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Review Article

Soybean Production in Pakistan: Experiences, Challenges and Prospects

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Abstract

Pakistan disburses lion's share of foreign exchange to import edible oil and oilseeds-based food/feedstocks for fulfilling domestic needs. Soybean (*Glycine max* [L.] Merr.), an oilseed crop has the potential to fill the gap between demand and domestic oilseeds production in Pakistan. Soybean seed contains 40–42% protein, 20–22% oil contents, and 20–30% carbohydrates along with numerous other essential vitamins and minerals and termed as a 'miracle crop' and potential food security crop. Soybean was introduced in Pakistan as an oilseed crop during the early 1960s, but its cultivation remained limited until 1970s when adaptability and production trials conducted all over the county yielded promising results. Based on these trials' vast areas of Khyber Pakhtunkhwa (KP, formerly NWFP), Punjab and Sindh were found most suitable for commercial cultivation of soybean. However, at the onset of the current century, soybean cultivation was halted, and it gradually disappeared from cropping schemes of Pakistan. In the current review, we have analyzed the available literature and observed that despite suitable agro-ecological conditions, soybean is facing several challenges such as lack of germplasm with specific maturity groups adaptable to various environmental conditions, unavailability of climate-resilient high yielding and pest resistant genotypes and lack of marketing facilities. Moreover, the absence of area-specific production technology, non-existence of extension service, and lack of coherent policy to promote local oilseed production are the major bottlenecks for the cultivation of soybean in Pakistan. Along with the identification of gaps for low cultivation of soybean in Pakistan, we have proposed potential solutions for enhancing the cultivation of this very important oilseed legume for improved national food security.

Keywords: *Glycine max*; Adaptability; Genotypes; Limiting factors; Combat strategies

Introduction

Soybean (*Glycine max* [L.] Merr.) has been fast-growing, valuable, and multipurpose field crop for the past couple of decades. It holds the crown place amongst economically significant oilseed crops of the world. This oilseed legume crop accounts for 80% of the area and 68% in the world's legume produce (Herridge *et al*. 2008; Naamala *et al*. 2016). It is cultivated on 110 M ha worldwide, with U.S.A. leading in the acreage and production of 36.42 M ha and 117 million metric tons (MMT), respectively. Brazil and Argentina with respective productions of 114 and 58 MMT rank 2^{nd} and 3^{rd}, respectively on the world arena (USDA 2017). It is widely grown on a large scale in both temperate and tropical regions including China, Thailand, Indonesia, Brazil, United States, and Japan, where it has become a major agricultural crop and a remarkable export commodity (Evans 1996).

Although soybean is primarily cultivated for its prime quality oil and protein, but its remarkable recent growth at global level coupled with vital role in meeting the world's ever-increasing food, feed and biofuel needs have rendered it a potential key player of global food security insurance (Masuda and Goldsmith 2009; Cardoso *et al*. 2018; Zheng *et al*. 2019). Owing to its nutritional value and multiple uses, it has earned several names such as 'golden bean', 'queen of pulses', 'wonder crop', 'farmer's friend', 'agriculture's cinderella', 'meat of the field' and 'meat without bones' (Kumar and Sharma 2018; Akram and Ahmad 2019). It is an important source of vitamins; E, K, riboflavin, thiamine, niacin, choline, and several antioxidants like isoflavones, chlorogenic, isomers, caffeic acid and ferulic acid (Meghvansi *et al*. 2010; Devi *et al*. 2012). Soybean seed contains 40–42% protein and 20–22% oil contents on a dry weight basis in addition to 30% carbohydrates (non-starchy), polysaccharides (pectin), cellulose, and hemicellulose (Liu 1997; Kanchana *et al*. 2015). The nutritional composition of soybean seed is presented in Table 1. Most of the soybean produced is milled for meal and oil contents, while only about 2% is consumed directly as pulse grain by the human (Khurshid *et al*. 2017).

Soybean is native to Eastern Asia (China, Korea, and Japan) from where it spread to Europe, U.S.A., and other parts of the world during the 18th century (Ngeze 1993). Evidence from Chinese history indicate its existence as early as 5,000 years ago as food and a component of drugs (Norman *et al*. 1995; Kanchana *et al*. 2015). However, researchers believe that Australia and Eastern Africa as other possible centers of origin of the genus *Glycine* (Addo-Quaye *et al*. 1993).

In Pakistan, soybean was introduced in the 1960's and after preliminary trials in Sindh province, its seed was released commercially in the 1970s along with sunflower and safflower (Khurshid *et al.* 2017). Although soil and climatic conditions of Pakistan are suitable for soybean cultivation, but, due to lack of genetic and breeding work, it could not get popularized among farmers (Arshad *et al*. 2006). Contradicting with these findings, recent reports show that from late 1990s to 2002, soybean had been growing successfully all over the country, wherein the acreage under soybean cultivation was > 6,000 hectares during the cropping season of 1994–95 (Khurshid *et al*. 2017).

Explosive population growth and variability in the dietary habits associated with higher demands of edible oil are mounting pressure on Pakistan's economy. Because of insufficient local oilseed production, edible oil needs are fulfilled through imports from soybean-producing countries resulting in exhaustive import bills. For instance, a foreign exchange of 1.455 billion US$ was spent during 2018–19 (July–March) to import edible oils to satisfy 80% of the total domestic needs of the country, while local produce contributed only 20% of total demand (GOP 2019). One of the major factors contributing to the setback of the oilseed sector is its marginal inclusion in our cropping systems. Soybean is also an alternative to conventional oilseeds barring health risks (GOP 2019).

