India's Sorghum Makeover - Progress and Prospects: 2018-19

Vilas Tonapi - on behalf of

All the PRINCIPAL INVESTIGTORS AND SCIENTISTS OF AICRP ON SORGHUM

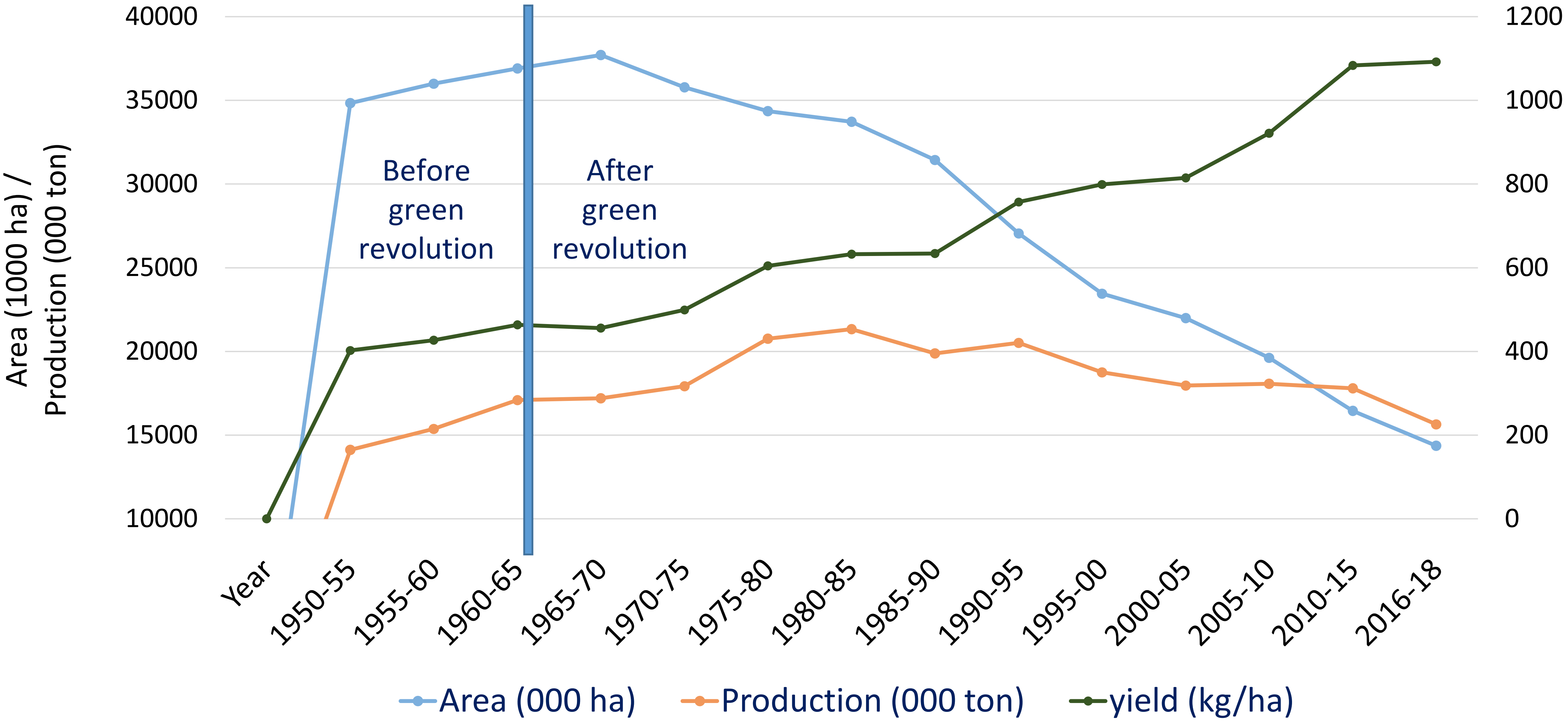
49TH GROUP MEETING OF AICRP ON SORGHUM, CCSHAU, HISAR

www.millets.res.in

Sorghum Scenario –

Need to reach Non-Traditional Areas

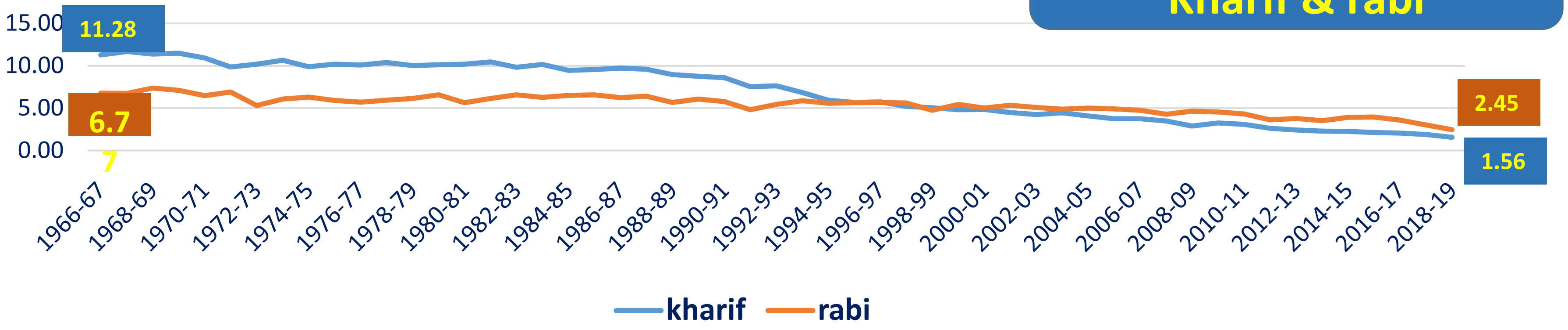
Quinquennial mean area, production and yield of millet in India



