Chapter

# Cereal Grains of Bangladesh – Present Status, Constraints and Prospects

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*"Bangladesh has emerged as a global model for combating hunger and obtained great success in becoming a country of food surplus from a country lagged with chronic food shortages"*

*– The Christian Science Monitor.*

## Abstract

The edible seeds or grains of the grass family Poaceae (conserved name Gramineae) is commonly known as cereals and are cultivated for the edible component, grain consisting of the germ (or an embryo), endosperm and bran. Bangladesh, predominantly an agrarian country, has a long tradition of cereal grains cultivation, consumption and conservation. Rice is the staple food for millions (of people) across the globe including Bangladesh. It occupies more than 96% of the land area under "Cereal Agriculture" in Bangladesh. Maize occupies the 2nd position both in acreage and production followed by wheat and other minor cereals *viz*. barley, sorghum and millets. In this chapter, the historical development and production scenario of different cereal crops and their present status, constraints, challenges and opportunities has been described and discussed. The information presented here would provide a clear inside of the "Cereal Agriculture of Bangladesh" to students, researchers, administrators, policymakers, and the common people as well.

**Keywords:** Cereal agriculture, Historical development, Production trends, Food and nutritional security, Bangladesh

## 1. Introduction

The name "cereal" derives from *Ceres*, the Roman and Greek goddess of harvest and agriculture. The edible seeds or grains of the grass family Poaceae (conserved name Gramineae) is usually referred to as cereals (botanically, a sort of fruit called a caryopsis) and are cultivated for the edible component highly nutritious grain consisting of the germ (or an embryo), endosperm and bran. The cereal grains have a high starch content and also contain varying amounts of protein, the embryos often contain oil, and vitamins occur in the outer tissues of the seed. The comparative nutrient composition of different cereal crops is presented in **Table 1**. Cereal grains have

| Cereal | Protein (%) | Fat (%) | Crude fiber (%) | Ash (%) | Starch (%) | Total dietary fiber (%) | Total phenol (mg/100 g) |
|---|---|---|---|---|---|---|---|
| Rice | 7.5 | 2.4 | 10.2 | 4.7 | 77.2 | 3.7 | 2.51 |
| Wheat | 14.4 | 2.3 | 2.9 | 1.9 | 64.0 | 12.1 | 20.5 |
| Maize | 12.1 | 4.6 | 2.3 | 1.8 | 62.3 | 12.8 | 2.91 |
| Barley | 11.5 | 2.2 | 5.6 | 2.9 | 58.5 | 15.4 | 16.4 |
| Sorghum | 11 | 3.2 | 2.7 | 1.8 | 73.8 | 11.8 | 43.1 |
| Oats | 17.1 | 6.4 | 11.3 | 3.2 | 52.8 | 12.5 | 1.2 |
| Rye | 13.4 | 1.8 | 2.1 | 2.0 | 68.3 | 16.1 | 13.2 |
| Finger millet | 7.3 | 1.3 | 3.6 | 3.0 | 59.0 | 19.1 | 10.2 |
| Pearl millet | 14.5 | 5.1 | 2.0 | 2.0 | 60.5 | 7.0 | 51.4 |
| Foxtail millet | 11.7 | 3.9 | 7.0 | 3.0 | 59.1 | 19.1 | 106 |

*Source: Saldivar [1].*

**Table 1.**
*Nutrient composition of cereal grains.*

been the most important suppliers of dietary energy for more than 24 centuries and hope to be continued in the coming years. The importance of cereals (in the human diet) is well represented within the logo of the Food and Agriculture Organization of the United Nations, a wheat ear with a Latin inscription below "*Fiat Panis*" (Eng. Let there be bread). Cereals also have a wide array of virtues and benefits. For example, a long time storage ability due to the yield of mature and imperishable grains that can be gradually used as food or seed for future sowing. The cereal grains were first domesticated by ancient farming communities about 8,000 years ago in the Fertile Crescent region, considered to be the cradle of agriculture and food production [2]. Rice and millets were starting to become domesticated in East Asia by the year 7,500 BC. Around the same time, Sorghum and millets were also being domesticated in sub-Saharan West Africa. On average, cereal grain products supply approximately 55% of calories and 48% of their protein requirement of a human diet [2].

Bangladesh, a low-lying, riverine country, lies in the north-eastern part of South Asia between latitude $20^0$34′ and $26^0$38' N and longitude $88^0$01′ and $92^0$41′ E. The country, with an area of 147,570 sq. km (56,977 sq. mi), is bounded by India on the west-north and north-east while Myanmar on the south-east and the Bay of Bengal on the south [3]. Bangladesh, predominantly an agrarian country, enjoys generally a subtropical monsoon climate. The country comprises a wide range of agro-ecosystems spread over the wetlands, (deltaic) flood plains as well as the hills. The agriculture sector contributes about 14.23% of the country's GDP and employs around 40.60% of the total labour force [4]. Due to its very fertile land and favorable weather conditions, a wide diversities of crops e.g., cereals, pulses, oilseeds, spices and condiments, fibers, vegetables, etc. grow abundantly in this country. Cereal crops occupied more than 75% of the total cropped area of Bangladesh [4].

Among the cereal crops, rice is the staple food for millions across the globe including Bangladesh. In Bangladesh, rice occupies more than 96% of the land area under "Cereal Agriculture". Bangladesh is the third-largest rice producer in the world after China and India [5]. Maize occupies the 2nd position both in acreage and production, but its production is insufficient to meet the national demand, followed by wheat and other minor cereals *viz*. barley, sorghum and millets. Minor cereals, sometimes also called poor man's crops, are rich in dietary fibers, phenolics and polysaccharides, antioxidants, mineral nutrients, etc. These are commonly used as constituents of special food preparations e.g., kheer or payes, moa (sweet ball of fried millets), porridge, pitha or cakes, pudding, flour, bread, sometimes cooked as rice, etc. and for feeding birds, poultry, livestock fodder and feed in developed countries. In Bangladesh, cereals provide a major part of the calorie intake, although their share in total calorie consumption has decreased from 92% in 1990 to 89% by 2010 with a projection of further decrease to 87% by 2031 and 86% by 2050 [6]. Cereal crops are also a dominating component of the present cropping patterns of Bangladesh. Presently, 316 different cropping patterns were recorded in this country excluding the minor ones, individually occupied less than 0.0001 per cent of the net cropped area [7]. Rice (Boro)-Fallow-Rice (T. Aman) was the most dominant cropping pattern which occupied 26.92% of the net cropped area; whereas the last cropping pattern was the Barley-Fallow-Fallow which occupied only 0.0002% of the net cropped area. Some of the most prominent cropping patterns among these are sown in **Table 2**.

