Indian Journal of Agricultural Sciences **93** (6): 583–590, June 2023/Review Article
https://doi.org/10.56093/ijas.v93i6.126191

Breeding varieties and seed production chain of minor cereals in India: Status and strategies

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Received: 27 July 2022; Accepted: 30 May 2023

ABSTRACT

Minor cereals such as barley and small millets contributed 1.13–1.73 and 1.95–2.78% to the total cereals production and acreage, respectively, during 2010–11 to 2020–21. The present study analyses the trends in area, production and yield (2010–11 to 2020–21); breeding varieties and seed production chain of minor cereals during 2010–11 to 2021–22. Barley acreage ranged between 7.0 lakh ha (2010–11, 2012–13) to 5.9 lakh ha (2019–20), registering a decline of 18.6%. Production showed an increase from 3.8% (2011–12) to 17.3% (2013–14) during this period except for 2015–16, when production declined by 7.9% over 2010–11. The changes in acreage, production and seed yield of finger millet during 2020–21 over 2010–11 were -11.0%, +3.6% and +1.1%, respectively. Other small millets (kodo millet, barnyard millet, foxtail millet, proso millet and little millet) showed declining pattern since 2010–11 in acreage from 8.0 lakh ha to 4.4 lakh ha during 2020–21, a reduction of about 45.0% and consequently decline in production by 21.5%. Nevertheless, seed yield/ha increased by 41.2% and reached 781 kg (2020–21) from 553 kg (2010–11). Of the 135 high yielding and climate resilient varieties developed during 2011–23, 107 were released and notified during 2016–22 and only 39 were inducted in to the seed production chain until 2021–22. Breeder and foundation seed production was always higher than the indent/demand during the period under analysis. Seed requirement of barley and small millets has also been worked out considering seed multiplication ratio, seed replacement rate (SRR) and highest acreage and suggested action plan to enhance production of these crops through seed/variety replacement.

Keywords: Barley, Breeder seed, Finger millet, Small millets, Seed chain, Varietal diversity, Varietal replacement

India attained an all-time high food production of 3086.5 lakh tonnes from 1293.4 lakh ha cropped area with an overall yield of 2386 kg/ha and cereals accounted for 91.8% of the production and 77.7% of the acreage of the food crops during 2020–21 (Anonymous 2022a). Among the cereals, predominant share in production and acreage was from five major cereals, viz. rice (*Oryza sativa* L.), wheat (*Triticum aestivum* L.), maize (*Zea mays* L.), pearl millet (*Pennisetum glaucum* L.) and sorghum (*Sorghum bicolor* L.). The minor cereals like barley (*Hordeum vulgare* L.) and small millets, viz. finger millet (*Eleusine coracana* [L.] Gaertn), barnyard millet [*Echinochloa frumentacea* (Roxb.) Link], Italian or foxtail millet [*Setaria italica* (L.) Beauv.], kodo millet (*Paspalum scrobiculatum* L.), common or proso millet (*Panicum miliaceum* L.) and small or little millet (*Panicum miliare* Lamk) accounted for 1.13–1.73% (32.7–42.4 lakh tonnes) and 1.95–2.78% (19.6 l–27.9 lakh ha) to the total cereals production and acreage, respectively, during 2010–11 to 2020–21. Use of quality seeds of appropriate varieties could enhance crop yield by up to 40% (Chauhan *et al*. 2016a, 2020a). Availability of good quality seed especially of recently released varieties results in increased seed and variety replacement and thereby production. The seed production system/chain comprises of diverse multi-stake holders as discussed for major crops earlier (Singh *et al*. 2008, Chauhan *et al*. 2016a; 2017; 2020a,b; 2022). But, such information is limited for minor cereals (Kumar *et al*. 2017). This paper discusses the trends in acreage, production and yield of minor cereals with focus on varietal development and seed production chain during 2010–11 to 2020–21 and suggests way forward to enhance and sustain production.

Trends in production

Barley has multiple usage, being food, feed and industrial crop and is very well adapted to harsh environments of drought, salinity and high temperature (Nevo and Chen 2010). It has low water and nutrient requirement and thus, offers great opportunity to resource