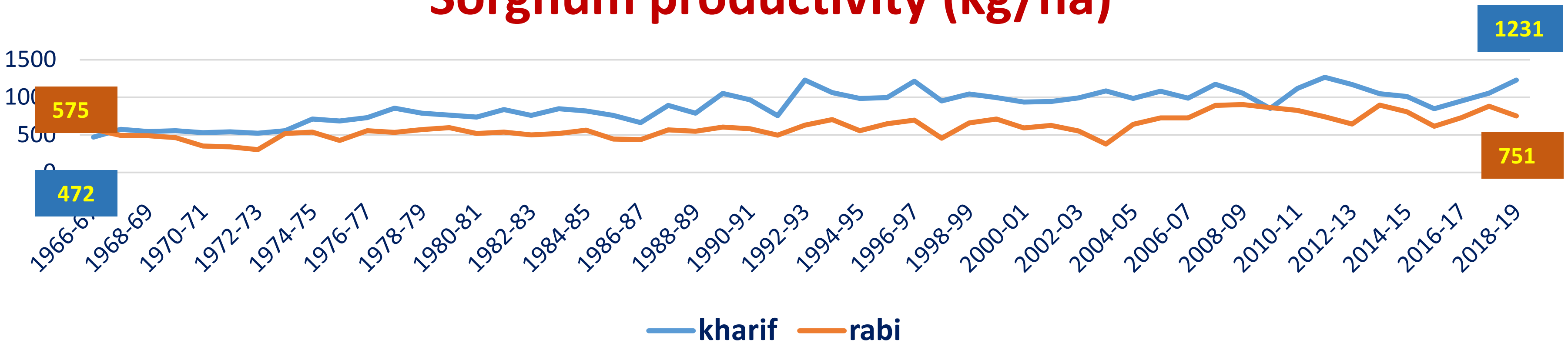
Source: Estimates based on data from Directorate of Economics and Statistics, Department of Agriculture & Cooperation, Government of India.

Grain sorghum in India Kharif & rabi

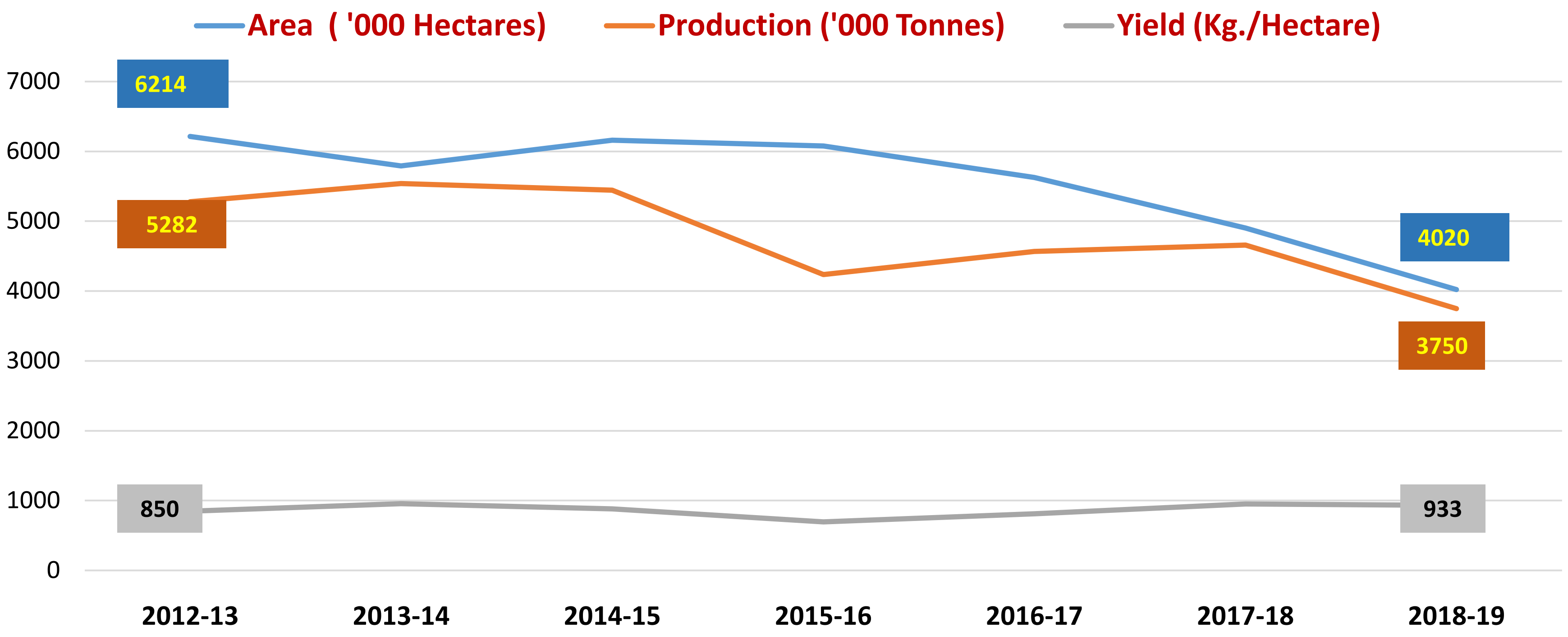
Sorghum area (m ha)



Sorghum productivity (kg/ha)



Trends in grain sorghum cultivation area, production and yield in India (2012-2018)



% Change	Area ↓	Production ↓	Yield ↑
	-35.3	-29.0	9.8

2018-19 data – 2nd advanced estimate   Directorate of Economics & Statistics, DAC&FW, Government of India