| No. | Cropping pattern | Area (ha) | % of NCA | District (no.) | Upazila (no.) |
|---|---|---|---|---|---|
| 001 | Boro–Fallow–T. Aman | 2306005 | 26.919 | 63 | 426 |
| 002 | Boro–Fallow–Fallow | 1139530 | 13.302 | 59 | 342 |
| 003 | Fallow–Fallow–T. Aman | 509480 | 5.947 | 36 | 162 |
| 004 | Boro–Aus – T. Aman | 209015 | 2.440 | 47 | 177 |
| 005 | Fallow–Aus – T. Aman | 193275 | 2.256 | 30 | 108 |
| 006 | Mustard–Boro–T. Aman | 184620 | 2.155 | 51 | 203 |
| 007 | Boro–B. Aman | 183070 | 2.137 | 32 | 113 |
| 008 | Potato–Boro–T. Aman | 180380 | 2.106 | 33 | 115 |
| 009 | Wheat–Jute–T. Aman | 147210 | 1.718 | 43 | 216 |
| 010 | Vegetable–Vegetable–Vegetable | 143270 | 1.672 | 61 | 283 |
| 011 | Mustard–Boro–Fallow | 143130 | 1.671 | 37 | 112 |
| 012 | Grasspea–Fallow–T. Aman | 108150 | 1.262 | 25 | 80 |
| 013 | Maize–Fallow–T. Aman | 101460 | 1.184 | 39 | 126 |
| 014 | Wheat–Fallow–T. Aman | 90910 | 1.061 | 39 | 100 |
| 015 | Mungbean–Fallow–T. Aman | 89650 | 1.047 | 22 | 70 |
| 016 | Grasspea–Aus – T. Aman | 81610 | 0.953 | 19 | 61 |
| 017 | Vegetable–Fallow–T. Aman | 74710 | 0.872 | 45 | 170 |
| 018 | Vegetable–Vegetable–Fallow | 63935 | 0.746 | 59 | 168 |
| 019 | Onion–Jute–T. Aman | 54185 | 0.633 | 39 | 102 |
| 020 | Mungbean–Aus – T. Aman | 53730 | 0.627 | 14 | 43 |
| 021 | Chili–Fallow–T. Aman | 52995 | 0.619 | 45 | 146 |
| 022 | Lentil–Jute–T. Aman | 51875 | 0.606 | 34 | 96 |
| 023 | Vegetable–Vegetable–T. Aman | 51745 | 0.604 | 49 | 127 |
| 024 | Wheat–Jute–Fallow | 48700 | 0.568 | 32 | 82 |
| 025 | Potato–Maize–T. Aman | 47690 | 0.557 | 19 | 68 |

*Source: Nasim et al. [7].*

**Table 2.**
*List of prominent cropping patterns in Bangladesh.*

In this chapter, the historical development and production scenario of different cereal crops of Bangladesh, their present status, constraints, challenges and opportunities have been described and discussed.

## 2. Major cereals

### 2.1 Rice (*Oryza sativa* L.)

In our tradition, rice is synonymous with food, the world's second-largest per capita rice consumption at 179.9 kg $yr.^{-1}$ [8], and is dominating the entire crop sector. It provides nearly 48% of rural employment, about two-thirds of the total calorie supply and one-half of the total protein intake of an average person in the country. The rice sector contributes one-half of the agricultural GDP and one-sixth of the national income in Bangladesh [3]. Due to favorable weather conditions (e.g., temperature, relative humidity, rainfall, day length, etc.), rice is grown all the year-round in three growing periods *viz*. Aus (summer rice; April–August), Aman (monsoon rice; July–December), and Boro (winter rice; November–June) in Bangladesh. The growth of rice production in Bangladesh was 2.8% $yr.^{-1}$ in the 1980s and 3.5% $yr.^{-1}$ from 1990 to 1991 until recently [9]. Since the late 1980s, most of this growth has occurred through the development and adoption of improved and stress-tolerant rice cultivars through irrigation in Boro rice (dry season) and supplementary irrigation in Aman rice. The introduction of Boro rice in low-lying areas by replacing rain-fed traditional Aus rice cultivars, jute and the other upland crop cultivars also played an important role [9].

The total rice coverage was about 11.52 million hectares (m ha) over three rice growing seasons in 2018–2019 (**Table 3**). Most of the modern rice cultivars are photoperiod insensitive, therefore, they could be cultivated almost throughout the year. Even in some specific ecosystems, farmers may harvest three rice crops a year from the same piece of land. The recent coverage of Aus, Aman and Boro area were 9.60, 48.82 and 41.58 per cent, respectively. Boro and Aman contributed 53.75 and 38.62 per cent, respectively of the total rice production whereas Aus only 7.63 per cent, although total production of Aus rice increasing very slowly [9].

Though the total rice-growing area did not change much during the last four and a half decades (**Figure 1**), rice production nearly quadrupled from 9.8 million metric tons (m t) in 1971–1972 to 36.4 m t in 2019, helping Bangladesh to achieve self-sufficiency in rice production and ensuring food security. There had been a major shift in ecotype based (Boro-Aus-Aman) rice cultivation. The area under HYVs of Boro rice was 0.32 m ha in 1971–1972, 4.11 m ha in 2007–2008 and 4.79 m ha in 2018–2019. Most of the traditional Aus cultivars were in the process of replacement with the introduction of HYVs. Around 50 per cent of the traditional Deep Water

| Season | Coverage (m ha) | Total production (m t) | Yield (t $ha^{-1}$) | % of total area | % of total production |
|---|---|---|---|---|---|
| *Aus* | 1.11 | 2.78 | 2.51 | 9.60 | 7.63 |
| *Aman* | 5.62 | 14.06 | 2.50 | 48.82 | 38.62 |
| *Boro* | 4.79 | 19.56 | 4.08 | 41.58 | 53.75 |
| Total | 11.52 | 36.30 | | — | — |

*Source: BBS (Bangladesh Bureau of Statistics) [4].*

**Table 3.**
*Rice statistics in 2018/19.*

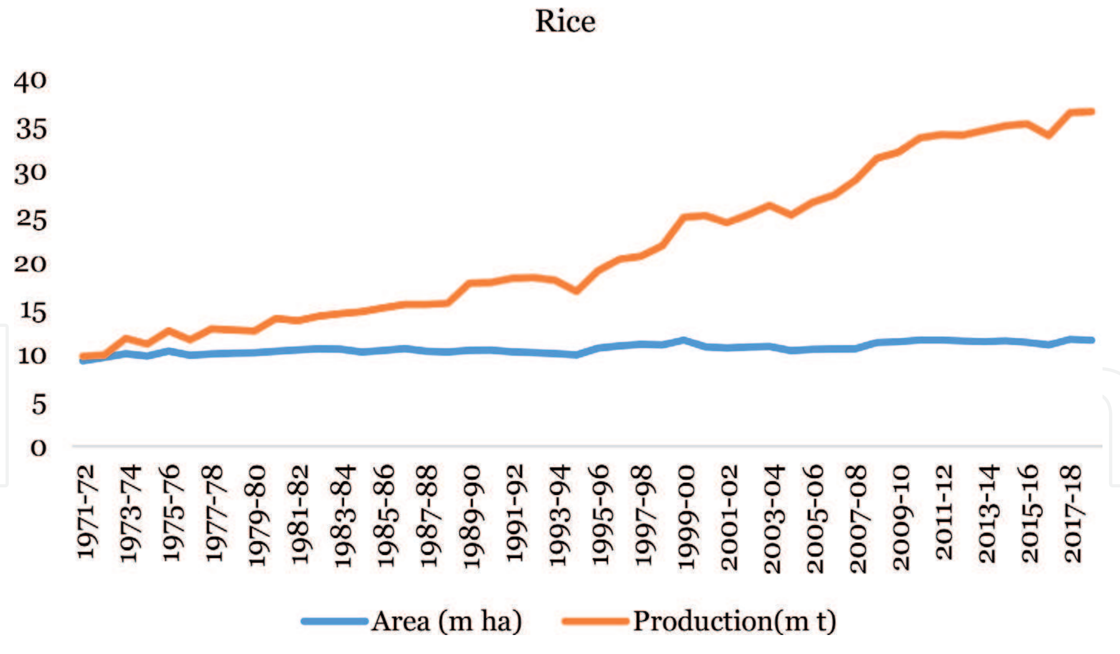


**Figure 1.**
*Area coverage and production trend of rice. M ha million hectare; m t million metric ton. Source: BBS [4, 10].*

Rice (DWR) lands were transformed into irrigated Boro land [9]. In 1971–1972 traditional Aus coverage was 2.95 m ha. More than two-thirds of the Aus area was given up mostly to Boro by 2014–2015. The coverage under Aman has experienced little change since 1971. The trends in area coverage and production under different rice ecotypes are described and discussed in detail in [9]. Recently, researchers of the Bangladesh Rice Research Institute (BRRI) and their collaborators had developed the rice vision leading to 2050 and beyond for Bangladesh [11]. They reported that rice production could reach 47.2 m t, having a surplus of 2.6 m t in 2050 and targeted to be continued thereafter, at the present increment rate of rice production. Several measures were also recommended to achieve the rice vision of Bangladesh leading to 2050 and beyond [11]. Although rice is the component of most of the cropping patterns of Bangladesh, 17 cropping patterns exclusively contained rice crops [7]. Five of them were most dominant among cropping patterns of Bangladesh.