Another sector of prime importance is the poultry industry in Pakistan, which demands soymeal as an important component in poultry feed. According to the United States Department of Agriculture (U.S.D.A.), the import of soymeal will hit a record of 2.5 MMT in the current fiscal year, which may put extra pressure on already dwindling economic conditions of Pakistan. This situation warrants accelerated efforts both at policy and research level for enhancing the local production of soybean. This review encompasses the past experiences for soybean cultivation in Pakistan. Digging deep into the gaps, which led to the disappearance of soybean from Pakistani fields, and suggestions for overcoming those bottlenecks for the successful cultivation of soybean in Pakistan are discussed in this review.

Status of soybean cultivation in Pakistan

The area under soybean cultivation in Pakistan has declined sharply after successful cropping until 2002. One important driving factor behind this downturn is post 9/11 USA-Afghan war security situation in northern-western areas especially the Swat, which had been the major contributors in domestic soybean production since its introduction in Pakistan. Soybean is a non-conventional oilseed crop and due to its marginal cultivation, it is less popular among Pakistani farmers (Malik *et al*. 2006; Khurshid *et al*. 2017). Soybean cultivation in Pakistan was primarily aimed at enhancing the production of edible oil, but it has a little share in domestic production as compared to other oilseed crops including cotton (*Gossypium hirsutum*), sunflower (*Helianthus annuus*) and rapeseed (*Brassica napus*). The area under soybean cultivation in Pakistan from 2001–2017 and corresponding yields are given in Fig. 1–2, respectively.

Data presented in Fig. 1 and 2 highlights that economic years 2001–2002 witnessed the maximum area under soybean cultivation and corresponding yield, which sharply declined thereafter reaching its lowest in 2017 both in terms of acreage and yield. According to the agricultural statistics of Pakistan, Punjab and Sindh had no area under cultivation of soybean. Imports of soybean, soymeal, and soybean oils during the last 55 years (1964–2019) are given in Fig. 2. As shown in data, soybean oil imports were doubled during this duration and then started declining afterward. This abrupt slump is because of shifting dependency on palm oil from soybean for cooking oil needs, where current imports (2018–19) of palm oil are >3000 MT (Fig. 3) for fulfilling the domestic needs.

Experiences

Introduction and adaptation of soybean germplasm: Although soybean was introduced in Pakistan during the early 1960s, one of its indigenous breeds had been under cultivation as a winter fodder before 1960's (PARC, 2020). Performance of 'Williams', 'Wood Worth' and 'Yellow Seeded' remained excellent in earlier trials conducted in Swat, Tarnab farms (Peshawar) and Ayub Agricultural Research Institute (A.A.R.I.) at Faisalabad under the International Soybean Program (INTSOY) run by the National Soybean Research Laboratory of the University of Illinois, U.S.A. (Quresh *et al*. 1983). The INTSOY had served worldwide, including Pakistan since 1972 for enhancing the nutritional and health needs of people and contributing to their economic and social development through soybean cultivation, processing, and utilization.

At the time of soybean introduction in Pakistan, three varieties; 'S.B.L.' (yellow seed), 'K-16', and 'K-30' (black seed) were selected for commercial cultivation in Sindh, the southern province of Pakistan. Trials were conducted for four years from 1961–1964 at Agricultural Research Institute (A.R.I.) Tandojam, Sindh for testing the varietal performance and standardizing the sowing dates, cultivation methods, and row spacing to obtain the required plant population (Chaudhury *et al*. 1966).

Table 1: Nutritional composition of soybean seed

S. No.	Contents/Nutrients	Percentage (%)
1	Protein	37-42
2	Oil contents	17-24
3	Carbohydrates; cellulose, pectin, phytic acid.	30
4	Lipids	20
5	Polyunsaturated fatty acids; Linoleic and linolenic acid.	85
6	Fiber	10
7	Vitamins; E, K, riboflavin, thiamine, niacin, and choline.	10
8	Mineral; K, Mg, Ca, Zn, Fe and Cu	5
9	Ash	6

Source; Amjad 2014; Naamala *et al*. 2016; Silva *et al*. 2013

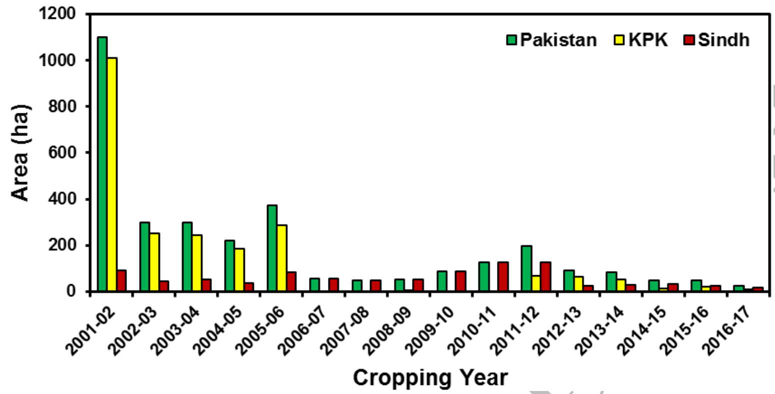

Fig. 1: Area under soybean cultivation in Pakistan during 2001-17 *(Source: Agriculture Statistics of Pakistan 2018)*