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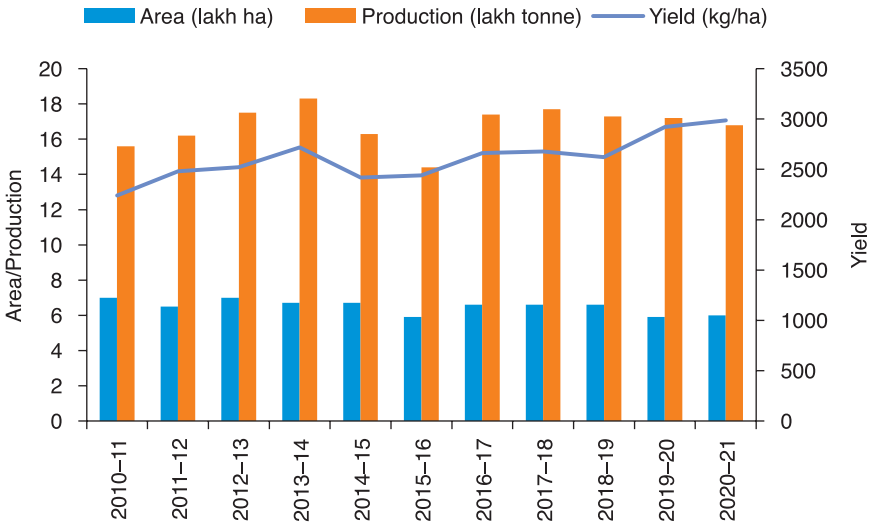

Fig 1 Area, production and yield of barley in India during 2010–11 to 2020–21. *Source*: Anonymous 2022c.

poor marginal and small farmers (Kumar *et al*. 2017). Barley, during 2010–11 to 2021–22 showed a decline of 18.6% in acreage, that ranged between 5.9 lakh ha (2019–20) to 7.0 lakh ha (2010–11, 2012–13). Except for 2015–16, when production showed a decline of 7.9% over the base year, registered an increase varying from 3.8% during 2011–12 to 17.3% during 2013–14 (Fig 1). During 2020–21, the increase in production was 7.1% higher over that of the base year and Rajasthan was the principal barley growing state contributing 45.1% and 56.1% to the national acreage (6.0 lakh ha) and production (16.7 lakh tonnes) followed by Uttar Pradesh with corresponding contributions of 26.3% and 29.0% (Anonymous 2022a). Punjab had the highest yield (3738 kg/ha) followed by Rajasthan (3482 kg/ha) and Haryana (3347kg/ha) as compared to national yield (2805 kg/ha).

Small millets also called nutri-cereals as they are rich sources of nutrients and vitamins, grow well under diverse agro-ecological and nutrient starved marginal lands (Gowari and Shivakumar 2020) and also offer great potential to alleviate malnutrition, food security and ecological sustainability. They are staple food especially in marginal semi-arid tropics of Asia and Africa (Mahendra Dev 2012). Finger millet is the principal crop among the small millets with an average contribution of 47.1% (43.6–53.5%) to the acreage and 44.9% (37.9–50.6%) to the production of minor cereals during 2010–11 to 2020–21. The major finger millet growing states are Karnataka, Uttarakhand, Tamil Nadu and Maharashtra accounting for 68.0%, 7.8%, 7.3% and 6.5%, respectively (Anonymous 2022a) of the national acreage (11.6 lakh ha) during 2020–21. Karnataka had the highest share of 69.0% in the total national production (19.6 lakh tonnes). But, Tamil Nadu had the highest seed yield/ha (3482 kg) followed by Karnataka (1740 kg) and Uttarakhand (1450 kg) with an overall national average of 1724 kg/ha. During the last 11 years, acreage declined consistently since 2010–11 with annual fluctuations from 12.9 lakh ha and reached the lowest (8.9 lakh ha) during 2018–19 (Fig 2) but, thereafter increased during 2019–20 (12.7%) and 2020–21 (30.1%).

The highest production (20.6 lakh tonnes) and seed yield (1747 kg/ha) were attained during 2014–15 and 2019–20, respectively (Fig 2). The changes in area, production and seed yield during 2020–21 over the base year were about -11.0%, +3.6% and +1.1%, respectively. Further, the remaining small millets such as barnyard millet, Italian/foxtail millet, kodo millet, common/proso millet and small/little millet have been cultivated on small acreage. During 2010–11 to 2020–21, these crops together contributed on an average 25.8% with a range of 20.5% (2020–21) to 30.4% (2011–12) to the acreage and 10.5% to production with a range of 8.2% (2020–21) to 12.4% (2011–12) of minor cereals. The cropped area under small millets showed declining pattern since 2010–11 (8.0 lakh ha) and reduced to 4.4 lakh ha (2020–21) by about 45.0% and consequently production by 21.5%. Nevertheless, seed yield/ha increased by 41.2% and reached 781 kg during 2020–21 from 553 kg in 2010–11. The highest production (4.5 lakh tonnes) and seed yield/ha (809 kg) were achieved during 2011–12 and 2019–20, respectively (Fig 3). Madhya Pradesh had the highest acreage (0.78 lakh ha) followed by Chhattisgarh (0.54 lakh ha), Uttarakhand (0.49 lakh ha) and Maharashtra (0.37 lakh ha) and together contributed 52.8%

