SBP Staff Notes

02/22

Investigating Pakistan's Seed Industry Dynamics

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June, 2022

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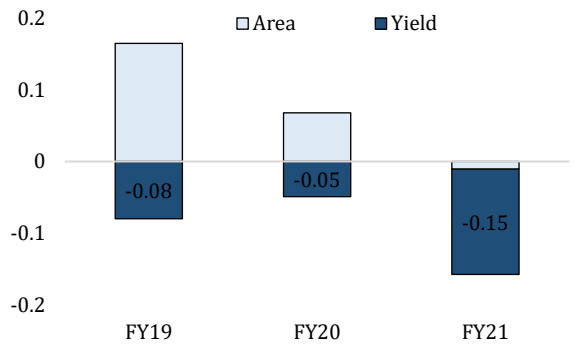
1. Introduction

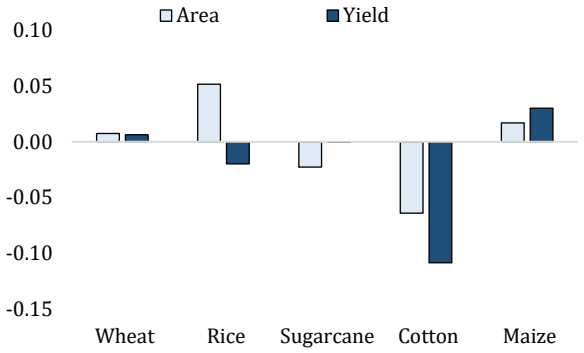
Agriculture sector is considered to be the backbone of Pakistan's economy. It accounts for around 19.0 percent share in the GDP, absorbs above 40 percent of total labor force, and contributes about 50 percent in industrial production as well as more than 55 percent in total export earnings.[1] Despite its importance for overall economic growth, agriculture contribution in GDP growth is modest, mainly because of declining yields of important crops since past few years. The contribution of important crops in overall GDP growth has remained volatile. Specifically, during FY19-21, important crops have led to on average 10.3 bps reduction in real GDP growth, which was mainly driven by declining yield of these crop. Specifically, the decline in cotton yield was the most pronounced (Figure 1&2). Sustained increase in crop production and productivity requires timely supply of essential inputs, especially quality seeds. However, the seed supply system in Pakistan is grossly underdeveloped leading to a significant gap in the availability of quality seeds – the availability of certified seeds could meet only 40.6 percent of the seed requirement in the country during FY19-20.[2,3] In this background, this note investigates the dynamics of Pakistan's seed industry, and highlights key reform measures that could address the declining trend in crops growth, with a special focus on cotton crop.

Figure 1: Important Crops Contribution in GDP Growth (percentage points)



Source: SBP calculations based on MNFSR data

Figure 2: Crop-wise Contribution in GDP Growth - FY19-21 (percentage points)



Source: SBP calculations based on MNFSR data

The yields of almost all major crops have also been impacted by climate change in the recent years that necessitates the development and distribution of new seed varieties to suit varying weather conditions. Sustained increase in crop production and productivity requires timely supply of essential inputs, especially quality seeds. The quality and quantity of seeds play an integral role in enhancing agricultural output and improved cultivars are a highly effective means of increasing agricultural productivity [Alston et al. (2000), Chauhan et. al, (2015), Evenson and Gollin, (2003)]. Ali (2016) and Paroda (2013) highlight that crop yields can be increased by up to 15-20 percent only by using good quality seeds and up to 45 percent by effective use of other inputs such as fertilizers, pesticides, and irrigation. The use of low-quality seeds negatively impacts crop yields.

[1] Source: Pakistan Bureau of Statistics
[2] Source: FSC&RD.
[3] FSC&RD estimates seed requirement based on the area under crop cultivation; this does not represent underlying demand for certified seed.

According to our findings, the efficiency of the seed market in Pakistan is marred by a range of supply and demand side issues.[4] Supply-side factors mainly include: inadequate and delayed legislation that marginalized the role of private sector; lack of Intellectual Property Rights (IPRs) protection that discouraged foreign investment; financial constraints and lack of required infrastructure that impeded Research & Development (R&D) activities in the public sector; political pressures; poor governance; administrative issues in public sector seed institutions causing weak regulatory enforcement leading to wide scale profusion of spurious seeds especially for Genetically Modified (GM) cotton crop. All these factors have constrained the development of a dynamic seed market in Pakistan.

In addition, the fiscal devolution in 2010, further aggravated the situation because of lack of clarity on legislative roles of provincial and federal governments. In the absence of clarity about institutional framework, seed development and distribution mostly took place in the informal sector for a number of years following decentralization. On account of the weak regulatory structure, the multinationals have avoided transferring their R&D setup to Pakistan for seed development, which has further weakened the capacity of seed supply system of Pakistan. On the demand side, economic, social and behavioral factors are largely responsible for the low demand of certified seeds. In addition, the weak role of agriculture extension services departments also led to lower use of quality seeds. On account of these supply and demand bottlenecks, Pakistan seed market evolution has not kept pace with developments in the global seed market, which has experienced sharp increase in the development and adoption of high yielding hybrid and Genetically Modified (GM) seeds for crops and vegetables.

Pakistan's experience GM cotton reflects poor implementation and partial failure of the legal framework of the seed sector and hints the need to redesign the seed market to ensure improved production and provision of high quality seeds with key focus on the following: (i) completely overhauling the seed industry legal and institutional framework to address various governance and administrative issues. Given the wide spread use of uncertified seeds, and farmer's indifference, the seed certification regime may be completely abandoned, while the regulator focus should be shifted on containing the spread of sub-standard seeds; (ii) addressing financial and human resource constraints of public sector institutions; (iii) provision of monetary and fiscal benefits to the seed sector to encourage investment in R&D activities and to incentivize joint partnerships with MNCs; (iv) ensuring strict enforcement of seed regulations and IPRs; (v) upgrading provincial Agriculture Extension services departments to improve service delivery; (vi) strengthening evaluation of imported seeds; and (vii) monitoring seed prices to discourage sharp fluctuations.

The note is structured as follows: Section 2 discusses the structure of Pakistan's seed market; Section 3 presents the key trends in important crops yields and production and seed availability situation in Pakistan; Section 4 investigates Pakistan's experience with GM seed technology in cotton and identifies major seed market issues that led to failure of cotton crop and the final section concludes the note with policy recommendations.

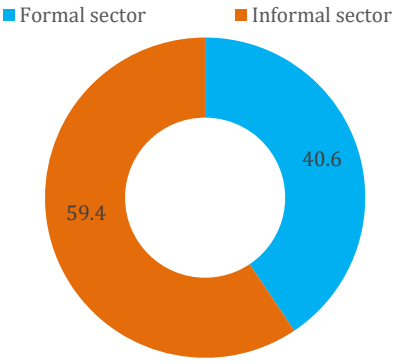
[4] To understand Pakistan's seed industry dynamics, we also conducted interviews with various private and public sector representatives operating in the seed sector, including government officials, local and multinational seed companies and farmers.

2. Structure of Pakistan's Seed Market

2.1 The Formal Seed Market of Pakistan

The formal seed sector of Pakistan comprises of private and public sector institutions and entities, which involve in various seed related operations such as research and development of new varieties, multiplication and distribution of authorized seed varieties, with the public sector's additional role of the overall regulation of the seed market. Thus, in the formal seed sector of Pakistan, the major entities include public sector seed corporations (mainly Punjab and Sindh Seed Corporations), regulatory organizations like Federal Seed Certification & Registration Board (FSC&RD), National Biosafety Committee (NBC), research institutions including Pakistan Agriculture search Council (PARC) and Pakistan Central Cotton Committee (PCCC), private seed companies, and input dealers.

