data on the area, yield, and production of various crops over the past forty-two years. Since FAO (2017)[18] has divided all food items into 12 different groups, we restricted our study to only important food groups and food items. In this study among cereals, we have studied wheat, rice, and maize as major cereal food crops while jowar, bajra, and barley as minor cereal crops. Among oilseeds, we considered mustard and rapeseed, sunflower, and cotton seed. Similarly, among the pulses group, we investigated gram, masoor, mung, and mash. Among the vegetables and fruit groups, the most commonly used vegetables (potato, onion, tomato) and fruits (apple, banana, citrus, mango, dates) have been explored. Among cash crops that also serve as food, sugarcane has been investigated. In addition to food crops, the livestock sector also significantly contributes to food. Therefore, milk and meat have also been analyzed.

3.5. The Growth Analysis of Major and Minor Cereals

It is important to note that the production growth is driven by the area and yield growth. The yield growth reflects the contribution of R&D while area growth is driven by the yield growth and profitability of the farmers. The profitability is based on yield and prices. Since, farmers are profit maximizer, higher profitability of a crop motivate them to allocate more area to that crop. The yield growth of wheat and rice are respectively 1.7, and 4.4 percent (Table 3.1). However, besides having positive yield growth rates of these grain crops, productivity is far below the world average and even of the neighboring countries such as China, Russia, and India. It is important to note that cereal crops cannot be compared with sugarcane in terms of area growth and profitability because of differences in crop duration. The duration of a sugarcane crop is one year while the duration of cereal crops is of only 4 to 5 months.

Maize stands at the top with a remarkable growth rate of production at 5.9 percent and a significant yield growth of 4.4 percent. The highest area growth of maize has been driven by its higher profitability, followed by rice and wheat. The notable success of maize production can be attributed to improved access to certified and imported hybrid seeds. Additionally, this crop has thrived under a market-driven approach without government intervention. Therefore, the experience with maize serves as a valuable example of efficient management for other crops that rely heavily on government support, particularly through support prices. The successful example of maize demonstrates that the strong hold of federal seed certification in controlling the imported and local seeds needs to be abolished to increase the role of the private sector in introducing hybrid seeds. Unless the seed sector is liberalized from different barriers, neither the private sector will invest in the development of new hybrid seeds within the country nor it will import high yielding varieties that can shift the Pakistan's production frontier above the world average.

[17] Ahmad, M., & Iqbal, M. (2004). Science and Technology Based Agriculture Vision of Pakistan and Prospects of Growth.
[18] FAO (2017). FAO/INFOODS Food composition database for biodiversity version 4.0 – BioFoodComp4.0. User Guide. Food and Agriculture Organization of the United Nations

Table 3.1 Exponential Growth Rate of Major and Minor Cereals (1980-2022)

Crops	Profit (Rs./acre) (2021-22)	Area	Yield	Production
Major Cereals				
Wheat	38,970	0.6	1.7	2.2
Rice	40,122 (48,741)	1.2	1.4	2.5
Maize	38,187*3= (114561)	1.4	4.4	5.9
Sugarcane	70,929	0.8	0.1	0.9
Minor Cereals				
Barley		-4	0.7	-3.2
Bajra		-0.3	1.5	1.2
Jawar		-2.4	0.3	-2

Data Source: AMIS

In contrast to major cereals, minor cereals exhibit negative growth of area and production with a positive yield growth. The negative growth of the area of Barley and Jawar is driven by the low profitability of minor cereal crops which are offsetting the positive growth of yield, making the production growth negative. But in the case of Bajra, yield growth (1.5 percent) is significantly higher than the yield growth of Barley (0.7) and Jawar (0.3) and this high growth of Bajra in yield is offsetting the negative growth of area to make the production growth positive. The analysis reveals that production growth of major cereals is all positive while the yield growth of minor cereals is negative except Bajra, implying that the primary focus of R&D remained on major cereals in the last 42 years. Low growth of Barley and Jawar led to the loss of comparative advantage of these crops in the cropping pattern which led to making the area growth negative of these crops.