### *2.1.1 Rice cultivars of Bangladesh*

Bangladesh was very rich in rice genetic resources. Name of nearly 12,500 traditional cultivars, those were cultivated in different seasons of Bangladesh, were listed [12]. The International Rice Research Institute (IRRI) Gene Bank contains more than 8,000 traditional rice cultivars collected from Bangladesh. Rice breeders used many of these landraces as donors to develop elite lines that have been used as parents for popular improved rice cultivars grown throughout Asia [13]. The Genetic Resource and Seed Division of Bangladesh Rice Research Institute (BRRI) has collected and conserved more than 8,000 landraces of rice were as long medium, and short-term storage (**Table 4**). Most of the traditional cultivars are out of cultivation due to comparatively low yield, although these have many exceptional qualities e.g., fineness, taste, aroma, etc. Only around eight per cent of the recorded landrace cultivars are still available with the farmers in some fragile pocket areas like saline, drought, deep water area and hilly areas of Bangladesh [13]. In recent years, the cultivation of traditional rice cultivars with exceptional features e.g., long grains, fineness, taste, aroma, etc. is retrieving popularity for a premium price, customer's preferences, national and international demand, etc. Presently, one specialized research institute, the BRRI and a few other organizations like Bangladesh Institute of Nuclear

| Cultivar/Line | Registered in accession |
|---|---|
| Indigenous *indica* | |
| Local landraces | 5202 |
| Pure line selection | 1030 |
| Exotic *indica* landraces (IRRI, China, USA, Turkey) | 790 |
| Exotic/breeding lines | 968 |
| Wild Rice of Bangladesh (*Oryza rufipogon*, *O. officinalis*, *O. nivara*, and *O. sativa* f. *spontanea*) | 42 |
| Wild rice from IRRI | 12 |
| Total | 8044 |

*Source: DoE [14].*

**Table 4.**
*Rice genetic resources in the BRRI Gene Bank.*

| Season | Cultivar |
|---|---|
| Aus | Broadcast – BR20, BR21, BR24, BRRI dhan27, BRRI dhan42, BRRI dhan43, BRRI dhan65 and BRRI dhan83. |
| | Transplant – BR1, BR2, BR3, BR6, BR7, BR8, BR9, BR14, BR16, BR26, BRRI dhan27, BRRI dhan48, BRRI dhan55, BRRI dhan82, BRRI dhan85, BRRI dhan98 and BRRI hybrid dhan7; Iratom 24, Binadhan-19. |
| Aman | BR3, BR4, BR5, BR10, BR11, BR22, BR23, BR25, BRRI dhan30, BRRI dhan31, BRRI dhan32, BRRI dhan33, BRRI dhan34, BRRI dhan37, BRRI dhan38, BRRI dhan39, BRRI dhan40, BRRI dhan41, BRRI dhan44, BRRI dhan46, BRRI dhan49, BRRI dhan51, BRRI dhan52, BRRI dhan53, BRRI dhan54, BRRI dhan56, BRRI dhan57, BRRI dhan62, BRRI dhan66, BRRI dhan70, BRRI dhan71, BRRI dhan72, BRRI dhan73, BRRI dhan75, BRRI dhan79, BRRI dhan80, BRRI dhan87, BRRI dhan90, BRRI dhan91, BRRI dhan93, BRRI dhan94, BRRI dhan95, BRRI hybrid dhan4 and BRRI hybrid dhan6; Binashail, Binadhan-4, Binadhan-7, Binadhan-11, Binadhan-12, Binadhan-13, Binadhan-15, Binadhan-16, Binadhan-17, Binadhan-19, Binadhan-21, Binadhan-22, Binadhan-23; BAU dhan1, BAU dhan2. |
| Boro | BR1, BR2, BR3, BR6, BR7, BR8, BR9, BR12, BR14, BR15, BR16, BR17, BR18, BR19, BR26, BRRI dhan28, BRRI dhan29, BRRI dhan35, BRRI dhan36, BRRI dhan45, BRRI dhan47, BRRI dhan50, BRRI dhan55, BRRI dhan58, BRRI dhan59, BRRI dhan60, BRRI dhan61, BRRI dhan63, BRRI dhan64, BRRI dhan67, BRRI dhan68, BRRI dhan69, BRRI dhan74, BRRI dhan81, BRRI dhan84, BRRI dhan86, BRRI dhan88, BRRI dhan89, BRRI dhan92, BRRI dhan96, BRRI dhan97, BRRI dhan99, BRRI dhan100, BRRI hybrid dhan1, BRRI hybrid dhan2, BRRI hybrid dhan3 and BRRI hybrid dhan5; Binadhan-5, Binadhan-6, Binadhan-8, Binadhan-10, Binadhan-14, Binadhan-18, Binadhan-24; BAU dhan3. |

*Source: BRRI [15]; http://www.bina.gov.bd/; http://www.sca.gov.bd/*

**Table 5.**
*Seasonal distribution of modern, both inbred and hybrid, rice cultivars in Bangladesh.*

Agriculture (BINA), Bangladesh Agricultural University (BAU), are working on the development of high yielding rice cultivars, both inbred and hybrids, for different seasons (**Table 5**). Seeds of some hybrid cultivars are imported by different organizations and seed companies from different countries.

### 2.2 Wheat (*Triticum aestivum* L.)

Wheat, one of the first cultivated plants, possesses unique dough-forming properties and is the leading source of plant (cereal) protein in the human diet, having higher protein content (14.4%) compared to other major cereals i.e., maize