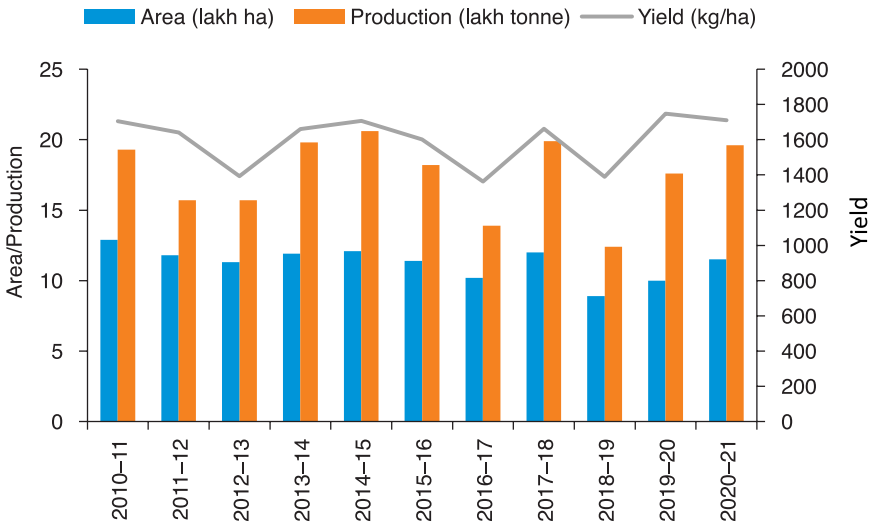

Fig 2 Area, production and yield of finger millet in India during 2010–11 to 2020–21. *Source:* IIMR, Hyderabad, 2022.

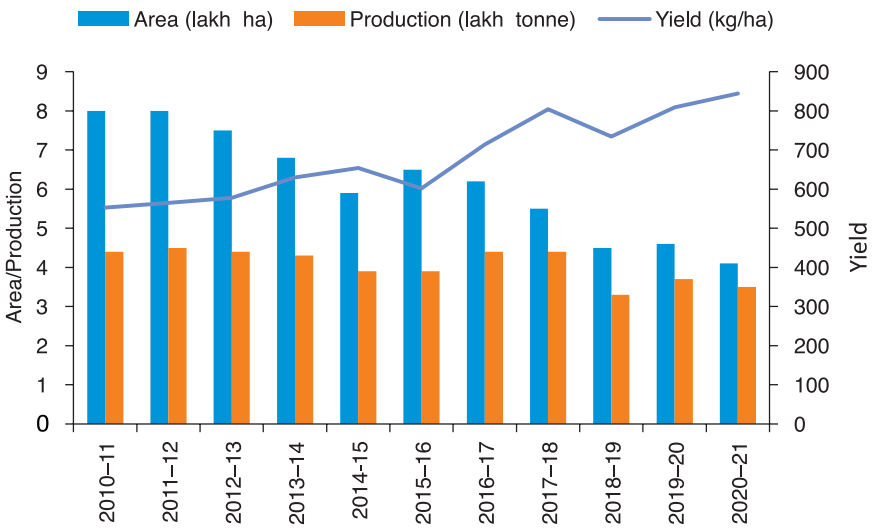

Fig 3 Area, production and yield of small millets in India during 2010–11 to 2020–21. *Source*: IIMR, Hyderabad, 2022.

and 40.0%, respectively, to the total national acreage and production (Anonymous 2022a). Uttarakhand had the highest seed yield/ha (1449 kg) followed by Gujarat (1193 kg) and Tamil Nadu (1186 kg).

Varietal improvement

The varietal development and breeder seed production programmes on barley and small millets have been in operation under the aegis of All India Coordinated Research Project on Wheat and Barley initiated during 1961 and located at Indian Institute of Wheat and Barley, Karnal, Haryana having 11 main and 30 voluntary centres; All India Coordinated Project on Small Millets initiated in 1986 and located at GKVK, Bangalore, Karnataka having 14 main and 20 voluntary centres (Chauhan *et al*. 2016b). The focus in the breeding programme is on developing high yielding, climate resilient varieties having built-in resistance/ tolerance to biotic and abiotic stresses. Since the last decade (2001–10), the concerted efforts have led to the development, release and notification of 135 varieties during 2011–23. Recently, the focus has also been on the development of bio-fortified varieties to mitigate malnutrition. The concerted efforts have led to the development of 121 varieties during 2011–22 (Supplementary Table 1). And, many of these varieties have better nutritive quality, viz. like VR 929 (Vegavathi) rich in iron; CFMV1 (Indravathi) and CFMV 2 rich in calcium, iron and zinc of finger millet and CLMV1 rich in iron and zinc of little millet have been released during 2020 (Yadava *et al*. 2022).