3.6. The Growth Analysis of Fruits and Vegetables

Pakistan produces a large number of diversified fruits and vegetables based on season. R&D sector has introduced a diverse range of varieties which includes 109 and 130 different types of vegetables and fruit varieties, respectively[19]. Pakistan maintains year-round cultivation of approximately 29 types of fruits and 33 types of vegetables. However, it is worth noting that the majority of this abundant production is primarily consumed within the domestic markets. The production of fruits such as citrus and mango is not only the largest in terms of volume but also contributes to export revenue significantly. As of the latest data, Pakistan exported 622.1 thousand tons of fruit and 939.7 thousand tons of vegetables in FY 2021-22[20]. An overview of the growth performance of fruits and vegetables over the past four decades and two years is documented in Table 3.2.

The production growth is highest for apples (3.8 percent per annum) followed by mangoes (3.1 percent per annum) and dates (2.4 percent per annum). It is important to note that production growth is mainly driven by area growth because yield growth is either negligible or negative except in oranges where the yield growth is 1 percent per annum. However, area growth is not sustainable over time because the land resource is limited and cannot be expanded beyond certain limits unless an additional area will be extracted from the competing crops. The important point that needs to be highlighted in the analysis is the yield growth which is negative in most of the cases, implying that the contribution of the R&D sector in the case of fruits is negligible. This

indicates that resources have not been allocated to these high-value crops to increase their productivity which leads to either negative or stagnant yield growth of fruits. Hence, focus of investment in R&D needs to divert from grain crops to fruit crops by increasing the number breeders for fruit crops. The high positive growth of area of apples, mangoes, and dates, indicates that these fruit crops have a comparative advantage over other competing crops due to which these crops are fetching more area under cultivation. However, it appears that area growth under orange production is approaching to zero, making it a less attractive crop for the farmers. It might be that the comparative advantage of orange production is approaching close to other competing crops which makes farmers indefinite in making a clear choice between orange and other competing crops.

In the case of vegetables, production growth is significantly higher than fruits, implying that production of tomatoes, potatoes, and onions has increased at the rate of 4.5 percent, 6.7 percent, and 4 percent per annum, respectively during the last forty-two years (Table 2). These production growths are mainly driven by area growth, implying that additional production is mainly coming from the expansion of the area under cultivation which is not sustainable in the long run. However, the yield growth of tomatoes and onions is less than 1 percent which is negligible but in contrast, the yield growth of potatoes is 2.6 percent per annum which is significantly higher compared to tomatoes and onions. The high yield growth of potatoes is mainly the outcome of the industry and private sector linkages.

The introduction of fast food in Pakistan has significantly increased the demand for potato chips. With the ongoing production process, the agriculture sector could not meet the additional demand for potatoes for the fast food industry. Because of low yield, it was difficult for the agriculture sector to spare such a large area for potato production unless the fast food industry offers high prices to the producers. But at high prices it was difficult for the fast food industry to survive. Hence, fast food industry with the help of private sector introduced hybrid varieties of potatoes which increase the yield of potato many folds in the last two decades. The model again followed here is similar to that of maize. Hence, again it leads to the conclusion that engagement of private sector in the seed industry is the only solution to shift the production frontiers upward.

Table. 3.2 Exponential Growth Rate of Fruits and Vegetables (1980-2022)

Crops	Area	Yield	Production
Fruits			
Apples	5.7	-1.9	3.8
Mangoes	2.8	0.3	3.1
Citrus	0.7	1	1.7
Banana	1.7	-1.3	0.4
Dates	3.2	-0.9	2.4
Vegetables			
Tomatoes	4.2	0.3	4.5
Potatoes	4	2.6	6.7
Onions	3.4	0.6	4

Data Source: AMIS

[19] http://www.federalseed.gov.pk/
[20] https://mnfsr.gov.pk/SiteImage/Misc/files/Fruit%2CVegetables%20update.pdf