Figure 3: Sources of Seed Availability - FY19-20 (shares in percent)



Source: FSCRD

Seed development in the public sector. Various research institutions at federal and provincial levels undertake research activities to develop high-yielding seed varieties. At the federal level, the main agricultural research centers include Pakistan Central Cotton Committee (PCCC), Pakistan Agricultural Research Council (PARC), and research institutes of Pakistan Atomic Energy Commission (PAEC). While at the provincial level, Ayub Agricultural Research Institution (AARI) in Punjab is the leading organization in plant breeding and development of new seed varieties. In addition to these public research institutions, academia is also playing a significant role in development of agriculture and horticulture activities, with University of Agriculture, Faisalabad (UAF) being the largest University.

Table 1: List of Multinationals operating in the Seed Industry of Pakistan

Sr#	Multinationals	Operations started	Hybrid seeds introduced
1	Monsanto Pakistan Agri. Tech.	1984	Wheat, Cotton, Maize, Rice, sorghum
2	Pioneer Pakistan Seed	1989	Maize, sorghum, Wheat
3	Syngenta Pak. Seeds Pvt. Ltd.,	1991	
4	ICI Pakistan (Pvt.) Ltd.	1996	Canola
5	Bayer Crop Science Pakistan	1999	

Source: FSC&RD, Rana *et all* (2015)

Private sector has gradually increased its share in seed varieties development. With growing financial and management difficulties in the public sector institutes as well as the expansion in the private sector, the role of the former in seed development has been overtaken by the latter. Specifically for the crops of cotton, maize and rice, a large share of seed requirement is met by private sector. The private sector is dominated by local seed producing and distribution companies along with the thin presence of MNCs. Four of the total five multinationals operating in Pakistan, namely Bayer, ICI, Pioneer, and Syngenta started their operations in the country in the 1990s, while Monsanto launched its operations in 1984 (Table 1). It is important to note that these MNCs have played a pivotal role in introducing the hybrid seeds. Monsanto and Pioneer introduced the hybrid seeds of maize and sorghum, while Canola hybrid seeds were

introduced by ICI. Pioneer and Monsanto also invested in the development of high yielding seeds of major crops of wheat, cotton, and rice in the 1990s, but ultimately withdrew due to germplasm safety issues. The current R&D programs of these MNCs manly focus on screening and testing imported seeds before introducing them to Pakistan.

2.2 Informal Sector

The informal sector dominates the seed supply in Pakistan. The informal seed sector in Pakistan comprises of: farmers saving their seeds for planting in future; sale of seed in brown bags on a medium to large-scale; non-commercial seed exchange between farmers; and small-scale sale by farmers-to-farmers with the first two accounting for the majority of the informal sector [Rana et. al (2015); Huda et. al (2011)]. Within the informal sector, the seed supply relies on traditional channels of exchange as well as information between farmers. In addition to cash transactions, seed exchange for labor, seed swaps, and in-kind seed loans are few of the mechanisms of seed trading (Ali and Ali, 2004).

Provision of uncertified seeds. Uncertified seeds are usually sold in brown bags from a number of key actors in the seed industry, ranging from seed companies and agricultural input dealers. Hence, there is almost no indication or guarantee of the quality or source of the seed. Seed companies also at times sell uncertified seeds in company packaging to avoid seed certification process. Even some public entities and research institutes provide uncertified seeds of non-registered varieties to the market. This is usually done for a profit motive. The unscrupulous elements in the public research institutes prematurely release varieties to take benefit of high/unregulated seed prices.

Key factors determining demand for certified seeds. The farmers' access and affordability and the availability and adequacy of desired quality seeds formulate a demand-supply scenario in the seed system. On the demand side, a number of social and behavioral factors, ranging from farmers' age as well as the willingness to adopt improved technology, risk preferences, level of education, income, assets, and wealth levels, exposure to peer effects, access to credit and information, distance to and from the market, type (joint or nuclear) and size of family among other reasons influence the adoption of certified seeds [Ali et. al, (2015), Rana et. al, (2015)]. Baglan (2020) et al has identified crop profitability, access to financing, and farmers' education as the key determining factors of adoption of certified seeds, while the distance from the market as the negative determinant of the adoption of certified seeds. Iqbal (2001) et al., identified overall landholding size, level of education, and area under crop cultivation as the significant factors to determine the adoption of certified seeds. They found ownership of tractor and irrigation source being positive but insignificant factors while farmer's age and tenancy status and tenure as less constraining factors.

Key supply side impediments in Pakistan's seed market. On the supply side, Pakistan's public and private sector have been unable to supply certified seeds of the required quality and quantity to the market, especially to small-scale farmers who constitute 90 percent of all farmers in Pakistan [Malik et al, (2016), Rana et al, (2015)]. There is a significant gap in the requirement and supply of high-quality seeds, which ultimately leads to low crop productivity.

3. Important Crops Yields and Seed Availability in Pakistan

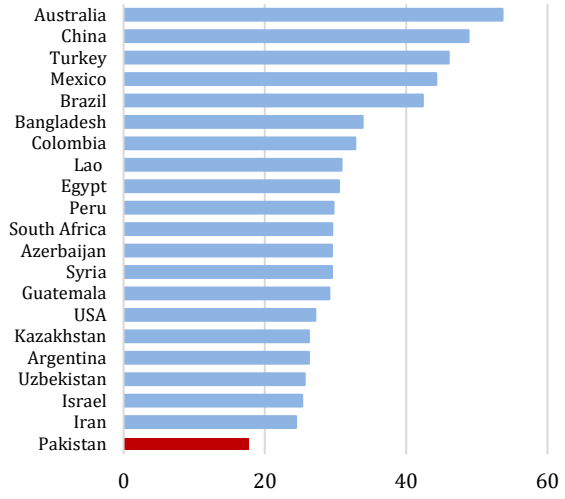
3.1 Trends in Important Crops Yields & Production

The crop sector has around 35.9 percent share in agriculture and 6.8 percent share in GDP. This sector includes sub-sectors of important and other crops along with cotton ginning. Important crops which include wheat, rice, cotton, sugarcane and maize have combined contributions of around 22.3 percent and 4.2 percent in overall GVA of agriculture and real GDP, respectively.

Important crops contribution in GDP growth remained negative during FY19-21. The contribution of important crops in overall GDP growth has remained volatile during past ten years. During FY19-21, important crops have led to on average 10.3 bps reduction in real GDP growth, which was mostly driven by declining yields of these crops. Among this group, the decline in cotton yield was most pronounced, which alone led to 10.9 bps reduction in GDP growth in these years. However, this impact was somewhat offset by improvement in area of rice and maize. The adoption of high yielding hybrid seeds has led to significant yield gains for the crops of maize and rice, whereas the yield of wheat crop is significantly below potential because of lower usage of certified seeds. In the recent years, the yields of almost all major crops have experienced declines because of climate change that necessitates the development and distribution of new seed varieties to suit varying weather conditions.