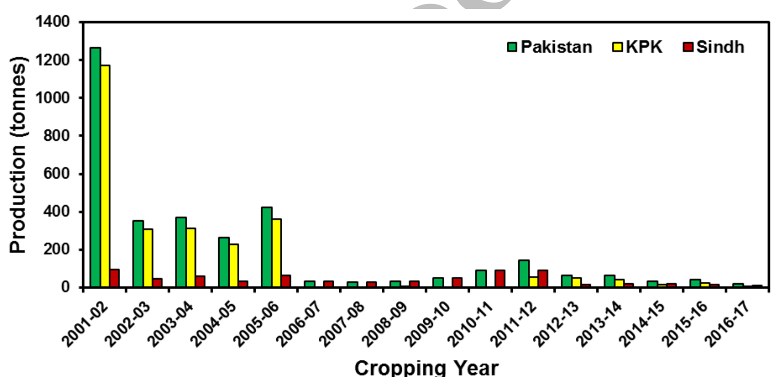

Fig. 2: Soybean yield over the last two decades over the time span of 2001-2017 *(Source: Agriculture Statistic of Pakistan 2018)*

Following the preliminary trials, exotic germplasm consisting of seven varieties; 'Diashoka' (Japan), 'Palmetto' (Taiwan, China), 'Improved Pelican' (U.S.A.), 'Numa Hung', 'Loppa', 'I-F/60' (China) and 'E-G-5' (Philippines) were evaluated to compare their performance with standard varieties, *i.e.*, K-30 and S.B.L. at A.R.I. Tandojam in Sindh. Data from performance trials revealed that 'I-F/60' and 'Improved Pelican' were the highest yielding varieties and best planting time was reported to be 22 June as compared to 22 May or 22 July (Mustafa and Safdar 1969). After successful preliminary experimentation at A.R.I., soybean cultivation was started at Lyallpur (Faisalabad) and Tarnab (Peshawar). During these national trials, salinity was noted as the major barrier for soybean cultivation in arid regions (Hussain and Clark 1969).

Commercial cultivation of soybean in Pakistan started in the 1970's within the framework of oilseed coordinated program at Pakistan Agricultural Research Council (PARC) after evaluating its adaptability at zonal research institutes in Quetta, Tandojam, Faisalabad, and Peshawar (PARC, 2020). Germplasm was received from various international organizations including Asian Vegetable Research and Development Center (A.V.R.D.C.), Ohio Agricultural Research and Development Center (O.A.R.D.C.), and INTSOY (PARC 1981–82). Despite concerted efforts at various fronts to promote soybean at the national scale, it was sown only on 1619 hectares with a total production of 600 tones, averaging 370 kg ha^{-1} of yield indicating very poor response from Pakistani farmers (Hussain *et al*. 1981). For winning the title of a successfully introduced new crop, this acreage was far below the benchmark. After this failed attempt to launch soybean, another collection of 19 varieties was introduced on 16 May 1973 in Swat. Amongst introduced germplasm, 'Lee 68' proved to be the highest yielding cultivar with 4826 kg ha^{-1} (Hussain *et al.* 1981). Preliminary inoculation trials conducted during 1977–79 yielded valuable results for nodule formation and elevated corresponding yield. Parallel with these investigations, experiments were conducted to standardize the complete production technology including irrigations, fertilization for the successful cultivation of soybean in different agro-ecological zones.

A screening trial of sixty varieties imported from the U.S.A., China, and Japan was conducted on a large scale in Faisalabad and Khanpur during 1979–80. From these trials, three varieties namely, 'Bragg', 'Williams' and 'Calland' proved to be promising due to their early maturity and high yields whereby the highest yield of 1469 kg ha^{-1} was obtained from Williams (PARC 1979–80). During autumn 1995, 320 more exotic germplasm accessions were included in the development of local soybean germplasm for evaluating early and late maturing varieties. Genotypes of various characteristics were also assessed during spring and autumn seasons on a yearly basis. Nutritive trials were conducted to check the effect of potassium application, which gave 200 kg ha^{-1} more yield than control (PARC 1995–96). While evaluating the performance of 82 genotypes of soybean for determining the yield contributing traits for semi-arid conditions it was observed that plant height, number of leaves and pods were the determining factors for cultivation under rain-fed conditions (Ali *et al*. 2013). The productivity of imported lines reduced over time because they were less adapted to the local conditions despite good yield in the early years. A gradual decline in production is attributed to the lack of sound basis for identifying the soybean cultivars suitable for different agro-ecological zones (Ali *et al*. 2013).

Breeding and varietal development

As of recent, nine varieties of soybean are released and commercially available for distribution to farmers (Table 2). Commercial varieties of soybean available in Pakistan are >20 years old and no significant developments have been made for breeding and developing new cultivars over this time span (Table 2). However, catching up with the lost treasure, some preliminary work by research organizations in Pakistan has been reinitiated over the last 2–4 years and undoubtedly PARC has taken lead in this initiative.

Two programs, international varietal evaluation experiment and national uniform soybean yield trial proved worthwhile in which cultivars were evaluated based on phenological and agronomic attributes in addition to their performance under different management trials encompassing depth of sowing, inoculation, fertilizer-cum inoculation and row spacing (PARC 1986–87). Under the international soybean program of the University of Illinois, fourteen varieties were selected during spring 1985. Varieties 'Mead', 'Herper' and 'CN-210' yielded as much as 1062.9, 898.4 and 888.4 kg ha^{-1} respectively (PARC 1985).