3.7. The Growth Analysis of Legumes

Pulses typically provide vital protein, minerals, vitamins, and dietary fiber for human nutrition. Simultaneously, they enhance soil fertility through nitrogen fixation and promote biodiversity. This dual benefit is why pulses are often regarded as intelligent crops, benefiting both human nutrition and the environment. However, the production of pulses falls significantly short of domestic demand, necessitating substantial imports to bridge the gap. Several factors contribute to this low production and yield of pulses in the country. But the key factor is the availability of high-quality seed to the farmers. Presently, approximately 80 percent of pulses are cultivated with home-produced seed i.e. saved from the previous years. Other significant factors responsible for inadequate production and yield are abiotic factors like drought, heat, and salinity, as well as biotic stresses such as weeds, diseases, and insect pests. Additionally, challenges related to soil, including marginal lands, alkaline soils with low organic matter, and erosion, further impact production. Climate change, the absence of crop-specific farm machinery, post-harvest losses, and marketing issues also contribute to these challenges[21]. The performance of R&D in terms of legumes has been analyzed over the last four decades and two years (Table 3.3).

The production growth of all legume crops discussed here is negative except moong which is reasonably high, 3.6 percent per annum. The high production growth of moong is driven by both area and yield. The yield growth of moong was initiated with the introduction of varieties developed by the Asian Vegetable Research Development Center (AVRDC) at the beginning of the 21st century. The high yield growth makes it profitable for the farmers and also creates a comparative advantage over other crops that leads to convincing farmers to fetch their area from other crops to allocate it for moong. Moreover, moong is mostly grown in irrigated areas which has high productivity but other legumes that are grown under dry conditions and thus have low productivity. The high profitability (Rs.26509/acre) of moong has made it the most lucrative option for farmers. Consequently, the positive results in terms of area expansion, production, and yield growth for moong are self-evident. On the other hand, crops with lower profits are naturally less appealing and convincing, and this is reflected in negative growth trends in both area expansion and production. The negative production growth is mainly driven by area reduction. Also yield growth is negative for gram and approaching to zero for masoor and mash, implying that these crops are losing comparative advantage mainly because of low yield. Thus farmers started to switch over to other crops because of the low profitability of legumes. The negative or near-to-zero growth rate of yield indicates the poor performance of R&D in the legume sector. Hence, without increasing the resources for R&D particularly for legumes it is difficult to revert the situation. The second option is to engage the private sector in importing the hybrid seed of legumes to increase their productivity so that the profitability of these crops can be increased which may lead to improving their comparative advantage.

Table 3.3 Exponential Growth Rate of Legumes (1980-2022)

Crops	Profit (Rs./Acre)	Area	Yield	Production
Moong	26,509	1.9	1.6	3.6
Masoor	9,575	-5.3	0.5	-4.7
Mash	12,320	-5	0.08	-4.9
Gram	6,575	-0.02	-0.5	-0.5

Data Source: AMIS

[21] https://www.researchgate.net/publication/342626740_Pulses_Production_in_Pakistan_Status_Constraints_and_Opportunities

3.8. The Growth Analysis of Oilseed Crops

Pakistan was self-sufficient in edible oil at the time of independence, but in later years, the country began to import edible oil in small quantities to support domestic production (Ali et al., 2008)[22]. From 1969-70, consumption of edible oil has grown at exorbitant rates, while domestic production failed to keep pace due to multiple reasons which include, poor quality seed, poor crop management practices, lack of specific seed drills, harvesting machines, and moving production towards marginal lands. Per capita use of vegetable oil has increased from 5.31 kg in 1973-74 to 20 kg in 2018 and is predicted to reach 22 kg by 2028, further worsening the demand-supply imbalance. Total consumption is projected to reach 6.5 million tons by 2028 (Rana et al., 2022)[23]. The value of the imports of edible oil is 43 percent of total food imports (US$7.57 billion) and is equal to 60 percent of the three-year International Monetary Fund (IMF) loan program of $6 billion. Hence, it is imperative to urgently reduce the dependency on imported edible oil to curb the foreign exchange deficit.

The government has taken several measures to address various issues within the oilseed sector. These initiatives include the establishment of a sub-group on oilseeds as part of the Agriculture Task Force and the formation of a committee comprising all stakeholders to engage in discussions on policy frameworks, domestic oilseed production, and the reduction of edible oil imports[24]. All these are cosmetic measures that cannot address the real issues.