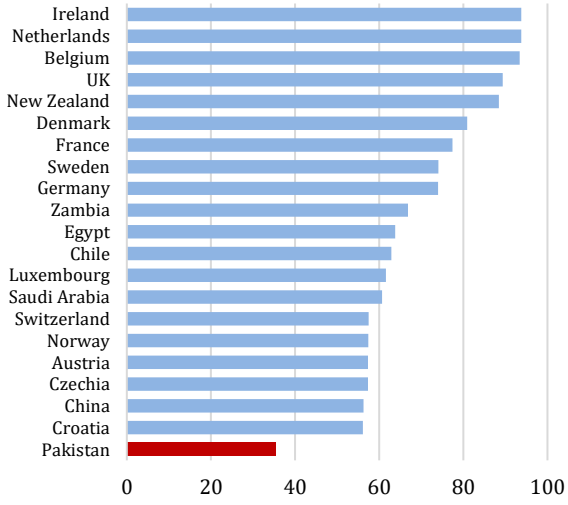
The average yields of important crops in Pakistan are significantly lower than the yields of the indigenous progressive farmers and the world's highest averages[5] (Figure 4-9). The yield gap is arising from a host of factors like inadequate accessibility as well as affordability of quality inputs like certified seeds, traditional methods of cultivation, water shortages, climate change, , imbalanced use of fertilizers and pesticides, below par extension services, poor regulatory oversight by relevant departments, etc.

Figure 4: Cotton Yield - International Comparison (HG/000 hectares)



Source: FAO

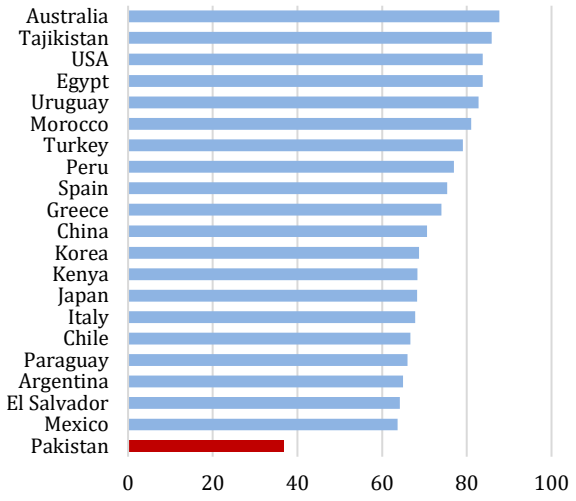
Figure 5: Wheat Yield - International comparison (HG/000 hectares)



Source: FAO

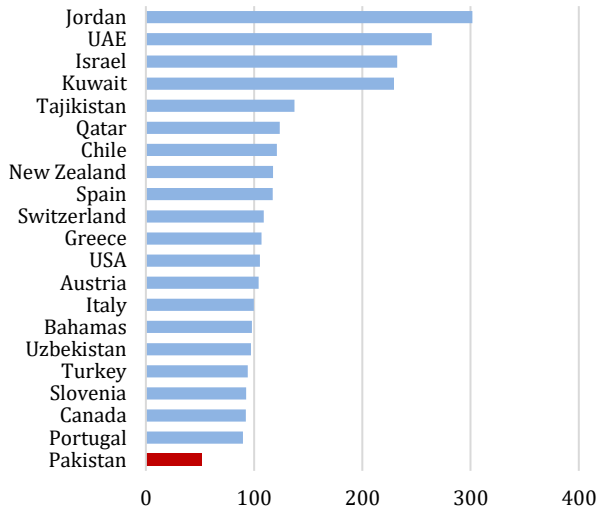
[5] Graph 6-8 compares the yield levels across the top ten producers of major crops of wheat, rice and sugarcane.

Figure 6: Rice Yield - International Comparison (HG/000 hectares)



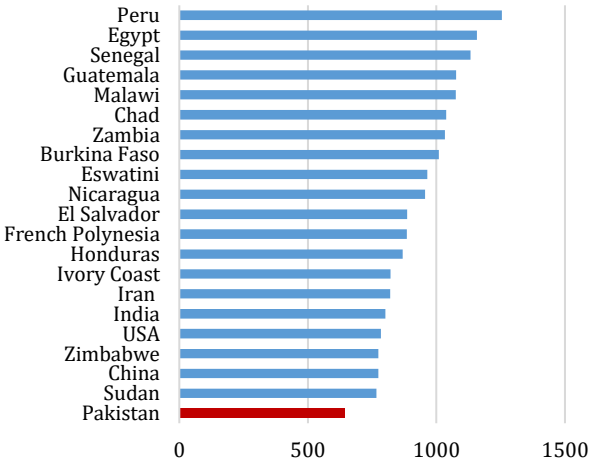
Source: FAO

Figure 7: Maize Yield - International Comparison (HG/000 hectares)



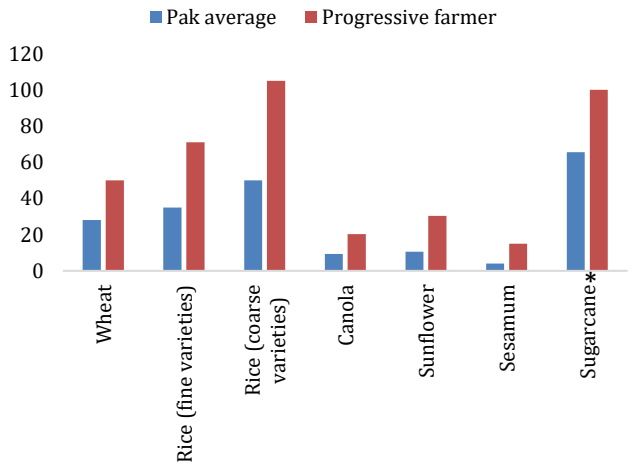
Source: FAO

Figure 8: Sugarcane Yield - International Comparison (HG/000 hectares)



Source: FAO

Figure 9: Yield (Mound per acre) Gap Between Progressive Farmer and Pak-Average



*Yield is tens of mound per acre
Source: MNFSR

3.1. Seed Availability Situation in Pakistan

Pakistan's crop sector is marked by low usage of certified seeds and a large gap between total seed requirement and availability. According to MNFSR estimates, the certified seeds met 40.6 percent seed requirement during FY19-20 (Table 2), while the rest of the demand was met through informal sources, which include farmers saved seeds and uncertified seed provided by seed companies and agriculture input dealers. A range of factors

including low availability of certified seeds, lack of information and lengthy variety approval process all lead various seed market players to operate in the informal market. However, the quality of uncertified seeds is a source of concern. According to market sources, while some of the uncertified varieties produce high yields, there is a significant presence of spurious seeds in the market for important crops like cotton, wheat and rice. On the other hand, the quality of old farms-saved seeds used by the farmers also gets eroded because of improper storage facilities. The use of these adulterated and low quality seeds results in poor germination rates and low immunity in plants against disease and pest infestation.