Breeding efforts in Pakistan were made periodically to develop soybean varieties by selection of potential lines. Trials were conducted at National Agricultural Research Centre (N.A.R.C.), Islamabad during late 90's under which 'AGS-194', 'NS-82-5250', 'Ciangman', 'Dukar' 'AGS-5', 'Sprito', 'Platte', 'Exp-15', 'Ocepar', 'PR-16', 'Decada' and 'M-83-104' were evaluated. Early maturing characters were identified in 'Dukar' and 'Exp-15' to cross further with high yielding lines in the future breeding program (Mansab *et al.* 2002). Decade long breeding efforts by N.A.R.C. resulted in the release of two promising varieties of soybean 'NARC-I' and 'NARC-II'. Preliminary trials for the seed multiplication of these varieties were conducted at Tarlai (Islamabad), Fateh Jang (Attock) and Swat with average yields of 4000 kg ha^{-1}.

In subsequent breeding trials, Muhammad and Shah (2003) reported significant indications in terms of phenological and agronomic parameters reflecting the genetic variations among genotypes. Similar studies were conducted at NARC in which significant variations were observed in days to 50% flowering, days to 50% maturity, pods per plant, seed weight and plant height among all genotypes (Malik *et al*. 2006). A study of correlation under which 139 genotypes including three approved varieties 'NARC-I', 'NARC-II' and 'Ajmeri' was carried out in terms of phenological and agronomic data collection. It was concluded that all the studied traits except plant height were positively correlated with the grain yield (Iqbal *et al.* 2010).

In addition to the leading role of N.A.R.C. in varietal development, there is also a major contribution of oilseed research institute (ORI) at A.A.R.I., Faisalabad. The oilseed research institute has developed a promising variety 'Faisal Soybean' suitable for climatic conditions of Punjab. Other two prominent soybean varieties 'Swat-84' and 'Malakand-96' declared for general cultivation in KP province were developed by agricultural research institute (A.R.I.), Swat in 1984 and 1996, respectively (Aftab *et al.* 2019).

Regional adaptability

Pakistan has wide range of environmental conditions differing from one region to another and variable edaphic factors making it more complicated for a delicate crop like soybean to adapt under these scenarios. Moreover, agro-ecological zoning of the country carried out in 1980s by PARC has become obsolete and same happened with soybean germplasm imported for local cultivation. Under adaptability trials during 1976–80 at A.R.I., Swat and farmer's fields, all the new cultivars were compared with the standard varieties 'Lee' and 'Brag' where 'Williams' and 'Wood Worth' proved to be the best yielding amongst all new lines (Quresh *et al.* 1983). After extensive trials

Table 2: Soybean varieties developed and released by different research institutes/organizations in Pakistan.

S. No.	Variety	Year of release	Institute/ Organization	Breeding method	Yield potential (kg ha^{-1})
1	NARC-I	1991	N.A.R.C.[1]	Selection	4500
2	NARC-II	1991	N.A.R.C.	Selection	4000
3	Ajmeri	1996	N.A.R.C.	Selection	3500
4	Rawal-1	1993	N.A.R.C.	Selection	N/A
5	FS-83	1983	O.R.I./A.A.R.I.[2]	Selection	N/A
6	FS-84	1984	O.R.I./A.A.R.I.	Selection	N/A
7	Faisal Soybean	1996	O.R.I./A.A.R.I.	Selection	2563
8	Swat-84	1984	A.R.I.[3]	Selection	2500
9	Malakand-96	1996	A.R.I.	Selection	3000

[1]National Agricultural Research Centre Islamabad; [2]Oilseed Research Institute, Ayub Agricultural Research Institute, Faisalabad; [3]Agricultural Research Institute Mingora, Swat

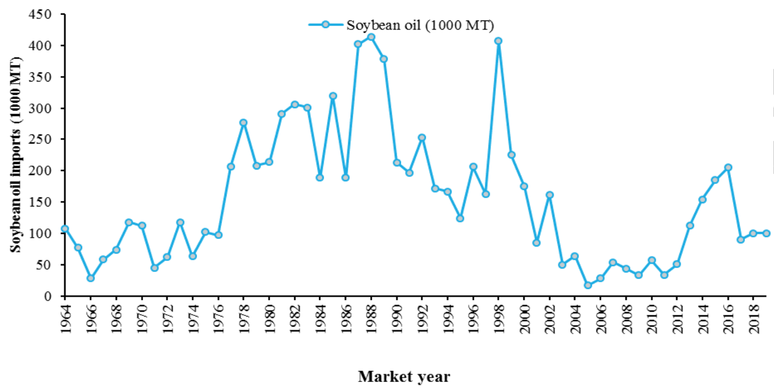

Fig. 3: Import of soybean oil to fulfill the domestic needs of cooking oil since the introduction of soybean in Pakistan 1964-2019 (*Source: United States Department of Agriculture and index mundi (Accessed on 19th November 2019)*

regarding adaptability, soybean variety 'Williams' proved to be successful and was cultivated on most of the area under soybean (Ahmad and Sandhu 1988). Induction of soybean in our existing cropping schemes could be highly rewarding in terms of increasing local oilseed production and increasing soil fertility. Undoubtedly, soybean possesses high nutritional and economic value making it an inexpensive source of protein and oil. Moreover, this oilseed legume plays key role in the nitrogen cycle through nitrogen fixation to make it available to plants (Nasir *et al*. 2017).

Worth noting that in 1980, there were 12 agro-ecological zones in the country, but now 14 agro-ecological zones are only in Punjab (FAO 2019; Fig. 4), while the re-zoning of other three provinces is in process by F.A.O. This situation warrants the need to multiply new germplasm and tested under different environments before being released into the market. This could be an effective strategy for successful cultivation of soybean in the country. Almost in every decade, adaptability trials were conducted under various schemes to boost up the oilseed's cultivation, but most of the times failing. These repeated setbacks resulted in increasing imports of oilseeds thereby putting a mounting pressure on national economy in the form of high import bills.