The production growth is positive for all crops except soybean it is negative which is mainly because of drastic decline in area. In recent years, the area under soybean cultivation has drastically decline because crop has lost its comparative advantage due to unavailability of Genetically Modified (GM) seed in Pakistan (Table 3.4). The yield growth of rapeseed and mustard and soybean has increased in recent years because government has allocated significant resources to reduce the import burden of edible oil but yield growth of sunflower and sesame is still very low, implying that lot of work need to be done along these lines. The low yield growth of edible oil crops indicates the poor performance of R&D sector, federal seed certification and extension services and reflects the poor coordination across departments.

Table 3.4 Exponential Growth Rate of Oilseeds (1980-2022)

Crops	Profit (Rs./acre)	Area	Yield	Production
Rapeseed & Mustard	42,596	-1	1.4	0.4
Sunflower	45,416	7.3	0.5	7.8
Soybean		-15.3	1.6	-13.7
Sesame	20,621	3.2	0.4	3.7

Data Source: AMIS

[22] Ali, M., Arifullah, S., & Memon, M. H. (2008). Edible oil deficit and its impact on food expenditure in Pakistan. Pakistan Development Review, 47(4), 531–543. https://doi.org/10.30541/v47i4iipp.531-546
[23] https://shorturl.at/bhIU1
[24] https://www.finance.gov.pk/survey/chapters_23/02_Agriculture.pdf

3.9. The Monetization of Achievable Yield

Recognizing that the full scientific potential is not achievable in the real world, so more convincing aim should be to reach the highest attainable levels of production. The highest attainable production is often represented by the output of progressive farmers. Therefore, a practical approach involves elevating the average production levels to match those of progressive farmers and subsequently multiplying this by the prevailing per unit price to calculate the total attainable benefits. This section is dedicated to estimating the monetary value of achievable production, with a particular focus on major crops in Pakistan. Our estimation demonstrates that if we just increase the average yield of cotton, sugarcane, rice (IRRI), rice basmati, maize and wheat equal to the yield of progressive farmers, the total value of these five crops will increase from Rs.2562 billion to Rs.4284 billion which is equal to 67 percent increase (Table 3.5). This implies that if all farmers start to get the yield equal to that of progressive farmers yield in five major crops which is also achievable because these progressive farmers also operate in the similar environment then the contribution of these major crops in agriculture GDP will increase up to 67 percent.

Among these five crops, wheat and cotton stand out as the highest contributors, with anticipated gains of Rs.609 billion and Rs.546 billion, respectively (Table 5). The cumulative potential gain from achieving attainable yields in major crops amounts to Rs.1722 billion.

Table. 3.5 Potential GAIN from reaching Achievable Yield

Crops	Existing yield	Potential Gain (billion Rs.)	Difference	Percentage Change
Cotton	146	693	547	374.7
Sugarcane	443	592	149	33.6
Rice (IRRI)	138	298	160	115.9
Rice (basmati)	293	469	176	60.1
Maize	354	435	81	22.9
Wheat	1188	1797	609	51.3
Total	**2562**	**4284**	**1722**	**67.2**

Conclusion Recommendations

- There are three key sources of the yield gap. First, varieties are approved based on potential yield which is not achievable. Second, farmers don't have access to quality seeds which is ultimately reflected in the lower average production, third poor farm management practices due to the weak role of extension services. This yield gap can be bridged but it requires the implementation of policies and interventions focusing small farmers with improved access to resources, technology, training, and financial support.

- The condition of certification of local and imported seeds need to be abolished so that seed market can expand and flourish. Imported hybrid seed of different crops have high potential and can play a significant role in shifting the production frontier upward. However, seed supplier need to bind with registration and true labelling.

- The yield growth of majority of the crops is negligible or negative except grain crops where government is mainly focusing while developing priority of R&D. Without shifting the concentration form grain crops to other crops and without liberalizing the seed sector it would be impossible to enhance the productivity and investment in R&D sector.

- Improving the performance of agricultural R&D in Pakistan is a long-term endeavor that requires sustained commitment of allocation of resources, which can develop a more resilient and productive agricultural sector that benefits both farmers and the country as a whole.

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