Table 2: A Summary of Seed Availability vs Requirement

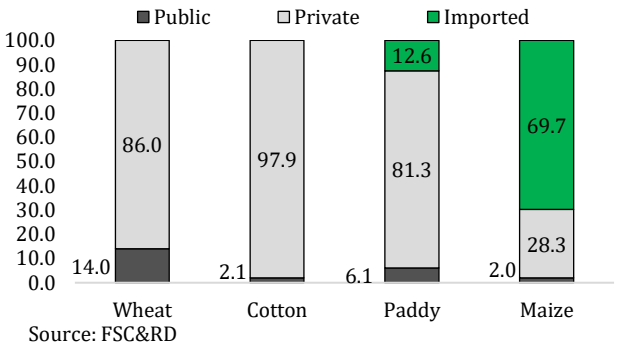
	FY16		FY17		FY18		FY19		FY20	
Crop	Available (1000 MT)	Percent of Required	Available (1000 MT)	Percent of Required	Available (1000 MT)	Percent of Required	Available (1000 MT)	Percent of Required	Available (1000 MT)	Percent of Required
Wheat	421.6	38.6	476.3	43.6	438.9	39.7	483.4	44.3	513.5	47.7
Cotton	44.1	79.7	29.4	73.4	55.8	95.5	65.9	115.2	33.0	72.3
Paddy	51.7	93.6	59.6	107.9	71.8	131.1	82.9	195.5	63.8	144.5
Maize	33.9	101.9	20.5	61.8	23.4	66.7	22.2	67.7	15.6	47.2
Pulses	3.2	6.6	5.4	11.2	3.3	7.7	2.3	5.4	2.8	6.6
Oilseeds	0.6	5.8	0.4	3.9	0.5	4.7	0.9	8.2	1.7	15.5
Vegetables	10.1	120.5	11.6	138.6	12.5	149.4	11.1	132.0	4.2	49.5
Fodders	36.5	59.7	40.8	66.8	44.3	72.5	78.1	127.7	26.5	43.3
Potato	6.8	1.8	7.1	1.9	7.1	1.7	5.7	1.4	6.0	1.4
Total	608.6	35.0	651.3	35.8	657.7	36.7	752.4	42.7	667.1	38.4

The availability of certified seeds showed little improvement during FY16-20. With the exception of paddy, certified seed availability showed sluggish improvement for other crops. The availability for cotton crop showed large fluctuation, with steep increase in FY18-19 followed by a large decline in FY20.

Private Sector is the Main Supplier for Certified Seeds

- The share of public sector in certified seed supply for cotton and maize is almost negligible (Figure 10).

Figure 10: Private Sector is the Main Supplier for Certified Seeds (FY16-20 Average)



Source: FSC&RD

- Maize crop mostly depends on imports for the certified seed requirements. This is because maize farmers have switched to the use of hybrid seeds to benefit from higher yields. However, these seeds are not available locally and are imported by the big MNCs. These companies have not transferred the seed development technology to Pakistan because of the absence of IPRs protection.

- The certified seed supply for paddy also largely comes from private sector, with a notable share of imports. This import dependence arises from the use of hybrid seeds. However, encouragingly the private sector is also involved in domestic production of these rice hybrid seeds.

- For the wheat crop most of certified seed is provided by the private sector.

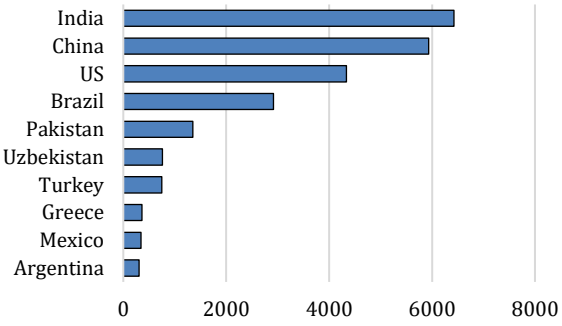
4. Pakistan's Experience with GM technology in Cotton – Causes of Failures

This section investigates Pakistan's experience with Bt cotton, and identifies the key factors leading to sharp decline in cotton crop yield in Pakistan, in the recent years.

4.1 A Peer Comparison of Pakistan' Cotton Crop Performance:

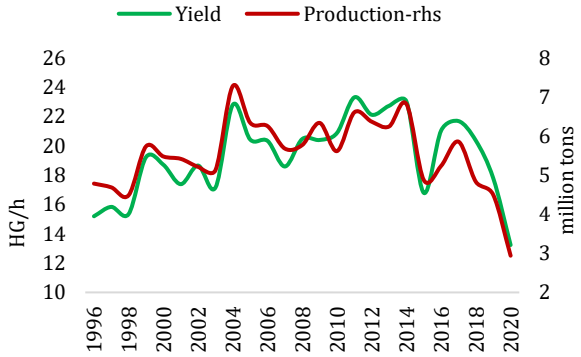
Pakistan is among the world's top five producers of Cotton (Figure 11). India is the world's largest producer of cotton, followed by China, the US, Brazil and Pakistan. Pakistan's cotton production showed some improvement during 2001-15, before starting a declining trend after 2015, reaching the lowest yield level among top five producers in 2020 (Figure 12 & 13). On the other hand, cotton production in India is increasing since 2010, reaching the world's highest in 2019, leaving China behind.

Figure 11: World Top Ten Producers of Cotton 2019-20 (1000 MT)



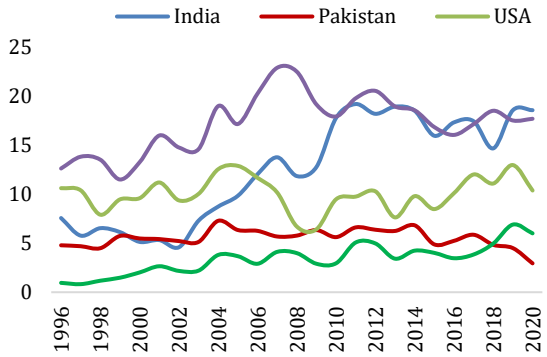
Source: statistica.com

Figure 12: Pakistan - Cotton Crop Performance



Source: FAO

Figure 13: Pakistan Cotton Crop Production Comparison With Peers (million tons)



Source: FAO

Yield comparison among international peers.

- ***China and Brazil have witnessed sustained increases in cotton yields and enjoy very high productivity compared to other countries.*** Specifically, the average cotton yields in these two countries were 79.2 percent higher than Pakistan, during 2010-20.

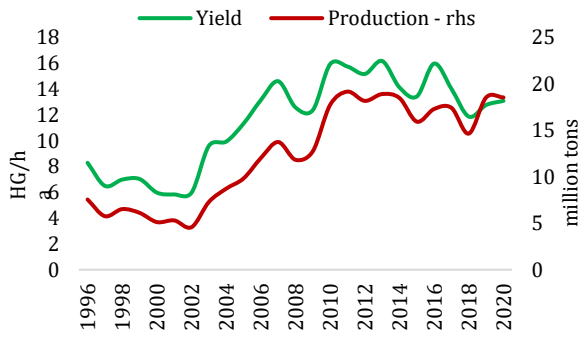
- ***Yield gains in China were mainly led by adoption of intensive farming techniques, which included, seedling transplanting, double cropping, plastic mulching, etc.,*** in addition to the use of Bt cotton, which reduced the incidence of bollworm infestation in the cotton crop [Dia J. and Dong H. (2013)]. Unlike the experience of other countries, who adopted the Bt cotton technology developed by Monsanto,

the Bt cotton introduced in China was home- grown. This technology was first introduced in China in 1997, reaching almost complete adoption in 2012.[6]

- ***The cotton yields in the US appear to have stabilized, with an average 2.7 percent increase during 2010-20.*** The commercial plantation of Bt cotton was allowed in the US in 1996. However, the yield gains appear to be modest. The literature highlights that changing weather patterns, new pests, focus on developing value addition traits in cotton and lack of focus on yield improvement has led to stagnation in yield levels [W.R. Meredith, Jr. (2000)].