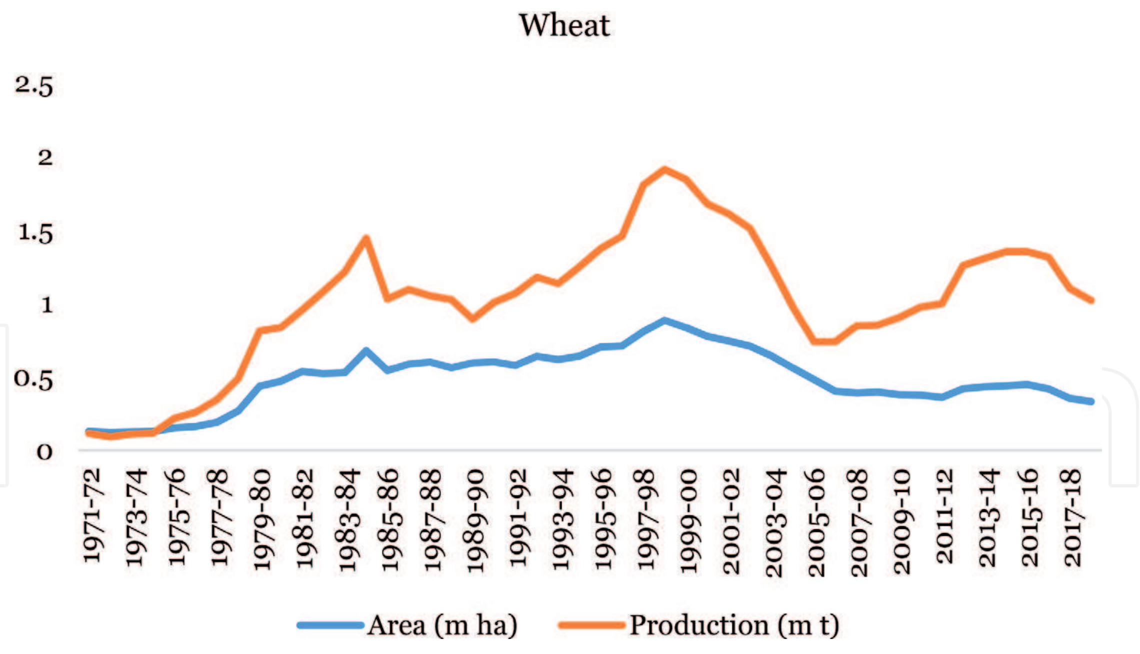


**Figure 2.**
*Area coverage and production trend of wheat. M ha million hectare; m t million metric ton. Source: BBS [4, 10].*

(corn) and rice (12.1 and 7.5%, respectively) (**Table 1**). In terms of total production tonnages used for food, it is currently second to rice as the main human food crop and ahead of maize, allowing for more extensive use in animal feeds. The increasing income level and urbanization lead to dietary changes such as switching from traditional rice to wheat and to livestock, poultry, and fish products, which in turn require large amounts of maize for their production [16].

In Bangladesh, it is a crop of Rabi (Winter; Mid-October to Mid-March) season; it requires dry weather, bright sunlight and well-distributed rainfall between 40 and 110 cm for congenial growth. Although wheat has some advantages in its cultivation compared to Boro and other winter crops i.e., less water requirement, echo-friendly, high nutritional value, diversified use, etc.; the command area under wheat cultivation showed a decreasing trend (**Figure 2**). In 1971–1972, the coverage was 0.127 m ha and the total production was only 0.113 m t. Since then the coverage area remarkably went up to 0.88 m ha in 1998–1999 which is almost 7 times in 27 years. However, the area declined to 0.39 m ha in 2006–2007 and maintained more or less the same level up to 2011–2012, thereafter, an increasing trend up to 2015–2016 and the 0.33 m ha in 2018–2019 (**Figure 2**). The total production followed the same trend until 2006–2007 having the highest peak (1.90 m t) in 1998–1999. However, despite a small increase in the coverage area (compared to 1971–1972), the production trend is quite inspiring (**Figure 2**). This might be due to the application of innovative approaches in wheat research and development [9]. A specialized research institute, the Bangladesh Wheat and Maize Research Institute (BWMRI) has very recently been established in 2017. Formerly, it was a (Wheat) Research Centre under the Bangladesh Agricultural Research Institute (BARI). Until today 33 high yielding wheat cultivars are developed by BARI (**Table 6**). Just getting separated from BARI very recently, BWMRI has released three cultivars, *viz*. WMRI Gom 1, WMRI Gom 2 and WMRI Gom 3, within a short period. The Plant Genetic Resources Centre (PGRC), BARI has also collected and conserved 602 wheat accessions in its gene banks and conservatories [18]. Despite the governmental heartfelt afford and policy supports the wheat-growing area declining day by day due to climate change impacts e.g., shorter winter, high temperature, early or late monsoon rainfall, etc. Among the cropping patterns, the number of wheat-based cropping

| Serial Number | Name of cultivar | Year of Release | Yield (t $ha^{-1}$) |
|---|---|---|---|
| 1 | Kalyansona | 1968 | 2.6–3.2 |
| 2 | Sonora 64 | 1974 | 1.6–2.2 |
| 3 | Norteno 67 | 1974 | 2.8–3.2 |
| 4 | Mexi 65 | 1974 | 2.6–3.6 |
| 5 | Inia 66 | 1974 | 2.5–3.0 |
| 6 | Sonalika | 1974 | 3.0–3.5 |
| 7 | Tanori 71 | 1975 | 2.8–3.2 |
| 8 | Jupateco 73 | 1975 | 3.0–3.2 |
| 9 | Nuri 70 | 1975 | 2.5–3.0 |
| 10 | Balaka | 1979 | 2.6–3.0 |
| 11 | Doel | 1979 | 2.5–3.0 |
| 12 | Pavon 76 | 1979 | 3.0–3.6 |
| 13 | Akbar | 1983 | 3.5–4.5 |
| 14 | Kanchan | 1983 | 3.5–4.5 |
| 15 | Ananda (BAW 18) | 1983 | 2.1–3.4 |
| 16 | Barkat | 1983 | 3.4–3.8 |
| 17 | Agrahani | 1987 | 3.5–4.0 |
| 18 | Protiva | 1993 | 3.5–4.5 |
| 19 | BARI Gom –19 (Sourav) | 1998 | 3.5–4.5 |
| 20 | BARI Gom –20 (Gourab) | 1998 | 3.6–4.8 |
| 21 | BARI Gom –21 (Shatabdi) | 2000 | 3.6–5.0 |
| 22 | BARI Gom –22 (Sufi) | 2005 | 3.6–5.0 |
| 23 | BARI Gom –23 (Bijoy) | 2005 | 4.3–5.0 |
| 24 | BARI Gom –24 (Prodip) | 2005 | 4.3–5.1 |
| 25 | BARI Gom-25 | 2010 | 3.6–5.0 |
| 26 | BARI Gom-26 | 2010 | 3.6–5.0 |
| 27 | BARI Gom –27 | 2012 | 4.0–5.4 |
| 28 | BARI Gom –28 | 2012 | 4.0–5.5 |
| 29 | BARI Gom –29 | 2014 | 4.0–5.0 |
| 30 | BARI Gom –30 | 2014 | 4.5–5.5 |
| 31 | BARI Gom –31 | 2017 | 4.5–5.0 |
| 32 | BARI Gom –32 | 2017 | 4.6–5.0 |
| 33 | BARI Gom –33 | 2017 | 4.0–5.0 |

*Source: Azad et al. [17].*

**Table 6.**
*Modern wheat cultivars developed by Bangladesh Agricultural Research Institute.*

patterns was 27 which occupying 5.36% of the net cropped area [7]. Wheat-Jute-T. Aman was the most dominant cropping pattern followed by Wheat-Fallow-T. Aman with a net cropped area of 1.72% and 1.06%, respectively. Late planting of wheat due to delayed harvesting of T. Aman rice, a longer time for land preparation, formation of plow pan due to puddling in transplanted rice, low organic matter and micro-nutrients deficiency in the soil, unavailability of labourers, hotter winter, late monsoon rain and some cases of excess moisture in the soil, causes a significantly lower yield in every year.