Seed production chain

Seed production chain in formal seed system involves both public and private sector organizations and begins with the indent and production of breeder seed and is followed by its conversion to foundation and certified seed. The leading varieties in the seed chain in the present analysis were selected on the basis of frequency of their occurrence in the seed chain (at least four times or indented during 2019–20 and thereafter) and their contribution (%) to seed indent.

Varietal scenario: In barley, number of varieties indented for breeder seed production ranged from 22–39 (Table 1). The contribution of varieties released during the past 10 years, ranged from 56.7% in 2015–16 to 85.4% during 2021–22. Varieties developed during 2011–15 had the major share in breeder seed indent up to 2019–20 except during 2011–12 to 2015–16 wherein varieties developed during 2006–10 had the highest contribution up to 52.1% (2013–14) in breeder seed indent. But during 2020–21 and 2021–22, the seed chain had pre-dominance of varieties released during 2016–2020 that contributed 46.0% and 66.8% to the breeder seed indent (Table 1). Top five varieties in the seed chain contributed from 45.5% (2015–16) to 75.1% (2019–20). A total of 20 varieties appeared in the top five varieties from 2011–12 to 2021–22. Of these, DWRB 137 (13.3–28.6%), RD 2786 (7.8–24.0%), RD 2035 (6.3–19.8%), RD 2794 (10.6–19.6%), RD 2899 (11.6–12.4%), RD 2907 (7.0–10.4%), PL 426 (8.4–10.0%), BH 393 (6.8–8.6%), DWRUB 52 (7.4–8.3%), HUB 113 (11.8%), BH 946 (6.8%) and BH 959 (8.3%) were the leading varieties. Except RD 2035, PL 14 and BH 393 which were old released during 1994, 1996 and 2002, respectively, the rest were released within the last 10 years. Of the 28 varieties developed during 2011–22, only 18 were in the latest seed chain.

In finger millet, the highest (34) and lowest (13) varieties were indented during 2021–22 and 2011–12, respectively (Table 1). Topmost five varieties in the seed chain had a share of 54.3% during 2021–22 and 87.8% during 2011–12 in the total breeder seed indent. Varieties developed during 1996–2000 were predominant in seed production chain until 2013–14 and those developed later were also gradually indented but their contribution was low (Table 1). Varieties developed during 2006–10 had the highest contribution, ranging from 37.9% from five varieties to 65.6% from four varieties, from 2014–15 until 2019–20. Thereafter, share of varieties released during 2011–15 and 2016–20, gradually increased since 2018–19 and was 46.2% from six varieties during 2020–21 and 38.4% from 11 varieties during 2021–22, respectively (Table 1). Contribution of old varieties released prior to 10 years gradually reduced from 99.6% (2013–14) to 27.4% (2020–21) but was 38.6% during 2021–22. Only 18 varieties occurred in the topmost five varieties in the seed production chain from 2011–12 to 2021–22. The leading varieties were ML 365 (18.8–32.9%), GPU 67 (15.0–32.3%), VL Mandua 352(5.3–18.5%), Chhattisgarh Ragi 2 (5.7–15.9%), Indira Ragi 1 (4.2–13.5%), Bhairabi (5.2–8.5%), Chililka/OEB 10 (3.2–8.5%), VL

Table 1 Varietal replacement in minor cereals as assessed from the contribution of varieties developed during different quinquennial phases to the breeder seed indent during 2011–12 to 2021–22*