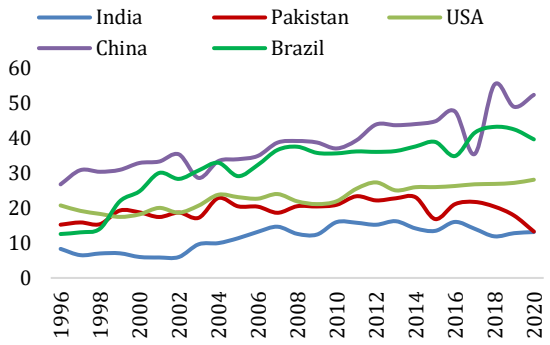
- ***The adoption of Bt cotton variety led to significant gains in production in the case of India (Figure 34).*** The commercial plantation of Bt cotton was allowed in India in 2002. The area under Bt rose from 0.4 percent in 2002 to 36 percent by 2006 and almost 95 percent in 2014. The yield of the cotton crop also witnessed around 8.5 percent average increase during 2002-14. With impressive yield gains in the initial years after the introduction of Bt cotton, the area under cotton crop also increased, which helped India to achieve the status of the world's largest cotton producer by 2019. However, the yield losses in the recent years resulted from changing weather patterns, new pests and lack of focus on R&D for yield improvement and germplasm development [Kouroudis, S. (2020)].

Figure 14: India - Cotton Crop Performance



Source: FAO

Figure 15: Pakistan Cotton Crop Yield Comparison With Peers (000 hg/ha)



Source: FAO

- ***Pakistan experienced improvement in cotton yield initially, before the crop yield fell to the lowest among top five producers (Figure 15).*** The commercial planation of Bt cotton was allowed in Pakistan in 2010-11 season, however, this technology had been illegally transferred to the country since early 2000s [Malik & Ahsan (2016), Abdullah, A. (2010)]. On account of lower cost of crop management because of pest resistant nature of the seed and lack of knowledge among farmers about the issues associated with these varieties, almost 95 percent of the entire area under cotton crop cultivation shifted to Bt varieties in Pakistan in few years [USDA (2017)]. According to literature the use of Bt varieties had positive impact on cotton yield in Pakistan because of its resistance against bollworms. [Bakhsh

[6] Source: https://allianceforscience.cornell.edu/blog/2018/09/gmo-cotton-prompts-dramatic-drop-chinas-pesticide- use/

(2016), Nazli et al (2010), Abdullah (2010), Ahsan and Altaf (2009)]. Pakistan witnessed 3.7 percent average increase in cotton yield during the period of 2004-15. However, a confluence of factors including poor enforcement of seed sector rules/regulations, spread of spurious seeds, development of resistance in pests, lack of R&D for variety development, changing climatic conditions, etc., led to significant decline in yield after FY15.

4.2 Reasons of Cotton Crop Failure in Pakistan

4.2.1 Background:

***Pest attacks is one of the major factors limiting cotton yield in Pakistan*:** The major challenges restraining cotton yield in Pakistan include: Higher intensity of pest attacks, Cotton Leaf Curl Virus disease (CLCuV), Pink bollworm infestation of the crop, climate change, limited water availability, shortage of good quality seeds, seed adulteration, cotton marketing issues, etc. Specifically, pest attack is one of the major impediments of the cotton crop. In Pakistan, 27.4 percent yield losses were reported because of pest attacks in the year 2016, whereas the crop again witnessed 25.5 percent yield losses during 2020. According to an estimate, cotton crop consumes highest volume of insecticides and pesticides internationally and in Pakistan around 60 percent of the overall pesticides used is directed towards cotton crop [Babar et al (2020) and Malik & Ahsan (2016)].

***Pest resistance properties of Bt Cotton*:** The development of Bt cotton is a major advancement in the field of biotechnology in agriculture research, because of its pest resistant properties [Ahsan and Altaf (2009)]. Cotton infestation with bollworms was an important factor leading to substantial yield losses in various countries around the world in the decade of 90's. Hence, the Bt cotton resistance against this pest was a significant technological achievement, which also caused a decline in the use of pesticides in the crop areas under Bt varieties [Sahai (1999)], Limin et al (2018)].

***Delayed commercial adoption of Bt cotton in Pakistan*.** This technology was developed by Monsanto (a multinational company who is the global leader in GM seeds) [Spielman et al (2015)].[7] However, Pakistan was slow in allowing commercial planation of Bt cotton. The GM cotton was first allowed for commercial plantation in the US in 1996. Despite the international availability of Bt cotton variety since 1996, the commercial planation of Bt cotton was allowed in Pakistan in 2010-11 season, as the the government avoided violation of Monsanto's IPRs, which expired in 2010, giving way for official approval of the variety in Pakistan. On the other hand, India started commercial cultivation of Bt cotton as early as in 2002, to discourage the informal use of this technology.

***Informal transfer of Bt technology to Pakistan*.** In the absence of official approval, Bt cotton technology was informally transferred to the Pakistan's market around early 2000s [Malik and Ahsan (2016), Abdullah, A. (2010)]. Bt cotton was initially planted on a small scale, and on its success against pest attack, its planation grew rapidly. The farmers and a number of seed companies produced their local variants, by crossing the Bt material with indigenous varieties. The pest resistant properties of Bt cotton attracted a large number of growers because of lower cost of crop management. Also the growers were not aware about the potential issues that could emerge with the increasing use of these varieties [Rana (2013)]. Hence, almost 95 percent of the entire area under cotton crop cultivation had shifted to Bt varieties in Pakistan in few years [USDA (2017)].

[7] This initial variety had noticeable success in controlling various bollworm pests but less effective against cotton leaf worm and fall armyworm. A more robust variety i.e., Bollgard II® was introduced by Monsanto in 2002, which was effective against pink and American bollworm as well as cotton leaf worm and fall armyworm [Spielman et al (2015)].

The use of Bt varieties had positive impact on cotton yield. Various studies have been conducted in the literature to assess the impact of Bt cotton varieties on crop yield. The results of some studies for Pakistan found that the use of Bt varieties had positive impact on cotton yield, as they were found resistant against some types of pests, particularly bollworms [Bakhsh (2016), Nazli et al (2010), Abdullah (2010), Ahsan and Altaf (2009)].[8] However, since these varieties were illegally transferred to Pakistan and were not completely suitable for the country's climate, they showed little or no resistance against some other important cotton crop pests like Cotton Leaf Curl Virus, Mealy Bugs [Abdullah (2010), Ahsan and Altaf (2009)].

4.2.2 Factors Leading to Cotton Yield Losses

A number of studies and interviews with market players suggest that weak regulations, slow evolution of seed laws and absence of R&D in the formal sector were the key factors that led to the failure of cotton crop, as discussed in the following.

Spread of poor quality Bt cotton seeds. In the absence of officially approved varieties as mentioned earlier, the market saw proliferation of uncertified varieties of all qualities. These seeds were developed by both private and public sector plant breeders. Most of the quality concerns for Bt cotton seed used in Pakistan emerge because of following factors.

- The strength of Bt trait in a cotton seed has implications for the development of resistance in pests. A threshold level of Bt gene is very crucial; lower level of genetic strength may lead to the development of cross resistance [Ferrie and Van Rie (2002)]. In the case of Pakistan however, most of the seed development occurred in the informal sector that did not follow the required protocol for seed multiplication, and released premature varieties to make short-term profits leading to yield losses.[9] [10] According to a survey conducted in Sindh and the Punjab to assess the level of gene expression, only 42 percent of the samples in Sindh and 36 percent in Punjab had presence of required level of toxic Protein [Ali et al (2010)]. This practice led to loss of genetic potential of the Bt variety grown in Pakistan, after witnessing yield gains for some years.

- Mixing of poor quality of seeds, seed contamination, and unsuitable crop management practices also led to decline in crop yields.