### 2.3 Maize (*Zea mays* L.)

Maize, indigenous to the Americas and staple in South and Central America and Southern Africa, occupied the second position both in area and production and mainly used for animal and poultry feed industries in Bangladesh. It was an insignificant crop, still reported as a minor cereal in Bangladesh perspective [4], and a little development was observed until 2000. Then the area started increasing progressively while the total production increased quite significantly (**Figure 3**). Maize is now cultivated in both Rabi (Winter; Mid-October to Mid-March) and Kharif-1 (Early monsoon; Mid-March to Mid-July) seasons, and area and production of maize increased considerably. Now, it secured second position pushing wheat to third. In 1971–1972, the coverage and total production were 0.0028 m ha and 0.002 m t respectively which increased to 0.445 m ha to produce 3.569 m t in 2019 (**Figure 3**). The corresponding increments in percentages were *ca*. 16,000 and 180,000, respectively. The phenomenal rise in area and production of maize was mainly due to the favorable environment for higher productivity and a stable and expanding market as feed for the poultry and livestock. From 2010 to 2019, maize production increased at an average annual rate of 11.40%, with some wheat producers switching to the cultivation of maize [9]. Since maize is used mostly as poultry feed, the substitution of the wheat-growing area by maize hampered the supply of staple food for people and has put more pressure on other cereals (i.e., rice) to meet the growing food grain demand. And a substantial increase in wheat import is observed to meet up the local demand [3]. So far, 26 maize cultivars have been released by BARI (**Table 7**); and 92 maize accessions are conserved at the PGRC, BARI [18]. A total of forty-three maize-based cropping patterns were listed for Bangladesh [7]. The most dominant cropping pattern with maize was Maize-Fallow-T. Aman, which occupied 1.18% of the net cropped area. Maize-based cropping patterns altogether covered 3.85% of the net cropped area [7].

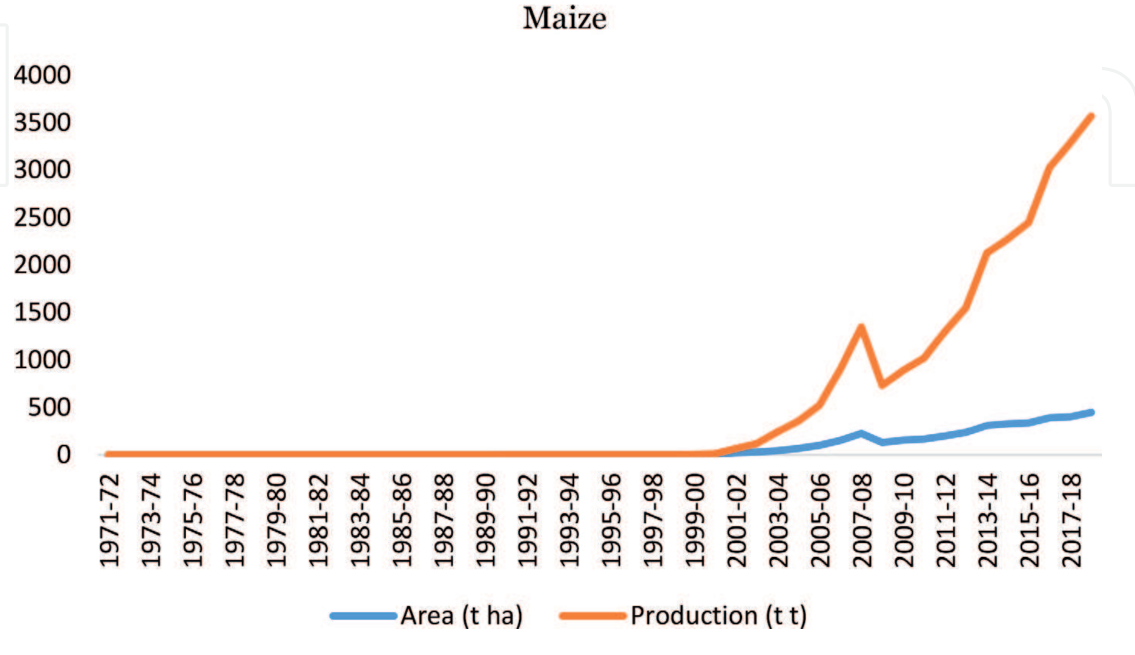


**Figure 3.**
*Area coverage and production trend of maize. Source: BBS [4, 14].*

| Serial Number | Name of cultivar | Season | Yield (t $ha^{-1}$) |
|---|---|---|---|
| 1 | Shuvra | Rabi | 4.5–5.5 |
| 2 | Khoibhutta | Rabi, Kharif | Rabi-3.5-4.0, Kharif-2.5-3.5 |
| 3 | Barnali | Rabi, Kharif | Rabi-5.5-6.0, kharif-4.0-4.5 |
| 4 | Mohor | Rabi, Kharif | Rabi-5.0-5.5, Kharif-3.5-4.5 |
| 5 | BARI Maize-5 | Rabi, Kharif | Rabi-6.5-7.5, Kharif-5.0-6.0 |
| 6 | BARI Maize-6 | Rabi, Kharif | Rabi-6.5-7.5, Kharif-5.0-6.0 |
| 7 | BARI Maize-7 | Rabi, Kharif | Rabi-6.5-7.5, Kharif-5.0-6.0 |
| 8 | BARI Sweet Corn-1 | Rabi | 10.5 |
| 9 | BARI Baby Corn-1 | Rabi | 1.27–1.30 |
| 10 | BARI Hybrid Maize-1 | Rabi, Kharif | Rabi-7.5-8.5, Kharif-6.5-7.0 |
| 11 | BARI Hybrid Maize-2 | Rabi, Kharif | Rabi-9.0-9.5, Kharif-7.0-7.5 |
| 12 | BARI Hybrid Maize-3 | Rabi, Kharif | Rabi- 10-10.5, Kharif-7.0-7.5 |
| 13 | BARI Hybrid Maize-4 | Rabi, Kharif | Rabi- 9.0-9.5, Kharif-7-7.5 |
| 14 | BARI Hybrid Maize-5 | Rabi, Kharif | Rabi- 9-10, Kharif-7.0-7.5 |
| 15 | BARI Hybrid Maize-6 | Rabi, Kharif | Rabi- 9.0-9.5, Kharif-7-7.5 |
| 16 | BARI Hybrid Maize-7 | Rabi, Kharif | Rabi- 10.0-11.0, Kharif-7-7.5 |
| 17 | BARI Hybrid Maize-8 | Rabi, Kharif | Rabi- 10.0-11.5, Kharif-7-7.5 |
| 18 | BARI Hybrid Maize-9 | Rabi, Kharif | Rabi- 11.5-12.5 |
| 19 | BARI Hybrid Maize-10 | Rabi, Kharif | Rabi- 10.0-11.5 |
| 20 | BARI Hybrid Maize-11 | Rabi, Kharif | Rabi- 10.5-11.5 |
| 21 | BARI Hybrid Maize-12 | Rabi | 10.0–11.1 |
| 22 | BARI Hybrid Maize-13 | Rabi | 8.1–8.9 |
| 23 | BARI Hybrid Maize-14 | Rabi, Kharif | Rabi- 10.84, Kharif-10.52 |
| 24 | BARI Hybrid Maize-15 | Rabi, Kharif | Rabi- 12.75, Kharif-12.07 |
| 25 | BARI Hybrid Maize-16 | Rabi | 11.57 |
| 26 | BARI Hybrid Maize-17 | — | — |

*Source: Azad et al. [17]; http://www.bwmri.gov.bd/*

**Table 7.**
*Modern maize cultivars developed by Bangladesh Agricultural Research Institute.*

## 3. Minor cereals

### 3.1 Barley (Bangla: Jab; *Hordeum vulgare* L.)

Barley, one of the oldest cereal crops, ranked fourth among grains behind maize, rice, and wheat. It is widely grown in marginally productive soils across the world points to the high adaptability of the genus *Hordeum* to edaphic stresses [19]. In Bangladesh, barley is a minor cereal crop grown in the small area of two Upazilas (sub-district), *viz*. Chowhali and Tarash, of Sirajganj district [20]. In 1971–1972, the coverage and total productions were only 28,700 ha and 21,300 t, respectively which decreased to 297 ha and produced 244 t in 2018 (**Figure 4**). The BARI has released 9 barley cultivars (**Table 8**), and 54 accessions of barley germplasm are also conserved at the PGRC [18]. The only barley-based cropping