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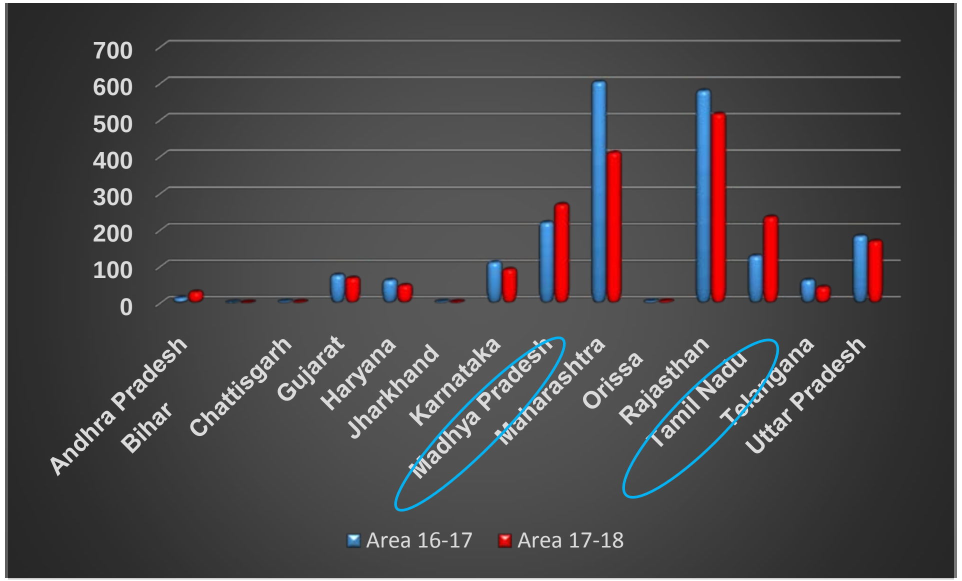
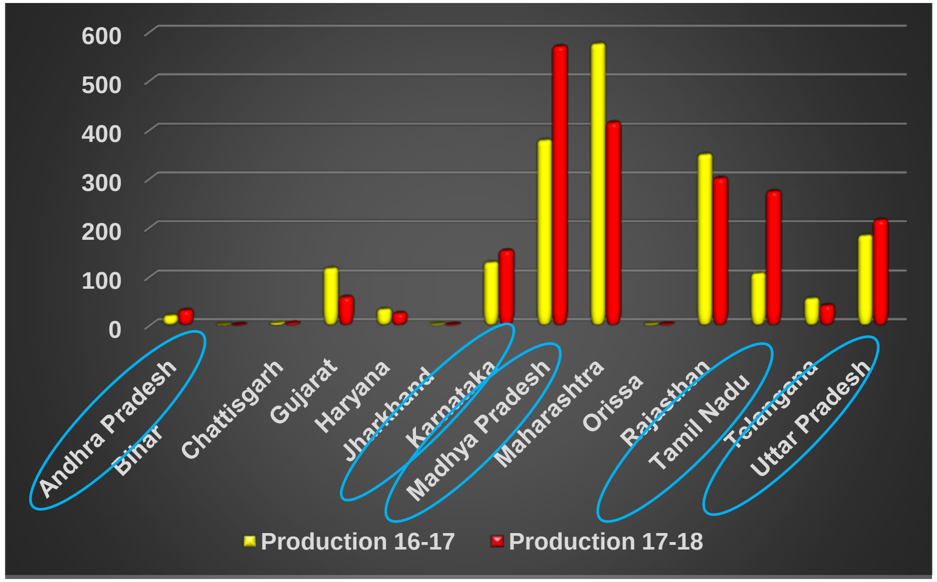
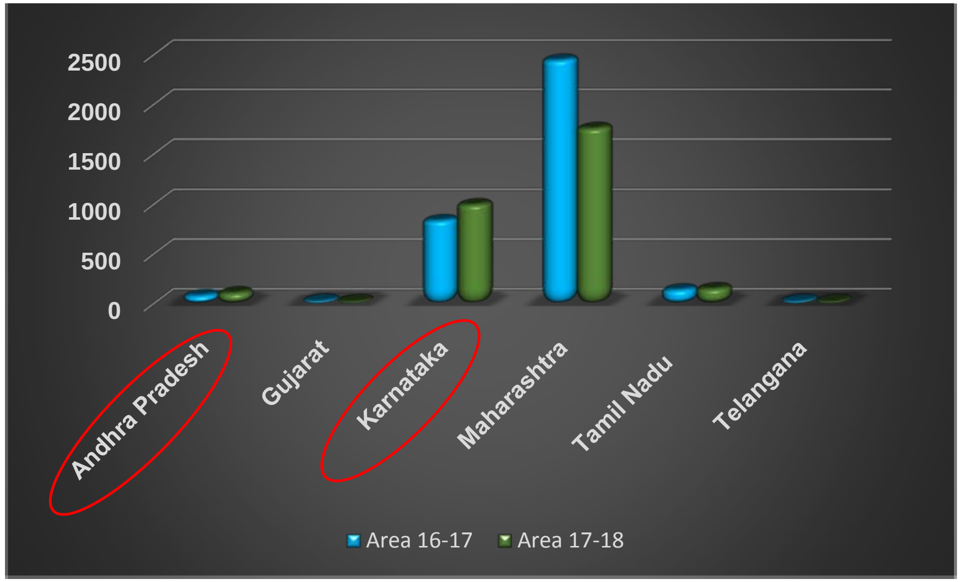
Area in Kharif 2016-18