Crop husbandry

In Pakistan, planting time for soybean has been established after voluminous experimentation at various locations all over the country. Depending upon the maturity groups of cultivars and existing cropping systems it can be cultivated during autumn and spring seasons by following some most common rotations: wheat (*Triticum aestivum* L.)-soybean-wheat; rice (*Oryza sativa* L.)-soybean-rice; cotton (*Gossypium hirsutum*)-soybean-cotton; sugarcane (*Saccharum officinarum* L.) + wheat-sugarcane + soybean-wheat. In Punjab and Sindh, planting of soybean as a spring crops is done between two rice and two cotton crops while in KP it is planted after sugarcane or as an intercrop. During autumn season, soybean is planted in Punjab, Sindh and KP from July to August, June to middle of July and May to June respectively (Quresh *et al*. 1983; Chaudhry *et al*. 1984; Bhatti and Rashid 1985; Hatam 1988). However, changing climatic conditions has resulted in significant changes in planting times and now June is recommended for autumn sowing of soybean (Khurshid *et al*. 2017; Asad 2020).

Fertile loamy soil with good drainage is best suited for soybean cultivation in addition to optimum pH range of 6–6.5. Soils with high organic matter and water holding capacity are appropriate for its good productivity (Ibrahim *et al*. 2018; PARC 2020). Right from sowing to harvesting and storage, moisture content in soybean seeds plays critical role. Optimum soil moisture at sowing is essential which can be maintained with 2–3 ploughings followed by 1–2 planking. For autumn crop, 3–4 irrigations are required, where first irrigation is applied three weeks after germination. Subsequent irrigations are applied at flowering, pod formation and seed development stages (PARC 2020). Soybean grows successfully both under rainfed and irrigated conditions with temperature range of 15–30ºC during germination but requires high temperature for rapid growth and maturity (Alsajri *et al.* 2019). However, high daytime temperature at reproductive stage may cause up to 10% yield reductions (Arshad *et al*. 2017; Prasad *et al.* 2017; Sita *et al*. 2017) depending on the intensity of temperature, exposure time and cultivar.

As a leguminous crop, its nutritional requirement is obvious due to nitrogen fixation by *Bradyrhizobium japonicum* present in root nodules. Nitrogen fixation usually fulfil one-third of the total nitrogen requirement which can contribute to produce a grain yield of 3000–4000 kg ha^{-1}. Studies have shown that extensive plant nodulation has been observed in KP especially in the tracts of Swat and Hazara, but it is a serious constraint in its cultivation in Punjab and Sindh. Phosphorus at the rate of 60–90 kg ha^{-1} is recommended to enhance productivity (Beg 1984; Quresh and Khan 1985; Hussain 1989).

Major insects attacking soybean were reported to be whitefly (*Bemisia tabaci)*, thrips (*Sericothrips variabilis*) and army worm *(Spodoptera frugiperda*) (PARC 1981–82). Whitefly and thrips can be controlled by spraying Pyreproxifin, while Lufenuron or Emamectin provide effective defense against army worm. Fungal diseases, top die back (*Diaporthe phaseolorum*) and Septoria leaf spot (*Septoria glycine*) were identified for the first time in Pakistan (PARC 1990). The use of high quality and thoroughly cleaned seed and crop rotation are the primary controls of *Diaporthe phaseolorum* (Pedersen and Grau 2010). Septoria leaf spot is more severe in continuously cropped soybean field; hence crop rotation is the best preventive strategy against this disease. Weeds compete with crop both for space and nutrients and may cause yield reductions up to 40% (Soliman *et al*. 2015), hence weed control is imperative for improved crop productivity. Several weed control strategies including, manual and chemical are suggested depending on the weed species and crop growth stage. Under Pakistan's scenarios, weeds impart no significant threats to soybean and in case of weed infestation, 1–2 manual weeding after irrigation are suggested (PARC 2020). Manual weeding has been proposed in many past researches because it is economically viable and environment friendly approach. Comparison of chemical and manual approaches for weed control in soybean fields revealed that manual weeding proved to be very effective compared with chemical control methods (Ibrahim *et al.* 2018). These researchers also observed increased plant height, yield traits and improved chemical composition of soybean seeds harvested from fields subjected to manual weeding compared with chemical control.

The most critical time for soybean lies between physiological and grain maturity. This is because, the matured grains remain intact with shoots and are more vulnerable to environmental stresses including pests, natural dehiscence, and plant tipping, so longer delays in harvesting lower the water contents of seeds. Even at this stage, water contents in grains would be still around 40%, making difficult for mechanical harvesting, causing injuries to seed, and deteriorating the quality of the produce. The ideal moisture contents for mechanical harvesting of soybean are 12–14%, the water content lower than this would increase grain losses in the field. Generally, the crop is harvested when >90% of the pods turn yellow and threshed after sun drying for further 5–6 days (PARC 2020).