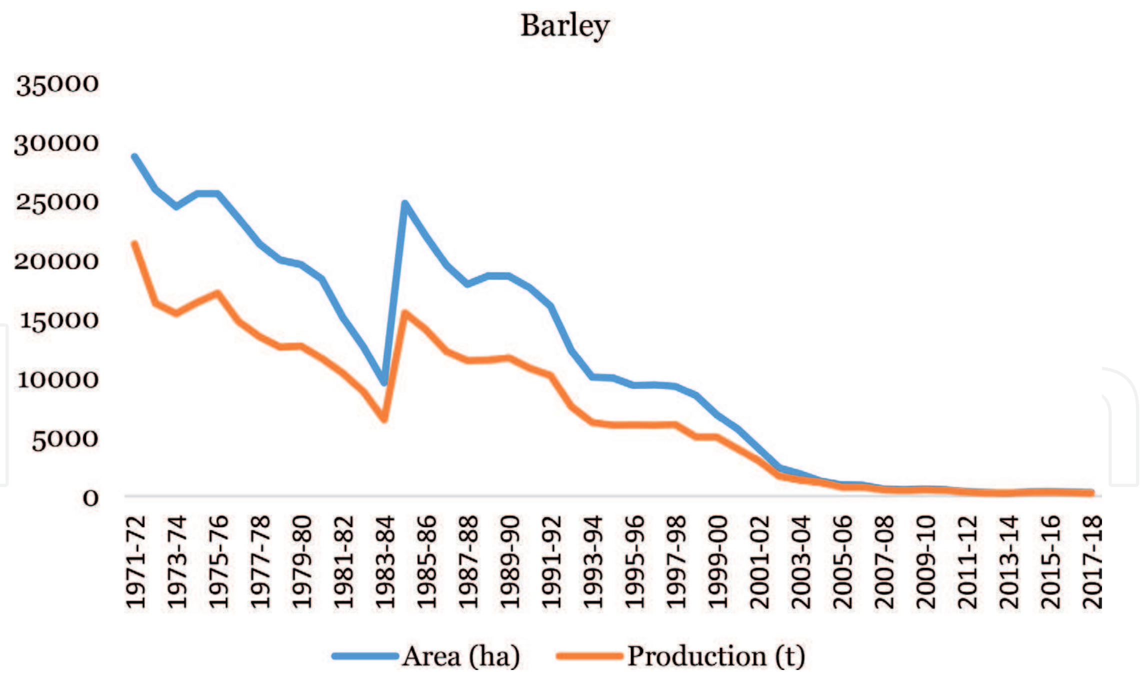


**Figure 4.**
*Area coverage and production trend of barley. T ha thousand hectare; t t thousand metric ton. Source: FAOSTAT 2020 http://www.fao.org/faostat/en/#data/QC.*

| Serial Number | Name of cultivar | Year of Release | Yield (t ha$^{-1}$) |
|---|---|---|---|
| 1. | BARI Barley-1 | 1994 | 2.2–2.5 |
| 2. | BARI Barley-2 | 1994 | 2.0–3.0 |
| 3. | BARI Barley-3 | 2001 | 2.2–2.5 |
| 4. | BARI Barley-4 | 2001 | 1.75–2.0 |
| 5. | BARI Barley-5 | 2005 | 2.5–3.0 |
| 6. | BARI Barley-6 | 2005 | 2.5–2.75 |
| 7. | BARI Barley-7 | 2015 | 2.0 = 2.5 |
| 8. | BARI Barley-8 | 2018 | 2.2–2.51 |
| 9. | BARI Barley-9 | 2018 | 2.2 |

*Source: Azad et al. [17].*

**Table 8.**
*Modern barley cultivars developed by Bangladesh Agricultural Research Institute.*

pattern in Bangladesh was Barley—Fallow—Fallow, which occupied 0.0002% of the net cropped area [7].

### 3.2 Sorghum (Bangla: Jowar; *Sorghum bicolor* (L.) Moench)

Sorghum, one of the most drought-resistant crops that originated in equatorial Africa, grown for grain, fodder, fiber and/or biofuel, is the world's fifth-most important cereal crop after rice, wheat, maize, and barley with 57.89 m t of annual global production in 2019 <http://www.fao.org/faostat/en/#data/QC>. In 1971–1972, the coverage and total productions were 1032 ha and 745 t, respectively which decreased to only 73 ha and produced 87 t in 2018 (**Figure 5**). The only recommended sorghum cultivar available in Bangladesh is BARI Jowar-1, the PGRC (BARI) has collected and conserved 268 sorghum accessions [21].

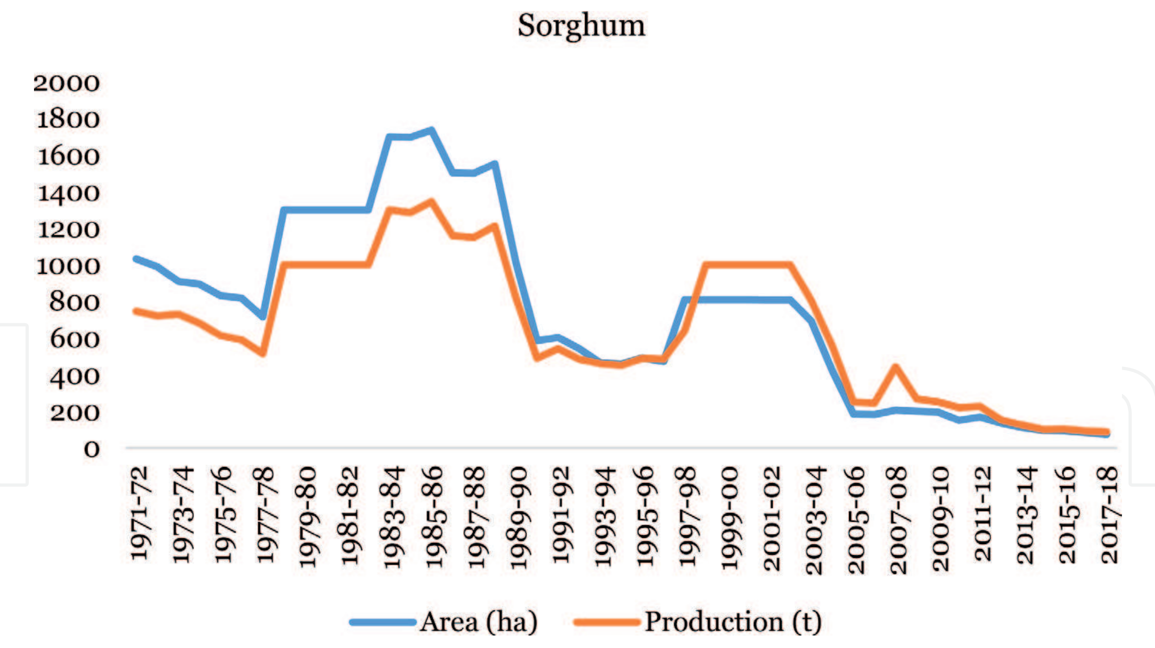


**Figure 5.**
*Area coverage and production trend of sorghum. Source: FAOSTAT 2020 http://www.fao.org/faostat/en/#data/QC.*