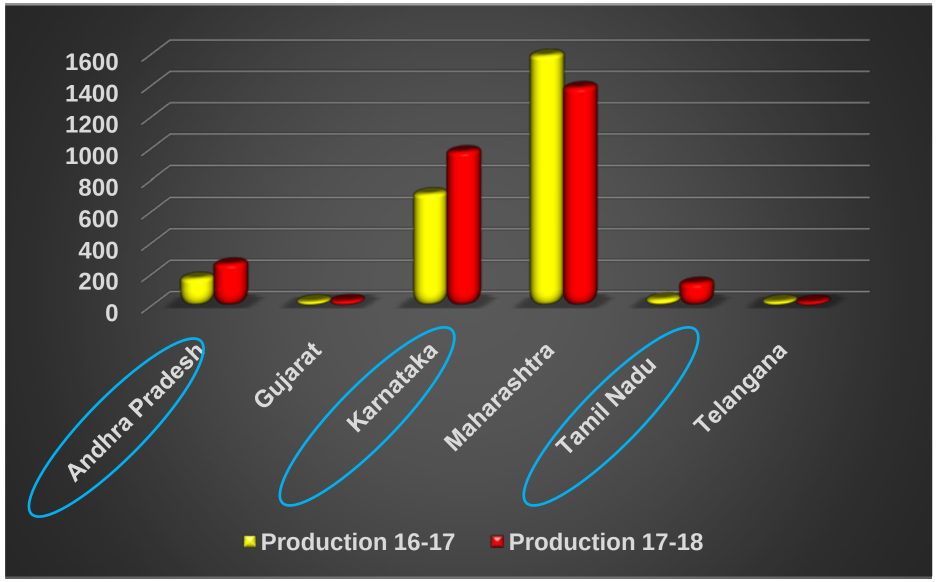
Production in Kharif 2016-18



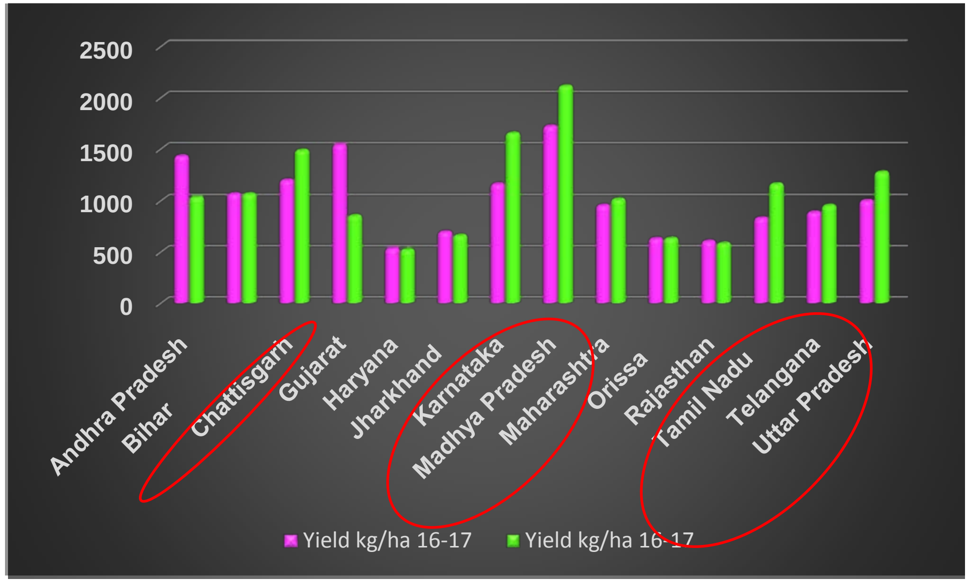
Area in Rabi 2016-18



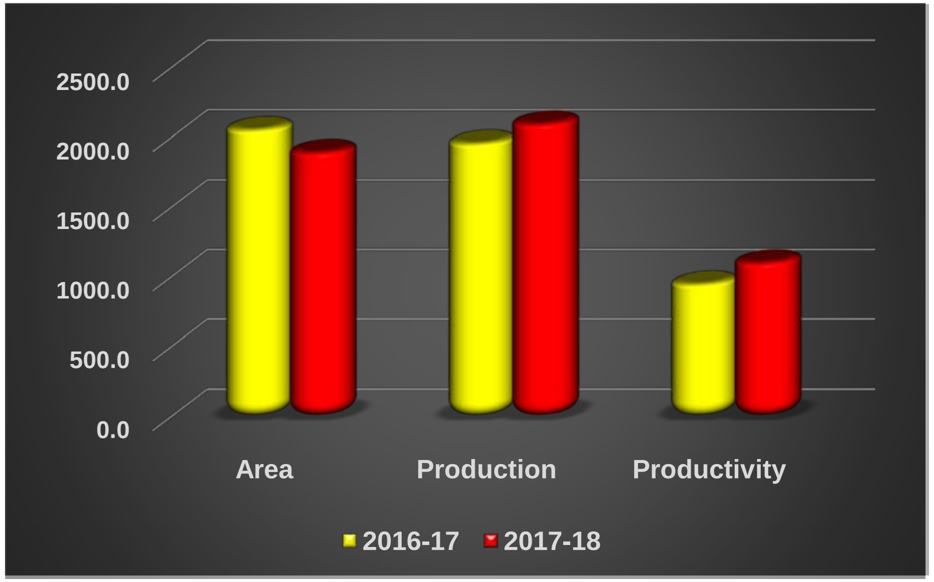
Production in Rabi 2016-18



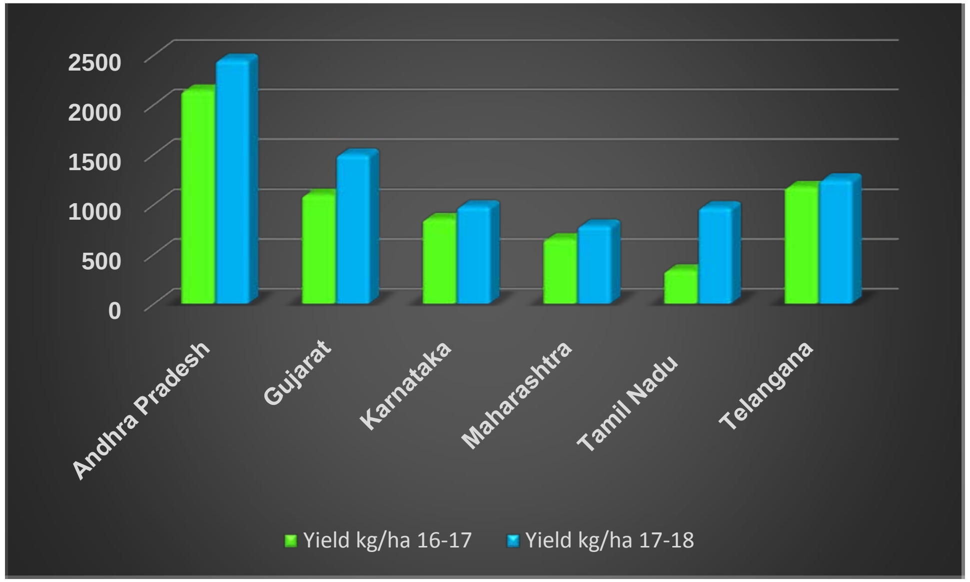
Productivity in *Kharif* 2016-18



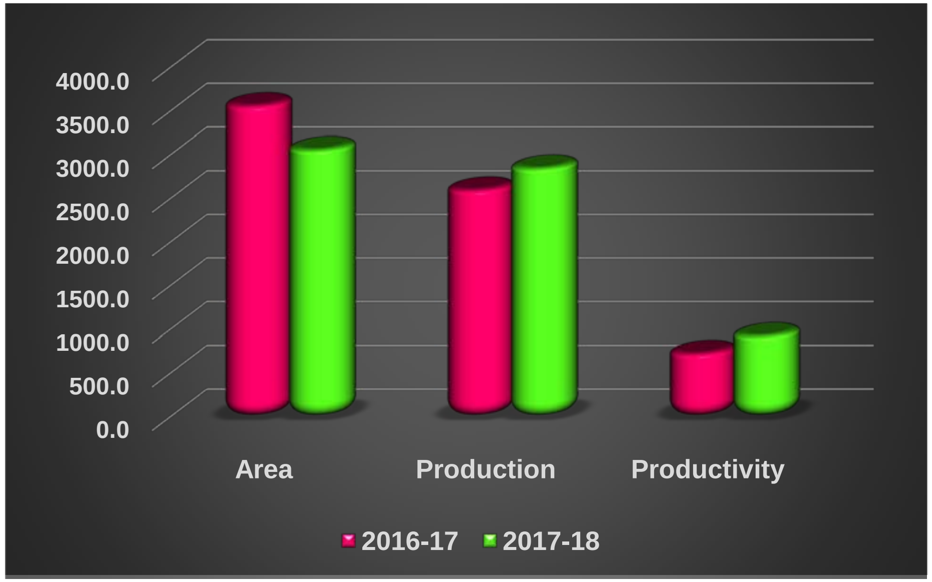
APY in *Kharif* 2016-18



Productivity in *Rabi* 2016-18



APY in *Rabi* 2016-18



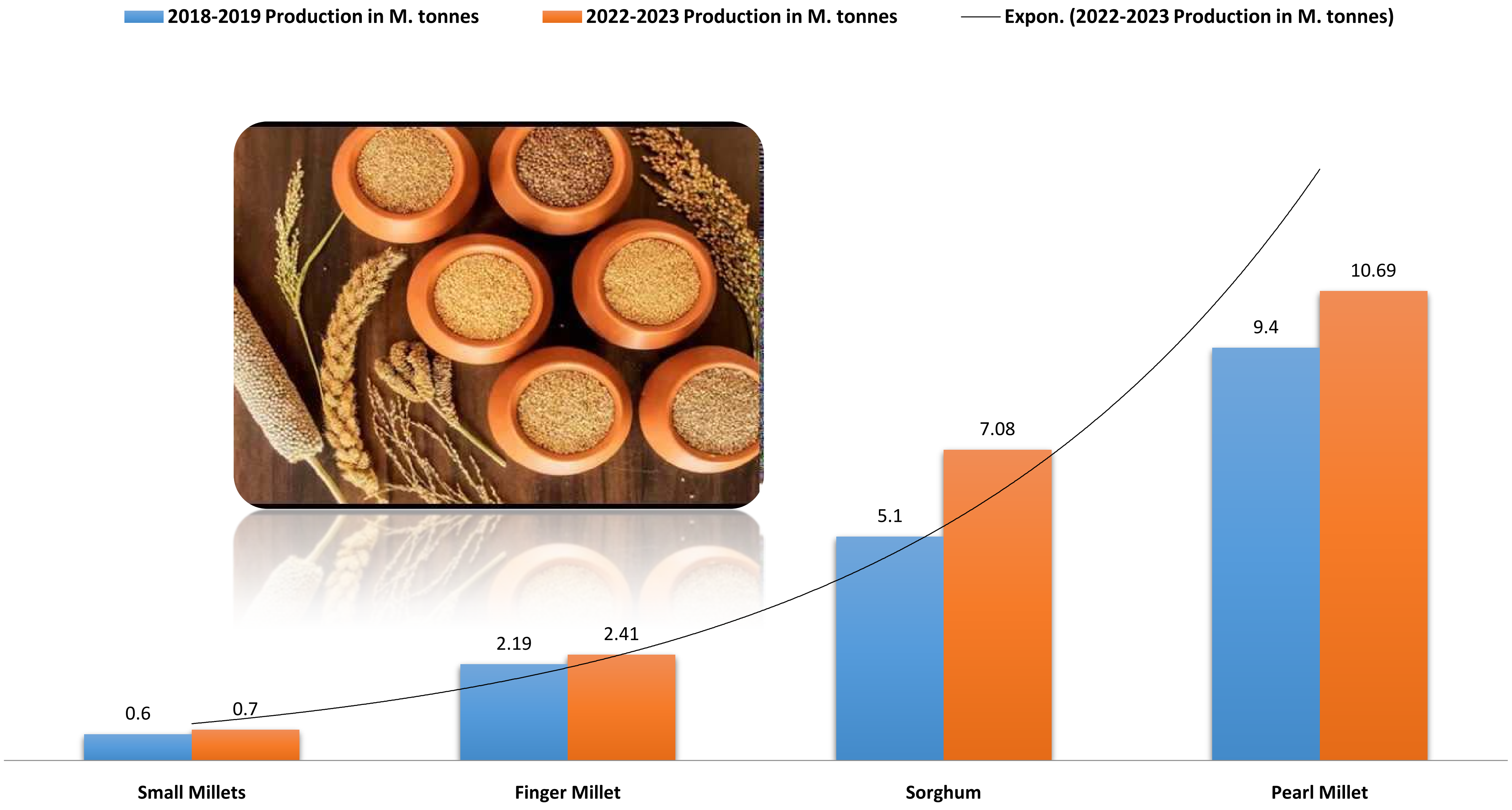
Future Projections

Production Estimates : 2018-19 to 2022-23

Crop	Constant area with current productivity			Constant area with Increased productivity			Increased area with Increased productivity		
	Area (M.ha) (TE)	Yield (kg/ha)	Production (M. ton)	Area (M.ha)	Yield (kg/ha)	Production (M. ton)	Area (M.ha)	Yield (kg/ha)	Production (M. ton)
Jowar	5.9	**900**	5.10	5.9	1200	7.08	7.08	**1200**	8.50
Bajra	7.37	**1275**	9.4	7.37	1450	10.69	8.48	**1450**	12.30
Ragi	1.25	**1750**	2.19	1.25	1925	2.41	1.5	**1925**	2.89
Small Millets	0.8	**750**	0.6	0.8	875	0.7	0.92	**875**	8.05
Total	15.32	**1129**	**17.29**	15.32	1362	**20.88**	17.98	**1765**	**31.74**