Crop	Year	Indent (q)	Varieties indented (no.)	Up to 1995	1996–2000	2001–05	2006–10	2011–15	2016–20
Barley	2011–12	1841.6	28	2 (25.4%)[a]	8 (25.3%)	8 (21.8%)	9 (25.0%)	1 (2.4%)	-
	2012–13	1043.2	29	3 (29.3%)	6 (22.9%)	8 (12.7%)	8 (32.8%)	4 (3.0%)	-
	2013–14	843.2	38	3 (13.1%)	5 (14.6%)	10 (13.8%)	11 (52.1%)	9 (6.4%)	-
	2014–15	1111.8	39	6 (12.0%)	4 (9.4%)	8 (15.0%)	9 (46.2%)	12 (17.4%)	-
	2015–16	1138.4	36	2 (10.6%)	4 (8.0%)	9 (24.7%)	10 (40.0%)	11 (16.7%)	-
	2016–17	1140.8	38	3 (10.1%)	5 (8.8%)	6 (9.3%)	9 (21.7%)	15 (50.1%)	-
	2017–18	1048.3	35	2 (10.2%)	4 (14.9%)	6 (11.7%)	9 (13.4%)	12 (36.5%)	2 (13.2%)
	2018–19	827.9	29	6 (16.0%)	3 (12.2%)	2 (9.2%)	5 (9.3%)	9 (33.2%)	4 (20.3%)
	2019–20	524.9	26	1 (1.0%)	1 (0.6%)	1 (1.0%)	3 (3.1%)	11 (54.5%)	9 (39.9%)
	2020–21	644.2	28	7 (10.0%)	1 (4.6%)	2 (8.7%)	3 (1.1%)	12 (29.5%)	8 (46.0%)
	2021–22	422.2	22	2 (4.0%)	1 (0.5%)	-	1 (0.1%)	8 (28.6%)	10 (66.8%)
Finger millet	2011–12	11.5	13	5 (13.0%)	3 (77.4%)	3 (7.8%)	2 (1.7%)	-	-
	2012–13	18.3	20	6 (23.0%)	5 (32.3%)	2 (30.6%)	7 (13.9%)	-	-
	2013–14	16.5	22	8 (34.1%)	5 (50.2%)	2 (7.3%)	6 (8.0%)	1 (0.4%)	
	2014–15	23.4	17	4 (29.7%)	4 (20.2%)	2(10.3%)	5(37.9%)	2 (1.96%)	-
	2015–16	16.7	15	2 (3.1%)	4 (20.9%)	2 (7.8%)	4 (65.6%)	3 (2.6%)	-
	2016–17	17.3	24	4 (2.8%)	5 (15.9%)	2 (6.9%)	6 (55.7%)	7 (18.6%)	-
	2017–18	17.8	21	5 (4.7%)	2 (14.0%)	-	5 (56.4%)	8 (24.9%)	-
	2018–19	21.0	17	4 (2.2%)	3 (13.4%)	-	5 (64.9%)	5 (19.2%)	-
	2019–20	24.8	27	5 (3.4%)	4 (12.7%)	-	7 (44.3%)	5 (25.7%)	6 (13.9%)
	2020–21	25.1	28	5 (4.2%)	4 (8.0%)	-	5 (13.3%)	6 (46.2%)	8 (26.4%)
	2021–22	30.3	34	8 (9.6%)	3 (2.2%)	-	5 (26.8%)	6 (23.0%)	11 (38.4%)

[a]Within parenthesis is the contribution of varieties. (**Source*: Anonymous 2020b, 2021b, 2022b, www.seednet.gov.in, accessed on January 20, 2022).

Mandua (8.0–8.4%) and VR 929 (6.9%).

Of these, Indira Ragi 1 (2012), Chhattisgarh Ragi 2 (2016), VL Mandua 347 (2012), VL Mandua 352 (2014) and VR 929 (2019) were released during the last 10 years. Among the leading varieties, GPU 28, Bhairabi and Chilika/ OEB 10 were very old released during 2001, 1998 and 1998, respectively. Of the 43 and 32 varieties released during 2011–22 and 2016–22, only 17 and 11, respectively, were in the seed chain during 2021–22.

Further, 10 varieties of kodo millet were indented for breeder seed production during 2011–12 to 2021–22 except 2012–13 and 2013–14 when there was no indent. The contribution of topmost five varieties varied from 87.8% (2021–22) to 100.0% (2011–12, 2019–20). The major varieties with high contribution to the seed indents across the year were Jawahar Kodo 439 (3.2–100.0%), Indira Kodo 1 (24.8–69.3%), Chhattisgarh Kodo 2 (12.6–45.1%), Jawahar Kodo 13 (1.1–21.9%), Jawahar Kodo 106 (5.4–13.0%), Chhattisgarh Kodo 3 (2.6–12.6%), TNAU 86 (27.0%) and RK 390-25 (3.2%). Except Indira Kodo 1 (2012); RK 390-25 (2018), Chhattisgarh Kodo 2 (2018), Chhattisgarh Kodo 3 (2019) and TNAU 86 (2017), the others were released prior to 10 years. Of the 11 varieties released during 2011–22, only four were in the seed chain during 2021–22.

In barnyard millet, there was no indent for breeder seed production during 2011–12, 2012–13, 2013–14, 2014–15 and 2016–17; seven varieties were indented in rest of the years and topmost five varieties accounted for 100.0% of the seed indent except during 2019–20 (97.4%). Of all the varieties, VL Madira 207 contributed the highest to the seed indent (21.6–90.1%) until 2020–21. During 2021–22, MDU 1 with 32.3% share was the principal contributor to the seed indent. VL Madira 207, PRJ 1 and Co (KV) 2 were old varieties released during 2008, 2009 and 2010, respectively, and MDU 1(2018), DHBM 93-3 (2018), DHBM 93-2 (2018) and Phule Barti 1 (2022) were the recently released ones.