- The over-reliance on a single technology, resulted in development of resistance in insects, specifically Pink Boll Worm, over the years [USDA (2016)].

The movement in seed prices remains unchecked. According to market sources, the new varieties developed by public and private breeders are introduced at exorbitantly high prices in the informal market. Some of the varieties developed in the public sector research institutes are leaked prematurely by vested interest groups for

[8] A study conducted on cotton farmers in Punjab found that cotton yields were 50 kg/acre higher for Bt cotton farmers, whereas average household incomes of adopters were between Rs. 16,500 and Rs. 17,500 higher than non-adopters [Ali and Abdulai (2010)].
[9] A one percent loss in purity lead to 0.5 – 0.9 percent reduction in yield losses. A farmer abandons the cultivation of varieties giving 9 percent yield losses [Rana (2010)].
[10] The development of Bt cotton seeds requires a series of backcrossing to introduce the desired genetic properties tovarieties of good agronomic characteristics. Backcrossing involves the transfer of desired trait from one variety into avariety bearing high agronomic traits within seven seasons [Showalter A. et al (2009)].

a profit motive, taking benefit from a weak regulatory infrastructure and farmers' ignorance. On the other hand, there are no provisions in the Seed Act and no control with FSC&RD to check seed prices.

Collusion between seed market players. According to market sources, the private seed companies earn huge profits by selling unregistered seeds in the informal market. These firms collude to ensure continuity of the current weak regulatory setup and are against any efforts to allow entry of MNCs in seed development in Pakistan, as they make profits by introducing copies of advanced technology seeds developed by these companies internationally. According to market sources, most of the seed companies are owned by influential people, hence field inspectors cannot report use of adulterated seeds in the farms. The farmers are left at the mercy of various seed providers including seed companies, dealers, wholesalers and retailers, big farmers, and unscrupulous elements in public sector who join the business of seed multiplication, to take benefit of the framer's ignorance about the seed quality.

Regulatory failure to check the spread of Bt cotton seeds of unknown quality. The legal framework must ensure smooth availability of high-quality seeds to farmers and check the spread of seeds of unknown quality. The GM crops are subject to strict regulations, implemented by an extensive legal framework, internationally. However, in the case of Pakistan, the Bt cotton spread through the informal sector remained unchecked as FSC&RD does not have the required human and financial resources to inspect the vast seed farms of a number of plant breeders for certification.

Inadequate role of agriculture extension services. Extension departments are primarily responsible for the dissemination of information for improving agriculture practices to obtain high yield and production by making the farmers aware of new technologies/better inputs and motivating them for adopting these [Shahbaz, B., and Ata, S. (2014)]. As the Bt technology was transferred through informal sector, the government institutions did not provide stewardship for the required crop management practices. The Bt varieties were produced by cross pollinating with local varieties of varying characteristics. These mix pollinated varieties have different picking time, and the farmers did not have knowhow of the required crop management practices. In this regard, the role of agriculture extension department also remained less than adequate. According to a survey conducted on Sindh cotton farmers, only 16 percent farmers reported having received extension advice from Extension Wing of the Sindh Agriculture Department, while 91 percent of the farmers reported to have never attended any workshop conducted by the Sindh Agriculture department. Furthermore, the evidence indicates that extension services in both public and private sectors target large and medium scale farmers, but seldom reach small and resource poor farmers that constitute overwhelming majority of around 90 percent (Shahbaz and Atta, 2014). The performance of extension services provided by private sector was found to be relatively better [Rana (2013)]. According to market sources, the extension departments have remained ineffective in achieving their core objectives due to factors like inadequate work force, lack of specialized knowledge, absence of effective monitoring and evolution system. So with inadequate access to extension services a large share of farming community remain unaware about the availability of better alternates in the form of high yielding seed varieties, proper use of pesticides/ fertilizers, etc.

Lack of Intellectual property Rights' (IPRs) enforcement for seed development. The seed certification by FSC&RD ensures that the seed sold to farmers possessed acceptable standards for purity, germination, homogeneity, etc. However, this does not provide IPRs to the breeders. In the absence of IPRs the breeders lacked incentives to invest in the seed business for development of high-quality varieties. This was the very reason, which discouraged the world renowned MNCs e.g., Monsanto, Syngenta, etc., to enter Pakistan's market.

The anecdotal evidence suggests that some notable MNCs like Syngenta and Pioneer started local breeding programs in early 90s in Pakistan, but winded up due to germplasm security issues.

Slow pace of improvement in legal framework. To address the intellectual property rights issues, the government-initiated preparation of Plant Breeders Rights Act (PBR) in 1999. While the draft was presented to Cabinet in 2007, it was finally approved in December 2016, after going through numerous revisions. However, even after the introduction of the Act, the rules were framed and finalized in 2018. Such lukewarm response to a key issue further constrained the development of seed market, discouraging potential foreign investment.

***Lack of regulatory certainty about the role of various players*:** The government had constituted National Biosafety Committee (NBC) in 2005, under the Pakistan Environment Protection Act, 1997, to regularize the release and commercialization of GM seeds. The bio safety rules contained provisions for various aspects of GM seeds and crops. These rules prohibited engaging in any activities related to GM seeds without a license from the federal government. However, this committee showed a lackluster performance with reference to regulatory approvals – It only approved the commercial release of Bt cotton in 2010 and allowed limited trials for a range of genetically modified (GM) crops, including drought-tolerant wheat, etc. This was on account of various administrative, capacity and legal issues. Specially, the Eighteenth constitutional amendment introduced in 2010 led to transfer of various functions of the federal government to provinces. This gave rise to substantial uncertainty about the regulatory framework. Hence NBC could not meet between 2011 and 2014 to accord regulatory market approvals. This inactivity led to the spread of uncertified seeds. By the time these institutions finally approved some Bt varieties, the farmers had already abandoned use of these seeds after incurring huge losses by using their pre-mature released versions [Babar et al (2019), [Spielman et al (2015)].

Weakening infrastructure of public sector R&D institutes. A review of the global seed market developments and the examination of India's experience (Box 1) shows that Pakistan is significantly lagging behind in seed sector R&D and adoption of latest technologies. While the snail pace of legal reforms has also discouraged MNCs to transfer the seed production technologies to Pakistan. Initially the role of seed development and distribution was mainly performed by the public sector. Overtime, however, public sector role in certified seed availability has diminished, whereas the variety development process has also slackened on account of following issues, as highlighted by the market sources.

- A mix of factors including lack of political will, poor governance, administrative issues, dearth of financial resources have curbed the R&D activities in the public sector. For instance, PCCC, which is the premier research institute for development of cotton seeds, did not have a permanent for a long time, a large number of workforce in this organization has retired, while the budget allocation of this institute has also reduced significantly. Similarly, Punjab Seed Corporation, which is the largest supplier of seed in the public sector, is not working efficiently, because of low work force, technical capacity and deteriorating R&D facilities.

- After the Eighteenth amendment in 2010, the Ministry of Agriculture was shifted to provinces, however these departments managed to keep the subject area under federal government by creating Ministry of National food Security and Research (MNFSR). However, since then the research institutes have very low work force, low budget and it's not possible to expand R&D activities.

Box 1: A Synopsis of Indian Seed Market

The Indian seed industry is the fifth largest in the world with a share of 4 percent, having a market value of USD 4.9 billion in the global commercial seed market.[11] From being pre-dominantly public-sector in the 1960's, the Indian seed industry has evolved into a vibrant private sector that includes around 550 private seed companies – 500 small and 50 big including MNC's [Chauhan et. al, (2016); Paroda (2019)]. The seed sector of India is projected to robustly grow at a CAGR of 13.6 percent during 2019-2024, reaching a value of US$ 9.1 billion by 2024 (Indian Council of Food and Agriculture, 2019, 2019).