### 3.3 Pearl millet (Bangla: Bajra; *Pennisetum glaucum* (L.) R.Br.)

Pearl millet, one of the earliest domesticated millets [2], is well-adapted to poor, droughty, and infertile soils and is, therefore, a vital subsistence crop in countries surrounding the Sahara Desert and in western Africa where soils are tough and rainfall is low <www.plantsoftheworldonline.org/taxon/urn:lsid:ipni.org:names:77105978-1>. In 2007–8, the coverage and total production of pearl millet

| Year | Pearl millet | | Proso- and Foxtail-millet | | Other Cereals | | Binnidana | |
|---|---|---|---|---|---|---|---|---|
| | Area (ha) | Production (t) | Area (ha) | Production (t) | Area (ha) | Production (t) | Area (ha) | Production (t) |
| 2007–2008 | 26.72 | 35 | 1770.44 | 1466 | 8110.12 | 5048 | | |
| 2008–2009 | 26.72 | 35 | 1251.01 | 1100 | 2618.62 | 1697 | | |
| 2009–2010 | 24.29 | 40 | 1214.57 | 1000 | 2024.29 | 2000 | | |
| 2010–2011 | 64.78 | 100 | 1214.57 | 1000 | 2429.15 | 2000 | | |
| 2011–2012 | 60.73 | 80 | 1214.57 | 1000 | 1619.43 | 1000 | | |
| 2012–2013 | 56.68 | 80 | 1214.57 | 1000 | 275.30 | 180 | | |
| 2013–2014 | 40.48 | 380 | 1214.57 | 2000 | 238.87 | 160 | | |
| 2014–2015 | 36.44 | 50 | 1214.57 | 7000 | 12.14 | 90 | | |
| 2015–2016 | 36.03 | 48 | 1214.57 | 1000 | 404.86 | 200 | | |
| 2016–2017 | 30.77 | 40 | 1214.57 | 1000 | 404.86 | 485 | | |
| 2017–2018 | 28.74 | 38 | 809.72 | 1000 | — | — | | |
| 2018–2019 | — | — | 809.72 | 1000 | — | — | 225.10 | 5 |

*Source: BBS [4, 22, 23].*

**Table 9.**
*Area coverage and production trend of some minor cereals.*

in Bangladesh were only 26.72 ha and 35 t, respectively which increased to 28.7 ha and produced 38 t in 2018 (**Table 9**). However, it went completely out of cultivation in the subsequent year [4]. Only two accessions of pearl millet germplasm are conserved at the PGRC, BARI [18].

### 3.4 Proso millet (Bangla: Cheena; *Panicum miliaceum* L.) and foxtail millet (Bangla: Kaon; *Setaria italica* (L.) P. Beauvois)

Proso millet is rich in protein, minerals, vitamins, and micronutrients; it is gluten-free and therefore, ideal for the gluten intolerant people. The nutritive parameters of proso millet are comparable to or better than common cereals [24]. Under drought and poor soil conditions, it also gives a better yield compared to all other crops, where there is a probability of complete failure of other grain crops [25]. Foxtail millet is an underutilized, drought-tolerant crop that stands to become much more important in a potentially much warmer and dryer future environment [26]. In 2007–8, the coverage and total productions were only 1770.44 ha and 1466 t, respectively which decreased to 809.72 ha and produced 1000 t in 2019 (**Table 9**). The only cultivar of Cheena, Tushar, and four cultivars of Kaon, *viz*. Titas, BARI Kaon-2, BARI Kaon-3 and BARI Kaon-4, are released by BARI [19]. One hundred ninety-seven proso millet accessions and 515 foxtail millet accessions are also conserved at BARI [18]. Two proso millet-based cropping patterns, *viz*. Millet (Cheena) – Fallow–Fallow and Millet (Cheena) – Jute–Fallow, occupied 0.018% of the net cropped area [7]. The proso millet and foxtail millet were grown in small patches especially the char land areas in Bogura and Rangpur regions of the country [20, 27]. A recent study shows that the cultivation of proso and foxtail millets is expanding in north, north-west, central parts (in the vicinity of mighty rivers *viz*. Padma/Ganges, Brahmaputra, Jamuna and Meghna) and hilly regions of the country and provide grain yield 400–1500 kg $ha^{-1}$ (Biswas and Biswas, unpublished data).

### 3.5 Other cereals (finger millet, ditch millet, rye, oat, triticale, pseudo-cereal buckwheat, quinoa, etc.)

Finger millet and ditch millet are grown on a very limited area in the districts of Kushtia and Rajshahi; others are cultivated all over Bangladesh with little inputs in poor and marginal lands including the river beds [28]. Oats and rye are extremely nutritious, with a higher fat content than most cereals and an excellent grade of dietary fiber. In 2007–8, the coverage and total productions were only 8110.12 ha and 5048 t, respectively which decreased to 404.86 ha and produced 485 t in 2017 (**Table 9**). Moreover, on cultivation data/information was available for subsequent years [4], perhaps went to out of cultivation also. A new cereal crop "*Binnidana*" was cultivated in 225.10 ha of land and produced 5 t grains in 2018–2019 [4]. A few accessions of other minor cereals germplasms *viz*. 5 accessions each of Buckwheat and Triticale, 2 accessions of Teff and 1 accession of Oat, are also conserved at the PGRC, BARI [18].

## 4. Constrains

Cereal (in fact rice) agriculture is synonymous with Bangladesh agriculture that plays a key role in food security and livelihood. Only 92 cropping pattern out of existing 316 was identified as an exclusive non-rice area which occupied less than 9 per cent of the net cropped area of Bangladesh [7]. The cereal agriculture, and agriculture in Bangladesh as a whole, is facing serious natural and man-made hitches that deserve special attention to this sector. The arable land is decreasing at an alarming rate (0.1% $yr.^{-1}$) due to urbanization, roads and highways, infrastructure development, etc., severe degradation of natural resources like soil, water, climate, etc., the recurrent occurrence of devastating flood and drought, and the looming threat of salinity increment in the coastal region. Further in Bangladesh condition, the global climate change and related adverse effects on agriculture are rendering the worst impacts in temperature rise, abnormal rainfalls, sea-level rise, frequency of cyclone and storm surges, the encroachment of more saline areas, aggravation of drought problem and reduction in the availability of surface and groundwater [29]. There is a substantial extent of degradation of agricultural lands caused by soil erosion (1.70 m ha), river erosion (1.70 m ha), soil fertility decline (8.00 m ha), depletion of soil organic matter (7.50 m ha), waterlogging (0.70 m ha), soil salinity (0.84 m ha), pan formation (2.82 m ha), acidification (0.06 m ha) and deforestation (0.30 m ha) [30]. Some other soil-related constraints to cereal crop production are heavy consistency, poor structure, high osmotic pressure or drought, both physical and physiological, causing a reduction in the ability of plants to absorb water and nutrients, etc. The soil health scenario becomes worsen due to imbalanced fertilization and unplanned increase in mono-crop based cropping intensity and thus, the quality agricultural land is getting scanty. A survey reported that 2% of arable land belongs to a very good type, 34% good, 39% moderate, 16% poor, and 9% very poor [30].

The quality and timely supply of agricultural inputs are other constrain for cereal crop cultivation in Bangladesh. For instance, about 18% of the entire seed requirement of the country can only be met from certified and truthfully labeled seeds of Government and private sources, and the remaining 82% comes from the seed storage of farmers' own. There are serious problems in the quality of seeds supplied by public, private, and farmers themselves [30]. The scarcity of irrigation water (and its resources) is added to another constrain for sustainable cereal production in Bangladesh and the world as well. For example, an increase in Boro growing area in Bangladesh to 6 m ha by 2050 will increase the irrigation demand to *ca*. 40 k $m^3$ from the current demand of *ca*. 31 k $m^3$; global warming may further aggravate the demand by about 3% for dry climate change scenarios [31]. Groundwater is the primary source of irrigation and supplies about 80% of the water requirement of the total irrigated area of the country [16]. There is non-regulated and excessive use of groundwater and limited effort to augment surface water. Moreover, water use efficiency is also poor at the farm level. The over-use of groundwater is most evident in a small sub-region known as the Barind Tract; this increased demand will further deplete the groundwater resources. The quality of irrigation water also comes forward as another constrain for agricultural productivity in Bangladesh because of water pollution due to the presence of arsenic, heavy metals, salts, agrochemicals, industrial wastes, etc. A countrywide campaign is, therefore, required to conserve water and use it judiciously and institute a proper land use planning system. Mandatory rainwater harvesting and water use efficiency deserve higher priority.