1. **Increase in estimated total production of all nutricereals is going to be 3.59 m tons higher over the base year 2018-19 when the productivity gains alone are taken into consideration.**
2. **When the area increase (2.66 m ha) is computed with increased productivity, the production levels for the end year 2022-23 will be 31.74 m tons. The difference in estimates can be attributed to area increase i.e. 10.86 m tons.**

Envisaged Production of Millets 2018-2019 vs 2022-2023



Millets cultivation and production: Projection up to 2050 AD

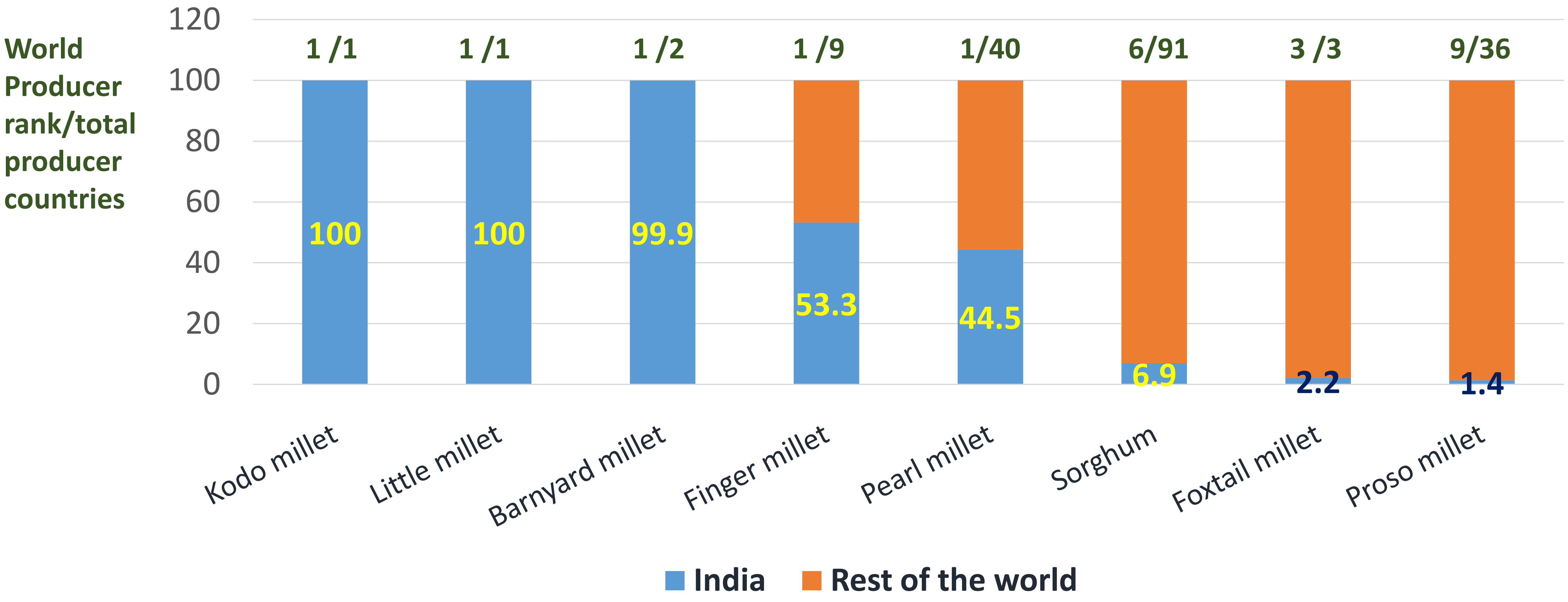
SORGHUM									
Ecology of production area	Scenario I			Scenario II			Scenario III		
	Area (m ha)	Yield (Kg/ha)	Produ- ction (m t)	Area (m ha)	Yield (Kg/ ha)	Produ- ction (mt)	Area (m ha)	Yield (Kg/ha)	Produ- ction (m t)
GRAIN SORGHUM									
Kharif									
Assured Rainfall area	1.32	1378	1.82	1.32	3000	3.96	2.00	3000	7.00
Non-assured Rainfall area	1.99	718	1.43	1.99	1500	2.99	3.00	1500	4.50
Kharif-Total	3.31	1048	3.25	3.31	2750	6.95	5.00	2750	11.50
Rabi									
Rainfed Area	3.51	616	2.65	3.51	1500	5.27	5.0	1500	7.50
Irrigated area	0.87	1597	1.39	0.87	4000	3.48	4.0	4000	16.00
Rabi-Total	4.38	1106	4.04	4.38	2750	8.75	9.0	2750	23.50
Grain Sorghum-Total	7.69	1077	7.29	7.69	2750	15.70	14.0	2750	35.00
						>2			>4

Millets cultivation and production: Projection up to 2050 AD

FODDER SORGHUM									
	Scenario I			Scenario II			Scenario III		
Ecology of production area	Area (m ha)	Green fodder Yield (t/ ha)	Produ- ction (000 m t)	Area (m ha)	Green fodder Yield (t/ ha)	Produ- ction (000 m t)	Area (m ha)	Green fodder Yield (t/ ha)	Produ- ction (000 m t)
Kharif, Rabi and Summer	18.70	92.0	17.20	18.70	100	18.70	27.0	110	29.70