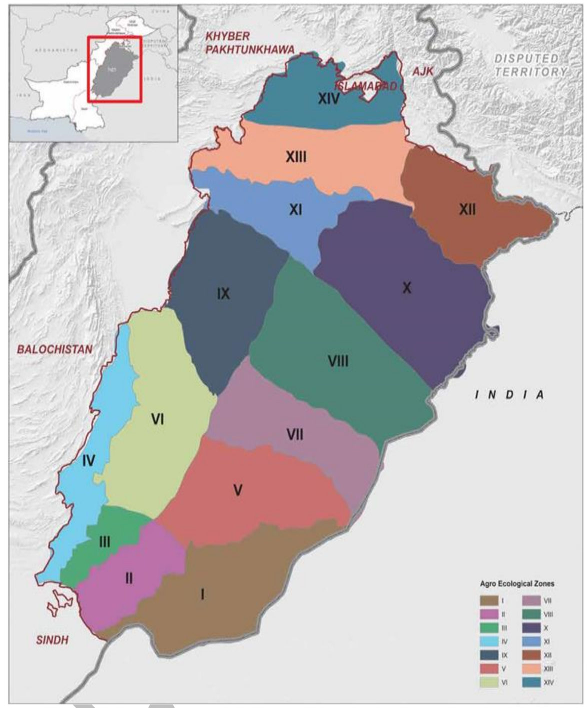

Fig. 4: Agro-ecological zones of Punjab (*Source: FAO 2019*)

Challenges

Major challenges for soybean cultivation in Pakistan are described in the paragraphs below:

Germplasm for different regions and seasons

Like other crops, soybean is also influenced by varying environmental conditions, hence it becomes imperative to develop new lines through advanced genetic tools, to withstand these environmental abnormalities (Baig *et al.* 2018). Genetic variability among different soybean lines can be investigated by comparing different quantitative traits of soybean (Iqbal *et al*. 2008; Ojo *et al*. 2012). For example, Khan *et al.* (1999) evaluated cultivars suitable for intercropping in orchards and irrigated land in the KP province. Those tested varieties were high yielding, having high germination percentage, early maturing and quality seed producers compared with commercial variety 'Bragg' although plant population influenced plant height and number of pods in these varieties (Khan and Bashir 2006). Major bottleneck for low cultivation of soybean in Pakistan is the non-availability of promising soybean cultivars, because the germplasm imported was neither high yielding (despite it produced promising yields in the early years of its introduction), nor adapted to local climatic conditions (Baig *et al*. 2018). Currently, 14 high yielding genotypes of soybean are at trial stage by PARC and after zonal evaluations, shall be ready for further multiplication and cultivation (personal communication; Dr. Doulat Baig, oilseed program at N.A.R.C.). Further efforts are needed to widen the scale of germplasm characterization for developing disease resistant, early maturing, climate smart and high yielding soybean varieties. These early maturing and high yielding varieties would provide enough opportunities to small farmers for cultivating in kharif season after wheat harvest, where around 30% of land after harvesting this staple remains fallow under arid agriculture.

Availability of quality seed

Availability of quality seed has been a challenging issue since the introduction of soybean in Pakistan. Although several initiatives were taken by federal and provincial research institutes throughout the country to ensure the availability of seed of highly yielding local breeds of soybean, but the target of self-sufficiency is still far away. Currently, oilseed research program of PARC possesses the largest stock of soybean seed of four cultivars registered by the institute (Table 2). Since last three years (2017–2019), PARC has been producing bulk seed at their farms for free distribution to farmers in the target districts of KP and Punjab. Other institutes, A.R.I. and O.R.I. are also making the availability of the seed of their respective varieties, but obviously limited capacity of institutes is heralding a big challenge for sustainable supply of seed. Despite all efforts by institutes, unfortunately seed companies and farmers are least interested to multiply the seed, hence dependency on imported seed would be looming in future. Major part of soybean seed is imported from U.S.A., where in 2018; Pakistan imported 1.72 MMT of soybean seed from U.S.A. The environmental conditions during seed production have notable influence on the quality of seed, protein, oil contents and seed viability. Modern agricultural practices have made the farmers more curious about the importance of seed quality and viability for uniform seedling establishment under varying environmental conditions. Increasing demand of soybean for various food and feed utilities has put enormous pressure on researchers for thorough testing on seed quality and vigor before releasing into the market. Soybean germplasm is very sensitive to environmental conditions, hence requires special arrangements for storage. It loses its viability during improper storage, hindering supply of quality seed (Ali *et al*. 2018), which may compromise crop expansion. Seed viability during storage is influenced by numerous physico-chemical factors including moisture, humidity, temperature, gaseous exchange, morphological conditions, storage and packaging material, initial seed quality and chemical compositions of seed (Ali *et al*. 2018; Chourasia *et al*. 2018). Soybean farmers do not have their storage facilities; thus, very much dependent on the government research institutes for seed supply which had been neglected maximally in the past (Iqbal *et al*. 2015; Ali *et al*. 2018; Baig *et al*. 2018). Viability and vigor of soybean seed was more pronounced when seed with moisture contents up to 8% were stored in polythene bags and plastic pots as compared with other storage conditions and materials (Ali *et al*. 2018). Bulk storage is not under controlled conditions which deteriorates the seed quality for next cropping season. Hence use of proper storage places/containers is suggested for maintaining and preserving the seed viability aimed for reducing seed quality and enhancing crop productivity.