Factors contributing to strong growth in Indian seed industry:

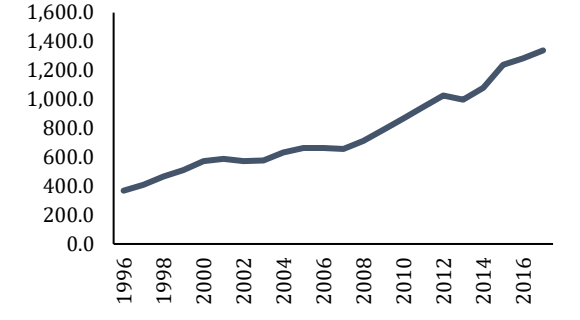
Progressive government policy measures and reforms to increase liberalization of seed industry. Starting in the 1980's, India began cultivating a welcoming environment for foreign firms as well as large Indian companies by reducing the barriers on entry and easing regulations on importing new agricultural technology. The liberalization of the seed industry through the New Seed Development Policy (1988 – 1989) transformed the Indian seed industry. The focus of the policy was to achieve the food production targets, enhance the seed replacement rate and create a conducive environment for growth of a competitive local seed industry by allowing import of germplasm [Trivedi (2013)]. Liberalization encouraged private investment (both by local and foreign firms) in crop research and breeding, boosted the competitiveness of the local industry, and increased research by seed firms [Pray and Ramaswami (1999)].

Provision of IPRs to plant breeders. The Protection of Plant Varieties and Farmers Rights Act (PPV&FR Act, 2001) was enacted in 2001 to accelerate agricultural development. It established a system for the protection of plant breeders, plant varieties, and rights of farmers. It continues to play a key role in providing intellectual property rights for all actors in the seed sector [Pal et al. (2007)].[12] The provision of IPRs encouraged MNCs to enter Indian seed market. Especially, Monsanto – the world leader in Bt cotton, introduced Bt cotton technology in India in 2002, with a joint partnership with a local firm – Mahyco. The introduction of BT cotton in India changed the seed scenario. The adoption of Bt cotton technology tripled (2.3 to 6.1 mt) cotton production, pesticide consumption reduced by 40 percent, incomes of 5 million cotton farmers increased by USD 100 to 300/ha, and export of cotton worth USD 3.5 billion (Paroda, 2019).

Increasing spending on R&D. India has continued to invest in the agriculture sector as evident from the increasing total agriculture R&D spending (**Figure B.1 & B.2**). The private seed sector is currently spending about 10-12 percent of its revenue on R&D and the R&D budget of medium-sized seed companies is increasing at around 20 percent each year (Chauhan et. al, 2016). MNC's remain the major contributors to investment in R&D with the top 5 MNCs accounting for 44 percent of the total R&D investments. The remaining 56 percent of investment in R&D is accounted for by approximately 30 Indian companies [Paroda (2013)].

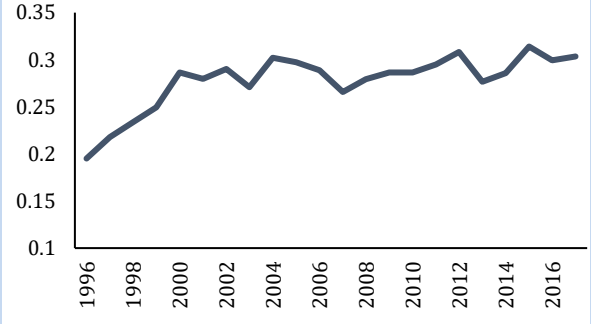
[11] Source: IMARC Group and Indian Council of Food and Agriculture, 2019.
[12] As of August 2020, 4106 variety registration certificates have been issued (http://www.plantauthority.gov.in/List_of_Certificates.htm).

Figure B.1: Total Agriculture R&D spending in India (million constant 2011 USD)



Source: ASTI

Figure B.2: Agriculture R&D Spending in India (as a share of Agriculture Output %)

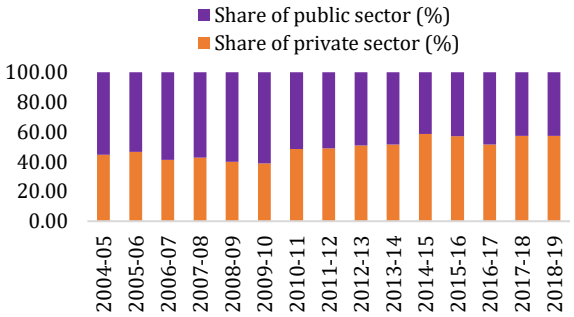


Source: ASTI

Improvement in agriculture extension and information services. Rising disposable incomes of farmers, increasing awareness about the advantages of using certified seeds provided by the agriculture extension services departments, and provision of subsidy on use of quality seeds have led to a high demand of certified seeds.

Adoption of hybrid seeds. Given that hybrid seeds guarantee a uniform crop with higher yield, require less pesticides, and relatively less labor cost, farmers across India have overtime realized their value and progressively adopted hybrid seeds. Favorable government's policies have also encouraged the development of hybrid seed sector, which has seen a 15-20 percent annual growth in 2009-2019 and is expected to grow at 13 percent until 2021 [(Mordor Intelligence (2020) and Technavio (2017)].

Figure B.3: Contribution of private and public sector in seed production (In %)



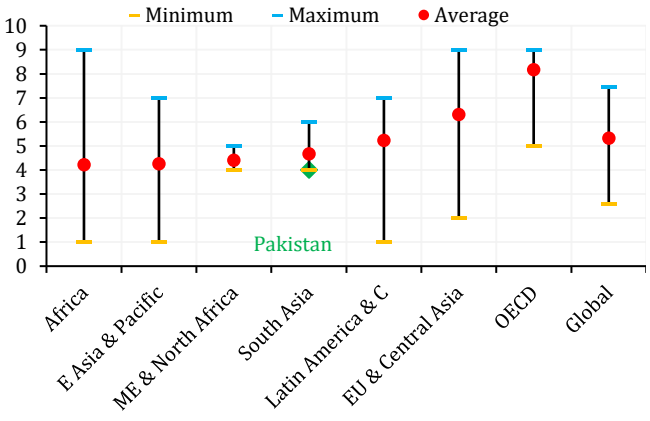
Both private and public sectors are contributing in seed production with the share of private sector increasing over the years **(Figure B.3).**

Lengthy process of variety evaluation and seed certification. Its takes around 10-12 years to develop a seed variety that exhibits required traits of homogeneity, distinctness and uniformity. However, the various steps in the process of variety development and seed certification need involvement of both federal and provincial research institutes, which impedes the pace of activity. Furthermore, FSC&RD lacks the required resources to inspect seed production fields of a large number of companies, farmers, breeders and agri-input dealers before seed certification. This results in delays in the variety evaluation and seed certification process, discouraging private sector breeders to apply for seed certification.

Reluctance of private sector in developing new varieties. The Seed Act Amendment in 2015, allowed the private sector to develop seed varieties. However, the development of new seed varieties is a long process taking around 10-12 years and involves significant investment. In the absence of efficient markets, strong demand and implementation of IPRs, the private sector is not likely to take interest in development of seed varieties.