SWEET STALK SORGHUM									
Ecology of production area	Area (m ha)	Green cane Yield (tonnes/ ha)	Produ- ction (000 m t)	Area (m ha)	Green cane Yield (tonnes/ ha)	Produ- ction (000 m t)	Area (m ha)	Green cane Yield (tonnes/ ha)	Produ- ction (000 m t)
Kharif/Rabi/summer	-	-	-				1	150	6.67

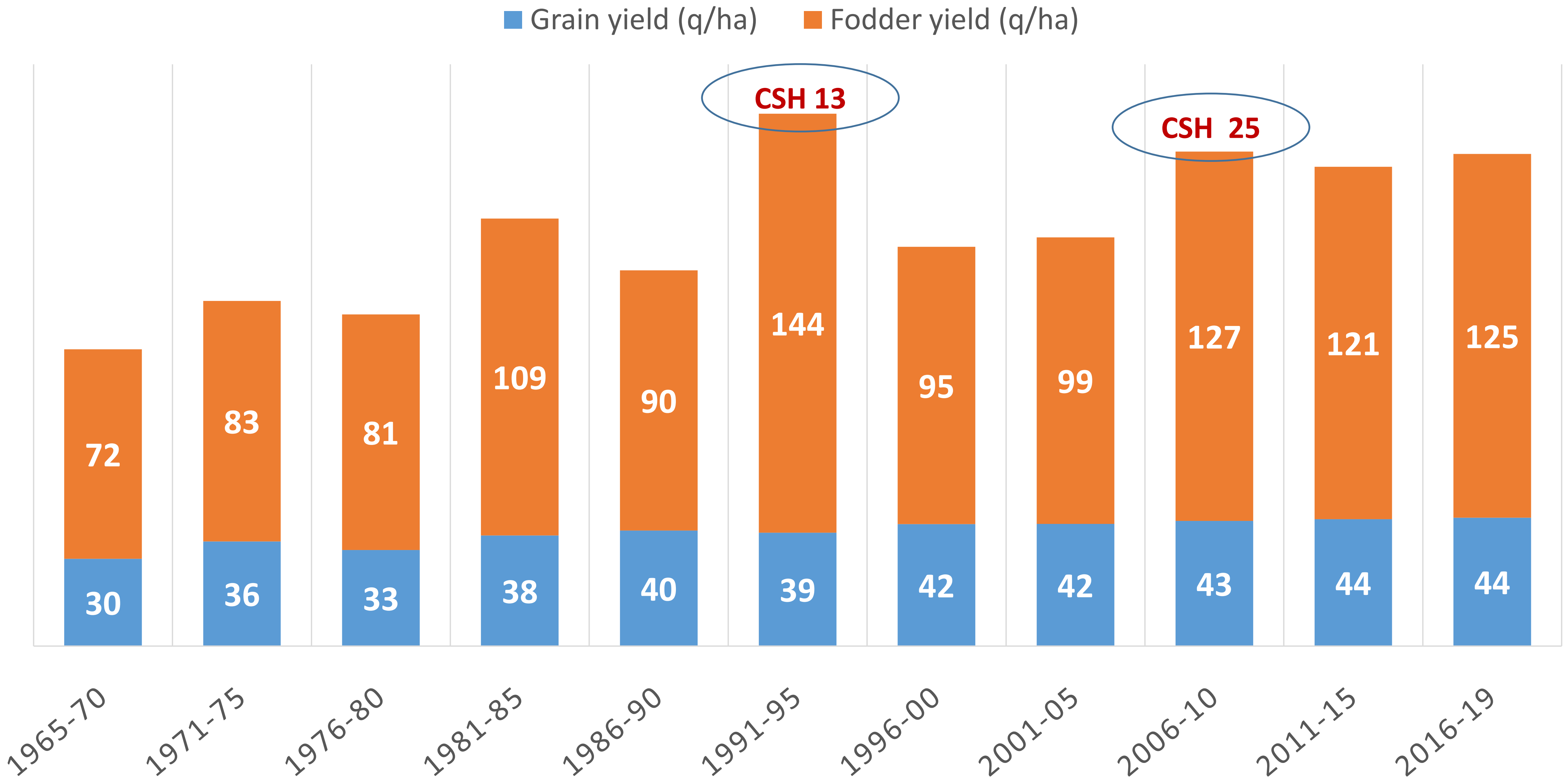
Per cent contribution of India to world production of millet crops