## 5. Challenges

Bangladesh, one of the highest densely populated country in the world, endures the 8th largest world population (*ca*. 164 m) which has been estimated to increase 186 and 202 m by the years 2030 and 2050, respectively [32]. One of the major challenges of cereal agriculture in Bangladesh is to produce more food, to feed this ever-increasing population. Other major challenges of cereal (crop) agriculture are to raising productivity and profitability, retaining sustainability, increasing resource-use efficiency, conserving natural resources and increasing land and water productivity, improving product quality and developing marketable production, improving post-harvest management, meeting demands for diversification and commercialization of agriculture [6]. The other emerging challenges include shrinkage of agricultural land every year due to urbanization, infrastructure development, roads, etc. The land quality is also deteriorating due to soil fertility degradation (e.g., nutrient imbalance, low organic matter, etc.), soil erosion, soil and water pollution, and increased soil salinity.

Due to climate change, sea-level rise will cause inundation of about 16% of total cropped area, displace 10% of the population, increased salinity in the coastal zone and reduce crop yields, ultimately causing loss of 2 m t of crop harvest [29]. Global warming will cause cyclones and storm surges in high frequency and volume. Due to river erosion and storm surges, moderate to severe erosion will occur in flood plains and char lands. Out of 2.85 m ha, about 1.00 m ha in the coast is affected by different degrees of salinity which will continue to increase due to climate change. About 2.32 m ha and 1.2 m ha of net cropped area are respectively severely and moderately drought-affected and the problem will further aggravate. Moreover, about 1.32 m ha and 5.05 m ha of the net cropped area are, respectively severely and moderately flood-prone that seriously hamper crop production [29]. Besides, reduced availability of surface and groundwater in the dry season due to excessive extraction of groundwater for irrigation purposes is coming up as a serious problem. The development of water-saving techniques in agriculture is a critical issue. The inadequate facilities and programs for the production and distribution of quality seeds and other inputs to the farmers are the main reason for low productivity; there is a wide yield gap between demonstration and farmers' field yield. For example, the current yield gaps between demonstration and farmers' yield for Aus, T. Aman and Boro are 2.74, 4.89 and 4.08 t $ha^{-1}$, respectively [29]. Thus, the challenge is to reduce the current yield gap for cereal production enhancement. The farmers' knowledge-gap in adopting modern agricultural technologies also leads to low productivity. Further, the yield ceiling of modern cultivars needs to be improved by developing super cultivars. Low quality and adulterated agricultural inputs *viz*. fertilizers and pesticides, marketed by unscrupulous traders and absence of farm gate price support for the producers are a few of several other challenges that exist in the cereal agriculture and crop subsector as well. The low level of mechanization serves as a huge impediment towards cereal production, which in turns, results in a high cost of production for these crops. The creation of adequate institutional development in the areas with poor infrastructure, research funds and facilities, and skilled manpower for the adoption of innovative agro-technologies is also an emerging challenge in the agricultural sector.

## 6. Prospects

Although Bangladesh faces huge constrains and challenges in achieving food and nutritional security due to its high population, diet changes, and limited room for expanding cropland and cropping intensity, Bangladesh will remain self-sufficient in rice at least to 2050 at the present rate of technological, in both cultivar and management, advancement and population growth [16]. The Intergovernmental Panel on Climate Change estimates, on contrary, reported that the rice production in Bangladesh could decline by 8 per cent and wheat by 32 per cent due to higher temperatures and changing rainfall patterns by 2050 [33]. For achieving food and nutritional security in the coming days, the following actions may be taken to increase cereal grains yield (per unit area) and production –

i. Minimize the yield gap by (i) increasing actual farmers' yield corresponding to current yield potential (Yp) levels by improving the crop management practices, *viz*. improved seed, soil, water, nutrient, pest and disease management, and (ii) maintaining or increasing the rates of progress of Yp by either adopting modern plant breeding and molecular techniques [34].

ii. Develop new cultivars with greater yield potentials and stress tolerance.

iii. Replacement of current low yielding cultivars with and other recently released high yielding hybrid, short-duration and fast-growing, drought and salt resistant cultivars. The expanded availability of modern rice and other cereal crops cultivar(s) could endure climate change impacts without yield penalties [16].

iv. New climate-smart agriculture/farming technologies e.g., climate-resilient (modern) cultivars for stress-tolerance, profitable location-specific cropping patterns, conservation agriculture, innovative cultural management to minimize yield gap, mechanization, etc., to be developed to grow four crops in a year (in the same piece of land) including three rice crops, and to bring unfavorable agro-ecosystem under productive sustainable agricultural practices.

v. A decrease in the dependence on groundwater by increasing surface water use for irrigation purposes, and replacing rice with wheat or other crops that use less water. Sustainable groundwater use in some areas combined with the use of more surface water (through rubber dam, sluice gate, flash gate and dug well) and moving some production to other less intensively cultivated areas will help meet this challenge. For example, barley is a stress-tolerant and saline adaptive crop [35]. Barley is best suitable as a Rabi (Winter; Mid-October to Mid-March) crop to cope with the saline-prone south coastal region of Bangladesh.

vi. Millets *viz*. pearl millet, foxtail millet, and proso millet, are short duration crops better adapted to dry and infertile soils with a certain degree of soil acidity and alkalinity, stress due to moisture and temperature, soils texture from heavy to sandy infertile soils, and less susceptible to disease and insect pests [36]. As climate change continues to affect the weather and rainfall patterns, the thermophilic characteristics of millets offer the advantage for subsistence farming and are likely to become an increasingly important crop for the future, especially in dry and/or char land areas.

vii. Stress-tolerant minor cereal cultivars generally possess poor yield potential; the development of high yielding cultivars would be a climate-resilient technology to secure food and nutritional security in the changing climate.

viii. Skill development of farmers, extension workers and researchers through appropriate training programmes.

ix. Promote farmer's rights through documenting farmer's indigenous innovations, farmer's creativity under plat variety and farmers' right protection act and establish a database for indigenous technologies owned and practised by the rural farming community [37].

x. Overall, the GAP (good agricultural practices) and SPS (sanitary and phytosanitary) measures will have to be popularized and promoted.

xi. Value addition to cereal grains and by-products ensures the nutritional and economic security of farmers and the economic growth of the country as a whole. For example, producing breakfast cereals, multigrain flours, bran oils, syrup, starch, health-foods, animal feed, nutraceutical/pharmaceutical products, substrates for (oyster) mushroom (*Pleurotus* spp.) production, etc.

The major cereal grains, *viz*. rice, wheat, and maize, make up a critical portion of many diets, and cereal-based foods are a major source of energy, protein, B vitamins and minerals for the world population. However, these possess a lower concentration of mineral elements (micro and macro-nutrients) which caused the hidden hunger due to micronutrients deficiency [38]. The inclusion of mineral nutrient-rich minor cereals in the everyday diet might also be helpful to meet the mineral requirements and to fight against the related problems.

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