Biotic and abiotic stresses

Soybean is sensitive to environmental variations, hence greatly influenced by myriads of biotic and abiotic stresses. For example, the soybean crop is often subjected to high-temperature stress particularly in tropical and semiarid tropical regions (Liu *et al*. 2008). Similarly, the growth of soybean is hampered under saline conditions causing drastic reductions in the yield (Khan *et al*. 2016). Soybean is sensitive to grow under saline conditions above 5 dS/m (Kamkar *et al.* 2014). Management of these biotic and abiotic stresses could significantly improve soybean yield (Suzuki *et al*. 2014). For instance, foliar application of micro and macronutrients relieved the soybean plants from salinity stress (Babar *et al.* 2014). Effects of stresses are more evident during early growth stages when underdeveloped root system may not uptake sufficient nutrients from the soil, hence foliar application of nutrients could potentially maintain the supply of essential nutrients such as phosphorous (P) and potassium (K) to the stressed plants (Mallarino *et al.* 2001).

The effects of water stress during seed-filling, seed-fill duration, and yield of soybean are of great concern for reduced yield. Brevedan and Egli (2003), investigated short stress periods on soybean cultivar 'Elgin 87' under controlled conditions and found that short periods of water stress during seed filling severely impacted seed size and crop yield. In this trial, initially, all experimental plants received adequate water, followed by a 60% reduction of water supply to half of the plants to ensure continuous water-stress, while remaining 50% of the plants were watered as before. The carbon exchange rate was quickly reduced by continuous water stress resulting in earlier maturity and 39% lower yield. Moreover, seeds size was 25–33% smaller compared with the counterparts receiving an adequate amount of water. Worth noting that in another experiment, when plants were relieved from stress by providing water at later stages, yield and seed sizes were greater than those plants exposed to permanent water stress. Cumulative effects of temperature and moisture are more pronounced, and many folds higher as compared with either temperature or moisture alone (Asad *et al.* unpublished data). Studies by these researchers noted yield reductions of up to 9% in soybean exposed to elevated temperatures compared with ambient temperature, but when moisture stress was coupled with temperature, further 21% yield reductions were noted in experimental plants as compared to control plants.

Climate change is another stressor impacting the cultivation of soybean. Chen *et al*. (2016) estimated the impact of climate change on corn and soybean yields in China using county-level panel data on daily weather and crop yields over the past decade. The study observed the adverse impacts of extreme temperatures on crop growth. Their results further suggested the existence of non-linear and asymmetric relationships between corn and soybean yields and climate variables. Particularly, soybean yields are predicted to decrease by 5–10% under the slowest warming scenario and by 8–22% under the fastest scenario by the end of the century. Diseases and insects/pests pose another serious threat for soybean production and may cause up to 11% reductions in seed yield and deteriorate seed quality (Rupe and Luttrell 2008). Although, considerable damage by insects/pests has not been reported in Pakistan but changing climate may result in the invasion of new species of insects and pathogens and even weeds which could severely damage the already limited progress for soybean cultivation in Pakistan.

Site-specific production technology

Along with other several challenges for soybean cultivation in Pakistan, the non-existence of improved production technology is of great concern. Production technology of soybean is as old as are the varieties *i.e*., >20 years old. Its varieties were not improved according to local climatic conditions; hence bear no attraction for farmers due to low yield and being non-resistant to different insects/pests. Agro-climatic conditions of Pakistan have changed drastically since 1980 when agro-ecological zoning was carried out at the national level and divided the country into twelve zones. Degree of variability in the agro-climatic conditions can be gauged from the fact, that now only Punjab province has been divided into fourteen agro-climatic (Fig. 4), while re-zoning of the remaining country is ongoing by the F.A.O. According to the re-zoning of Punjab, new locations have been identified and proposed suitable for soybean cultivation, while some regions have been omitted from the suitability list for soybean cultivation (Fig. 5). Such extent of variability warrants the need to redevelop the production technologies of all crops including soybean as per new agro-climatic classification. Legumes are very sensitive to environmental and climatic variabilities (Noble and Roger 1992), hence production technologies of all legumes including soybean need to be updated. Unfortunately, due to no recognized position of soybean in the cropping schemes of Pakistan, effective production technology has not been developed according to the changing soil and climatic conditions. This has resulted in significant declines in cultivation and widened yield gaps between research stations and farmer's fields throughout the country. In fact, these widening yield gaps can possibly be narrowed through farm management including irrigation, crop rotation, and precision agriculture. Water deficiency was reported as the single major factor towards reduced soybean cultivation followed by sub-optimal crop management in Brazil (Sentelhas *et al*. 2015). Similarly, the majority of the farmers are facing obstacles for area-specific production technology particularly limited access to information and lack of time-saving and yield-enhancing advanced agricultural mechanization. Selection of varieties recommended for target area, on time cultivation while maintaining high plant population and rotation of crops are key management practices for soybean cultivation (PARC 2020). Deviation from these practices could attract the insect/pest causing irreparable losses to the crop.

Public sector support

Government institutes have a remarkable role to play for introducing and establishing new crops as per national needs. Due to the least attention at the top level, soybean could not establish as an advantageous crop in Pakistan. Recently, the federal Govt. has launched an emergency program to uplift the productivity of selected agricultural crops including wheat, sugarcane, and oilseeds (GOP 2019). This program has forced the farmers to realign themselves with area-specific cropping schemes devised by researchers. Parallel with this, research organizations have accelerated to develop new varieties of soybean as part of this program. Farmers require the provision of good quality seed by Government at affordable prices to embed this crop in their existing schemes. The low commodity price is another factor for low acreage and hence yield, necessitating Govt. to fix support price of the commodity and potential buyers (*e.g*., poultry sector), to attract maximum farmers towards soybean cultivation (Akram and Ahmad 2019). These interventions may bridge the gap between supply and demand of local soybean produce.