There was no breeder seed indent for foxtail millet until 2014–15. Eleven varieties appeared among the topmost five varieties, which were indented during 2015–16 to 2021–22. Topmost five varieties contributed 100.0% to the breeder deed indent in all the years except 2019–20 (97.1%). SiA 3085 was the topmost contributor (9.1–99.6%) to the seed indent until 2019–20 and released in 2013. But, during 2020–21 and 2021–22, it was replaced by SiA 3156 (20.4–71.4%), released during 2014 and DHFT 109-3 (4.6–25.5%), released during 2018. The other varieties with substantial share in the indents across the years were, Co 7 (7.7–40.9%) released

during 2016 and SiA 3088 (10.2–38.5%) released during 2018. A few very old varieties like AK 132-1 (1990), PS 4 (1999), SiA 326 (1985) and TNAU 143 (1997) in 2015–16 and TNAU 196 in 2020–21 were also indented once.

In proso millet, only four varieties were indented during 2016–17 to 2021–22 and no indent for breeder seed was placed until 2015–16. BR 7 contributed the highest (71.4–100.0%) followed by Phule Ekadashi (3.8–100.0%), ATL 1 (28.6–66.7%) and DHPM 2769 (33.3%) and released during 1984, 2016, 2018 and 2018, respectively. In little millet, there was no indent during 2011–12 to 2016–17. In rest of the years, the major contributor to the seed indent was Jawahar Kutki 36 (8.3–100.0%) released during 2009, Jawahar Kutki 4 (29.2–50.0%) released during 2016, Chhattisgarh Kutki 2 (9.3–19.7%) released during 2016, Chhattisgarh Sonkutki 2 (9.3–19.7%) released during 2019, Chhattisgarh Kutki 1 (7–16.0%) released during 2014, BL 6 (16.7%), DHLM 14-1(25.0%) released during 2018 and DHLM 36-3(20.8%) released during 2019. Overall, eight varieties were in the seed chain during the period under study. Apart from the small millets, variety VL Chua 44, a grain amaranth (*Amaranthus caudatus/tricolor* [L.], a gluten free grain, released in 2006, was indented in small quantity (0.05–0.1 q) only during 2018–19 and 2019–20. Further, brown top millet (*Brachiaria ramosa* [L.] Stapf.) or (*Urochloa ramosa* [L.] R.D. Webster), a perennial millet grass, locally known as pedda-sama and limited to cultivation largely in Southern India as food and fodder crop was also indented in very small quantity of 0.02 q during 2021–22.

Seed production

Breeder seed: Barley had a share of 99.0% (2011–12) to 86.6% (2021–22) to the total breeder seed indent of minor cereals. Its indent increased marginally by 3.6% during 2011–12 over the base year (2010–11) and thereafter consistently declined with annual variations, viz. decreasing or increasing over the consecutive years but lower than that of 2011–12, registering a reduction of 70.5%, 65.9% and 77% during 2019–20, 2020–21 and 2021–22, respectively. Breeder seed production was always higher by 33.4% (2016–17) to 115.8% (2013–14) except for 2012–13 and 2015–16 wherein a shortage of about 33.1% and 1.3%, respectively, was recorded (Table 2). During 2021–22 the increase in breeder seed production against the indent was 49.9%. There was inconsistency in the indents for breeder seed of small millets, other than finger millet, during the period under study but for kodo millet (during 2012–13 and 2014–15), barnyard millet (during 2011–12, 2012–13, 2013–14), foxtail millet (during 2011–12, 2012–13) and little millet (during 2011–12, 2012–13, 2014–15, 2015–16, and 2016–17), breeder seed was produced even without indent (Table 2).