The impact of seed market reforms not realized fully. The impact of various reforms including the amendments in the Seed10 Act 1976 and the Plant Breeders Act in 2015-16 to encourage the private sector participation in the seed market has not materialized fully. The Supplying Seed Index (SSI) 2019 developed by (calculated during July 1, 2016-June 30, 2018) World Bank, for the assessment of the effectiveness of the seed sectors' legal framework, suggests that the existing regulations are not in line with the best practices adopted by developed countries, and hence create unnecessary hurdles in the way of smooth business operations of the seed market.[13] Pakistan's score is not only lowest in comparison to the South Asian peers, but also below the global average, implying the need to reform the existing statute pertaining to the breeders' seed varieties (Figure 16). Furthermore, Pakistan's score on the legal component of the Seed Supplying Index 2019 has not witnessed any improvement from the 2017-SSI level of 4.[14]

Figure 16: Legal environment Indicator



Source: World Bank

5. Conclusion & Policy Recommendations

A comparison of Pakistan seed market development, with the global situation, especially the developments in Indian seed market suggest that Pakistan seed industry have not kept pace with the development of global seed industry due to supply as well as demand side issues. The most important constraining factor is the dearth of human and financial resources to conduct R&D for development of new and high yielding varieties. The situation has been worsened by slow and inadequate evolution of legal framework which discouraged MNCs to enter Pakistan's market. This has left farmers at the mercy of informal sector, dealers, who sell seeds of unknown quality, leading to consistent yield losses. The policy uncertainties and lacunas in legal framework led to creation of various vested interest groups who lobbied to prevent the formalization of required rules and regulations for improving the market mechanism. Pakistan's experience with the Bt cotton exposes poor implementation of the legal framework of the seed sector and hints the need to redesign the seed market to ensure improved production and provision of high quality seeds. Some of the required reform measures are discussed in the following.

- ***Redesigning the legal framework to check spread of spurious seeds.*** FSC&RD is responsible for controlling the quality of seeds. This function is performed by field inspection of the crops of registered varieties and released varieties intended for sale as basic seed or certified seed. The Seed Amendment Act 2015 protected the farmer from cheating practices via the "Misbranded Seed" clause, creating

[13] Supplying Seed Index, developed by World Bank, estimates the impact of laws and regulations regarding the release of new seed varieties for the farmers. It takes into account the set of three indicators including; (i) average time it take to register a seed variety, (ii) average cost incurred to register a variety, and (iii) nine other legal points with the assigned score of 1 or 0 in case of "yes" or "no" respectively, to assess the efficiency of legal framework governing the variety release processes. The indicator pertaining to the legal environment's efficiency scores the countries from 1 to 9, and 1 being the lowest score indicating either the lack of regulations necessary to create enabling environment or excess of laws creating impeding complications for the breeders to operate efficiently in the seed market. Simple average of the scores of these three indicators is calculated to get the aggregate indicator of the Supplying Seed Index, whose higher value indicate the presence of enabling laws regarding the seed market.

[14] Pakistan's score on the legal component of 2019-SSI has remained unchanged at 2017 level of 4.

barriers against illegal seed varieties by enhancing penalties against the sale of sub-standard seeds. Despite the presence of legal and regulatory provisions the widespread availability of spurious seeds in the market indicates the need to transform the legal and institutional regime towards more practical and realistic setup. Specifically, given the wide spread use of uncertified seeds, and farmer's indifference, the seed certification regime may be completely abandoned, while the regulator focus should be shifted to control the spread of sub-standard seeds.

- ***Strengthening institutional setup to improve service delivery.*** There is a need to improve the institutional setup by addressing financial constraints and workforce shortages which have exacerbated after the fiscal devolution announced in 2011. The lack of financial and human resources has weakened the R&D setup in the public sector. The government research institute are in very bad shape, need complete overhauling, improvement in remuneration, hiring of trained staff, and improvement in infrastructure.

- ***Fiscal and monetary incentives to attract foreign investment in seed sector.*** The current decline/stagnation in yields of important crops warrants development of new seed varieties, which are climate change resistant. However, there is a significant dearth of research efforts in the public as well as private research institutions. The sunk cost nature of these expenditures greatly discourages the private sector from undertaking extensive R & D activities. Given the scarcity of financial resources, low returns on investment, and inadequate domestic R&D setup, there is a need to incentivize private sector joint ventures with MNCs in the seed sector by providing fiscal and monetary benefits in the form of tax holidays and subsidized financing. This will help in transfer of technology from some world leading MNCs in the seed sector to Pakistan. Similarly, the joint ventures between public and private sector should also be encouraged for development of better seed varieties.

- ***Proper enforcement of existing Intellectual Property Right (IPR) regime to encourage domestic and foreign investment in new seed varieties.*** The MNCs have played a pivotal role in introducing high-yielding hybrid seeds in Pakistan, however, the unchecked duplication and adulteration of their seed varieties limited returns on their investment and forced them to wind up the varietal development operations. Resultantly, Pakistan has lagged behind peer countries like India in the adoption of hybrid seeds. United States Trade Representative Report 2020 put Pakistan on the watch list, indicating serious concerns regarding IP enforcement.[15] There is a need to ensure proper enforcement of intellectual property rights to encourage varietal development investments in the seed market. In this regard, the government has introduced Plant Breeders Rights Act in 2016, whereas the rules for the act were devised in 2018. However, there are still concerns regarding the housing of PBR registry in FSC&RD. Given the presence of a separate Intellectual property Rights Organization (IPO), PBR should be registered with IPO, which is a relevant department and a neutral body.

- ***Agricultural extension services should be expanded to the small farmers predominantly involved in traditional agriculture.*** There is a need to strengthen provincial Agriculture Extension departments by imparting trainings, hiring relevant workforce and strengthening the evaluation mechanism of the staff. The education of farmers for the adoption of agricultural technology is an enormous task and has to be carried out systematically and effectively. Extension services should be expanded to small farmers to

[15] United States Trade Representative Report 2020
https://ustr.gov/sites/default/files/2020_Special_301_Report.pdf

improve dissemination of information. Thus, there is a need to impart the necessary training to the growers. These training workshops can be imparted at three stages: one at (or before) the sowing process, second during the growing stage, and third at (or before) the time of harvesting.

- ***Subsidy on use of quality seeds*.** There is a need to encourage farmers to use high yielding varieties by providing subsidies in line with other sectors like fertilizer. The relatively high prices of certified seeds are another constraint behind the low adoption of certified seeds among small farmers. The provision of subsidies will help to lower their prices and will enhance the ability of a larger proportion of farmers to use them.

- ***Mechanism to check seed prices*.** The prices of new varieties of seeds and imported seeds are very high. This has raised the profitability of seed producers/importers at the expense of growers. There is a need to build a mechanism to check seed prices.

- ***Time limits for seed registration process*.** Given the lack of manpower and infrastructure within the government system, the varietal approval and registration is subject to delays, which discourage private sector to apply to seed registration. There is a need to standardize and strengthen this process and make it time bound.

- ***Need to strengthen evaluation of imported seeds*.** There is a need to strengthen the regulatory mechanism for the import of seeds and the prices of imported seeds.

- ***The profitability of crops is another determining demand-side factor behind the usage of certified crops.*** The profitability of crops should be increased by lowering input costs to encourage the adoption of certified seeds. High prices of seeds particularly of crops with relatively low profitability are a significant impeding factor behind the low usage of certified seeds. There is a need to increase the return on crops by either lower input costs or increasing the output prices to encourage the use of quality seeds.

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