Marketing

Marketing of soybean like other minor crops is of great concern and has never been paid due attention at the policy level. Similarly, the issue of creating demand is very much disturbing for soybean growers. For instance, during 2017–2018 approximately 2.5 MT of soybean was imported thereby forcing the local producers to sell their commodity at a discounted price of 80 US$ per 40 kg as compared to imported one. In fact, the marketing issue of local soybean needs to be addressed to make it comparable with the international market for avoiding the surplus supply of imported soybean.

The high cost of production of local soybean as compared to the international price is another major impediment in its cultivation and subsequent poor marketing. Importers can purchase international soybean which is much cheaper than our local produce. Due to these facts' importers prefer to purchase soybean and other oilseeds from the international market. This heavy dependence on oilseeds import has unfortunately resulted in the installment of solvent extraction units near the ports thus making the importers more and more inclined towards the international markets. The government should convince and force the importers and solvent extraction industry for encouraging the local producers through investments in projects focused on lowering the cost for local production of soybean. Subsidizing the inputs like seeds and fertilizers and ensuring the support price may improve the grave situation regarding the local production of soybean.

Awareness among the farmers

Soybean is a new addition to the conventional cropping system of Pakistan; hence its cultivation has been unparalleled since its inception in the 1960s. As is evident from the data shown in Fig. 1 and 2, maximum cultivation and accompanying yields are reported on the onset of the current century followed by gradual decline afterward. Such declines in cultivation may be attributed to the policy matters, no research, and extension services for promoting this crop. Multiplication and free distribution of soybean seeds by the PARC are not yielding satisfactory results. This is because, production technology of this crop is missing in this package and farmers do not pay due attention to seeds delivered to them without any knowledge and unfortunately, the education level of Pakistani farmers is very low (Ghazanfar *et al.* 2015).

In fact, farmers are unaware of the benefits of cultivating this oilseed legume both in terms of soil improvement, best quality food, feed, and economic wellbeing. Less support price of soybean, non-existence of marketing facilities, non-availability of quality seeds, and zone-specific production technology are few amongst many other shortcomings for soybean cultivation in Pakistan (Khurshid *et al.* 2017). Farmer's motivation and decision making are fundamental to Govt. policies, but ridiculously farmer's feedback is either not collected/documented or not given due attention most often. Most of our farmers are uneducated and unable to follow the instructions in languages other than local, which further adds to the miseries of farmers. Soybean is considered as a minor crop like other oilseed crops which is another factor of less acceptability among Pakistani farmers (Rehman *et al.* 2014). This could be attributed to the socio-economic

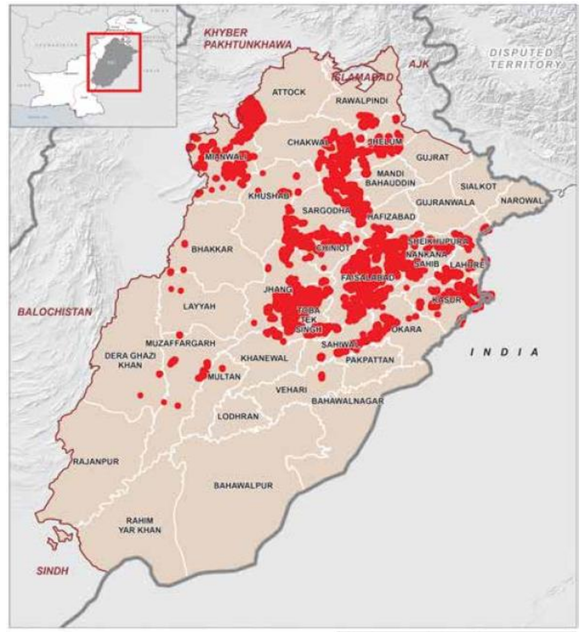

Fig. 5: Best suitable areas for soybean cultivation in Punjab. Land suitability classification is marked according to the new agro-climatological zoning of Punjab province (*Source: FAO, 2019*)

conditions of the farmers, lack of education, and extension services. Engagement of growers along with the provision of quality seeds and extended extension services may be quite supportive towards the successful cultivation of soybean in Pakistan.

Conclusions and Prospects

Soybean was introduced in Pakistan as an oilseed crop in 1960 and commercialized a decade later throughout the country. Despite several efforts at policy and research level, the required results in terms of local soybean production were not obtained mainly because of the least interest by farmers to accommodate this new crop in existing cropping schemes. Moreover, because of limited extension service to educate farmers regarding the benefits and uses of soybean on soil health and economic wellbeing of farmers and contribution towards the national economy, soybean could not be established as a rewarding crop in Pakistan. Parallel with this, soybean germplasm introduced in Pakistan was imported from other countries, which because of being non-native could not produce required yields under local climatic and edaphic conditions. Unfortunately, serious efforts to breed local cultivars of soybean were lacking from the very beginning which ultimately halted the process of evolution of new lines according to local requirements. Agro-climatic conditions of Pakistan are suitable for the cultivation of soybean in all the four provinces. There is a need to work on the adaptability of soybean cultivars under different climatic conditions of Pakistan to ensure the self-sufficiency in quality food, feed, and edible oil production, ultimately a step forward for achieving sustainable food security along with significant improvements in soil health. Parallel with adaptability, breeding climate-resilient high yielding local soybean varieties, and developing area-specific production technology of soybean are direly needed. Strengthening extension services to engage farmers, timely provision of quality seeds, buying back guarantees of produce may yield promising results. Concreted efforts at policy and research level are direly needed for the successful cultivation of this very important food and feed crop and save billions of US$ which are currently being spent on imports of soybean for taping the domestic needs.

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