Indents for finger millet followed similar trend that of barley and reduced considerably from that of 2012–13 till 2020–21 by 65.3%. But the reduction was highest (82.0%) during 2013–14. The production of breeder seed was always more than the indents during the period of analysis except

Table 2 Breeder seed indent [I] and production (P) of minor cereals (quintals) from 2010–11 to 2020–21*

Year	2010–11		2011–12		2012–13		2013–14		2014–15		2015–16		2016–17		2017–18		2018–19		2019–20		2020–21	
	Cereals																					
	I	P	I	P	I	P	I	P	I	P	I	P	I	P	I	P	I	P	I	P	I	P
Barley	1777.7	2900.2	1841.6	1905.8	1043.2	698.3	843.1	1819.6	1111.8	1141.2	1138.4	1123.6	1140.8	1521.9	1048.3	1452.2	827.9	1421.1	525.0	1068.6	606.1	830.0
Finger millet	18.2	39.7	11.5	25.8	18.3	87.7	15.8	110.2	23.4	33.9	16.7	139.5	17.3	86.8	17.7	44.7	21.0	41.0	24.9	195.9	30.4	139.3
Kodo millet	4.0	2.2	6.0	8.5	-	4.2	5.2	5.2	-	1.9	3.6	4.2	4.2	6.3	7.1	9.0	6.8	22.2	-	-	34.8	42.9
Barnyard millet	-	-	-	0.5	-	1.7	-	0.3	-	-	0.1	1.2	1.1	0.9	2.0	2.8	1.1	6.4	3.9	79.9	3.9	5.4
Foxtail millet	-	-	-	6.0	-	6.0	-	-	-	-	11.0	109.1	2.6	5.1	6.0	10.5	4.5	9.5	1.3	171.6	4.5	5.2
Proso millet	-	-	-	-	-	-	-	-	-	-	31.4	257.3	0.5	1.0	0.5	0.5	1.0	2.5	0.8	30.3	1.1	1.6
Little millet	-	-	-	5.5	-	10.9	0.8	0.3	-	0.5	-	3.1	-	5.9	0.02	0.5	0.4	8.1	1.2	40.0	10.9	13.2

**Source*: Anonymous 2020b, 2021b, 2022b.

2012–13 where a reduction of about 16.0% was observed. Further, breeder seed production surpassed or at par with indents for kodo millet except in 2010–11 (a shortage of 45.0%); for barnyard millet except in 2016–17 (a shortage of 18.2%); foxtail millet, proso millet and little millet. The highest indents for breeder seed were during 2020–21 for kodo millet; 2013–14 for barnyard millet; 2015–16 for foxtail millet; 2015–16 for proso millet and 2020–21 for little millet (Table 2). This highest surge in the indent was 532.7% for kodo millet during 2020–21. The indents were highest for barnyard millet, foxtail millet and proso millet during the base year that declined subsequently.

Foundation and certified/quality seed requirement and availability: Foundation seed is produced utilizing breeder seed and its mechanism such as qualified stakeholders to produce minimum seed standards, monitoring and certification by an appropriate agency (Chauhan *et al.* 2020a, Trivedi and Gunasekaran 2013). The requirement of foundation seed of barley varied widely, across the last 11 years (2010–11 to 2020–21) but was always higher than that of the base year by 1.2% (2011–12) to 133.7% (2016–17) and attained its peak during 2016–17 and declined, thereafter, until 2020–21 by 11.0% (Supplementary Table 2). Its availability was always higher than the requirement in all the years by 3.0% (2016–17) to 547.8% (2012–13) except during 2020–21, when it registered a decline of 5.2%.

Similarly, for finger millet, the foundation seed requirement reached the highest during 2020–21, showing an increase of 240.2% over that of the base year. The availability showed an increase over the requirement varying from 6.9% (2020–21) to 403.5% (2016–17) across the 11 years (Supplementary Table 2). Foundation seed for other millets was produced in abundance in comparison to the requirement, the increase varied from 43.5% (2019–20) to 193.3% (2017–18) in all the years except 2014–15 and 2018–19 when it was less than the requirement by 7.1% and 5.1%, respectively (Supplementary Table 2). Seed requirement reached its peak during 2014–15 with an increase of 512.9% over the base year and was 307.1% during 2020–21 (Supplementary Table 2).

Analysis of data of requirement and availability of certified/quality seed for barley during 2010–11 to 2020–21 (Anonymous 2022a, Selvraj 2013) revealed that there has been a continuous surge in the requirement for seed from 2011–12 until 2020–21 and peaked during 2016–17, a surge of 45.2% over 2011–12 and 29.1% over the base year. The increase during 2020–21 was 17.9% and 4.8%, respectively, over 2011–12 and the base year. Seed availability was always higher than the requirement during the period of analysis by 3.7% during 2010–11 to 88.8% during 2020–21 (Supplementary Table 2). Seed requirement for finger millet during the period under study showed inconsistent trend and varied from 0.27 lakh q (2010–11) to 0.34 lakh q (2013–14) registering an enhancement of 25.9%, which declined marginally to 22.2% during 2020–21. Nevertheless, seed availability was always either at par or surpassed the requirement across all the 11 years by up to 67.7% during 2018–19. The seed requirement for other small millets was adequately met by seed availability in all the years except 2011–12, 2012–13 and 2018–19 where shortage in seed availability by 98.0%, 60.0% and 10.0%, respectively, was recorded (Supplementary Table 2).

Certified/quality seed distributed: More than production or availability, the distribution of certified/quality seed to the stakeholders is critical for the commercial production of any crop. During 2010–11 to 2020–21, for barley, the quantity of seed distributed varied from 0.82 lakh q in 2017–18 to 3.80 lakh q 2011–12, with an increase of 363.4% but dipped for the next two years and peaked again during 2014–15 and 2016–17 (Anonymous 2022a) but remained lower than the highest ever attained (Supplementary Table 3). Except 2011–12, 2012–13, 2014–15 and 2016–17 when seed distribution was higher than that of the base year by 10.0–112.9%, in rest of the years it was lower by 7.8–54.2%.

Quality seed distributed for small millets was either at par with that of base year or higher until 2015–16 and the highest achieved during 2014–15, 2017–18 and 2020–21, registering an increase of 34.6%. Seed distribution was always higher than that of 2010–11 by 3.7–34.6% during the period under analysis.

Way forward

Except barley, small millets, in general, showed large variation in acreage and thereby production as they are cultivated largely in nutrient starved soils under fragile agro-ecological conditions mostly by marginal and poor farmers. Barley showed consistency in acreage and production. Acreage of barley did not show much variation and difference between highest and the lowest was of 15.7% during this period and production increased by 7.7% despite reduction in acreage by 16.7% because of yield enhancement by 33.9% during 2020–21 as compared to the base year. Similar was the trend for finger millet where acreage reduced by 10.9% but production and yield was marginally higher during 2020–21 but large difference of 31.0% was recorded between extremities in acreage. There was substantial reduction in cropped area and production of small millets other than finger millet by 48.8% and 20.5% but yield/ha increased spectacularly by 52.6% during 2020–21. The breeder seed indenting was irrational and inconsistent for most of the crops. In the present study, seed requirement of various crops has also been worked out considering standard seed multiplication ratio, seed replacement rate (SRR) of 40.0% against 33% for self-pollinated crops and the highest ever cropped acreage (Table 3). The analysis revealed that more than required breeder seed has been produced considering the recent cropped area (2020–21). Therefore, realistic indents of appropriate varieties for breeder seed should be timely placed with the concerned organization and also ensure its use in production of foundation and certified seed. Further, a total of 121 high yielding and climate resilient varieties of barley and small millets were developed during 2011–22. Of these 93 were released and notified during 2016–22 but only 39 were in the

Table 3 Projected demands for certified (CS), foundation (FS) and breeder (BS) seed for minor cereals in the next five years

Crop	Cropped area (lakh ha)		SMR*	Seed rate (kg/ha)	Targeted SRR (%)	Breeder seed (2020–21)		Requirement of seed (q) to achieve the target SRR by 2026–27		
	Highest ever since 2010–11	Actual (2020–21)				Indent (q)	Production (q)	CS (2025–26)	FS (2024–25)	BS (2023–24)
Barley	7.0	6.0	20	100	40	606.1	803.0	280000	14000	700
Finger millet	12.9	11.6	80	10	40	30.4	139.3	51600	645	8.1
Little millet	8.0	4.4	60	8–10	40	10.9	13.2	32000	533.3	8.9
Kodo millet						34.8	42.9			
Foxtail millet						4.5	5.2			
Proso millet						-	-			
Barnyard millet						-	-			

*Seed multiplication ratio; SRR, Seed replacement rate.

seed production chain until 2021–22. Therefore, emphasis should also be on phasing-out old and obsolete varieties in the seed chain, i.e. hasten varietal replacement.

Further, the per capita net availability of cereals apart from rice and wheat has been gradually and steadily increasing and reached from 18.8 kg/annum during 2010 to 30.1 kg/annum during 2021, with an increase of 60.1% (Anonymous 2022a). Now-a-days, there is greater focus on small millets and large number of value added products have been developed and marketed for possible crop diversification and improving the livelihoods of the farmers. India celebrated 2018 as National Year of Millets to bring back millets and create domestic and global demand and to provide nutritional food to the people. United Nations General Assembly accepted India's proposal which was supported by 72 countries, on March 5, 2021 and declared 2023 as International Year of Millets to draw greater global attention for renewed emphasize on research and development efforts for millets as a source of healthy food and that may play an important role in alleviating malnutrition. Therefore, a systematic and proper planning is urgently required to develop a futuristic plan for seed requirement of appropriate varieties and ways to make seed available to the farmers by synergizing the efforts of stakeholders from both public and private sector including farmers' producing organizations to meet their needs.

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