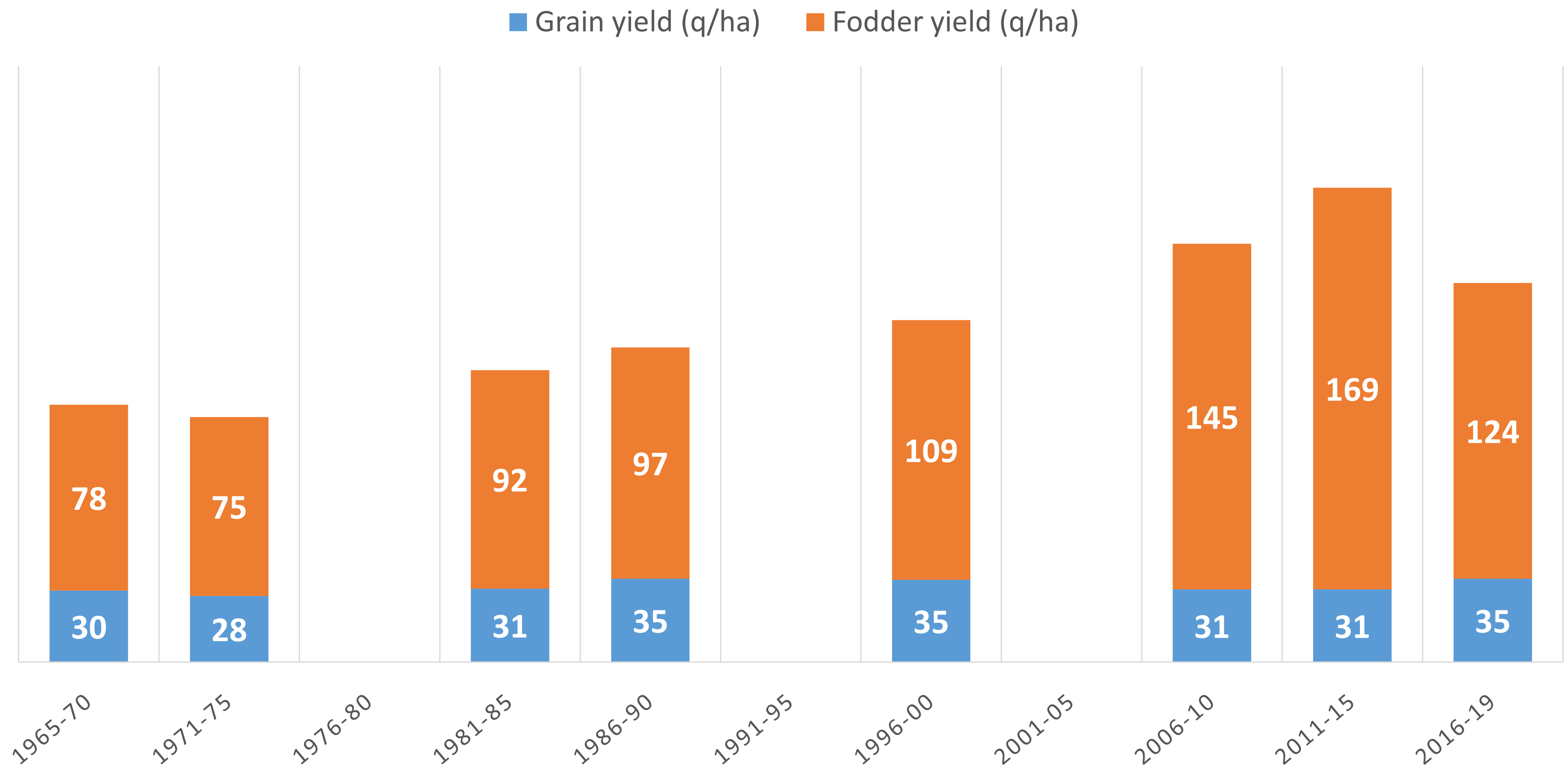
Source: Estimates based on data from Food and Agriculture Organization, United Nations & Directorate of Economics and Statistics, Department of Agriculture & Cooperation, Government of India.

No other crop has seen so much diversification

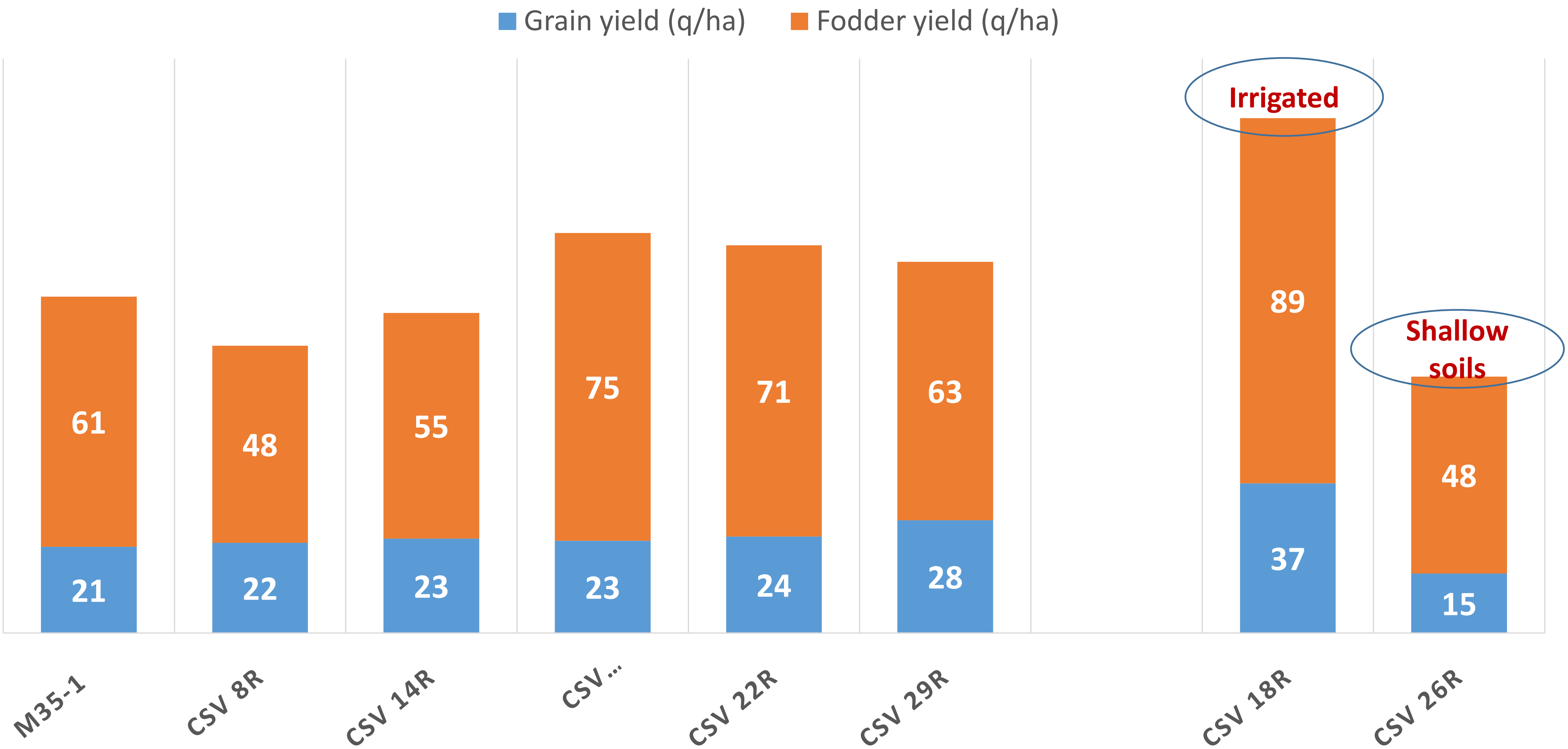
GRAIN SORGHUM- KHARIF HYBRIDS



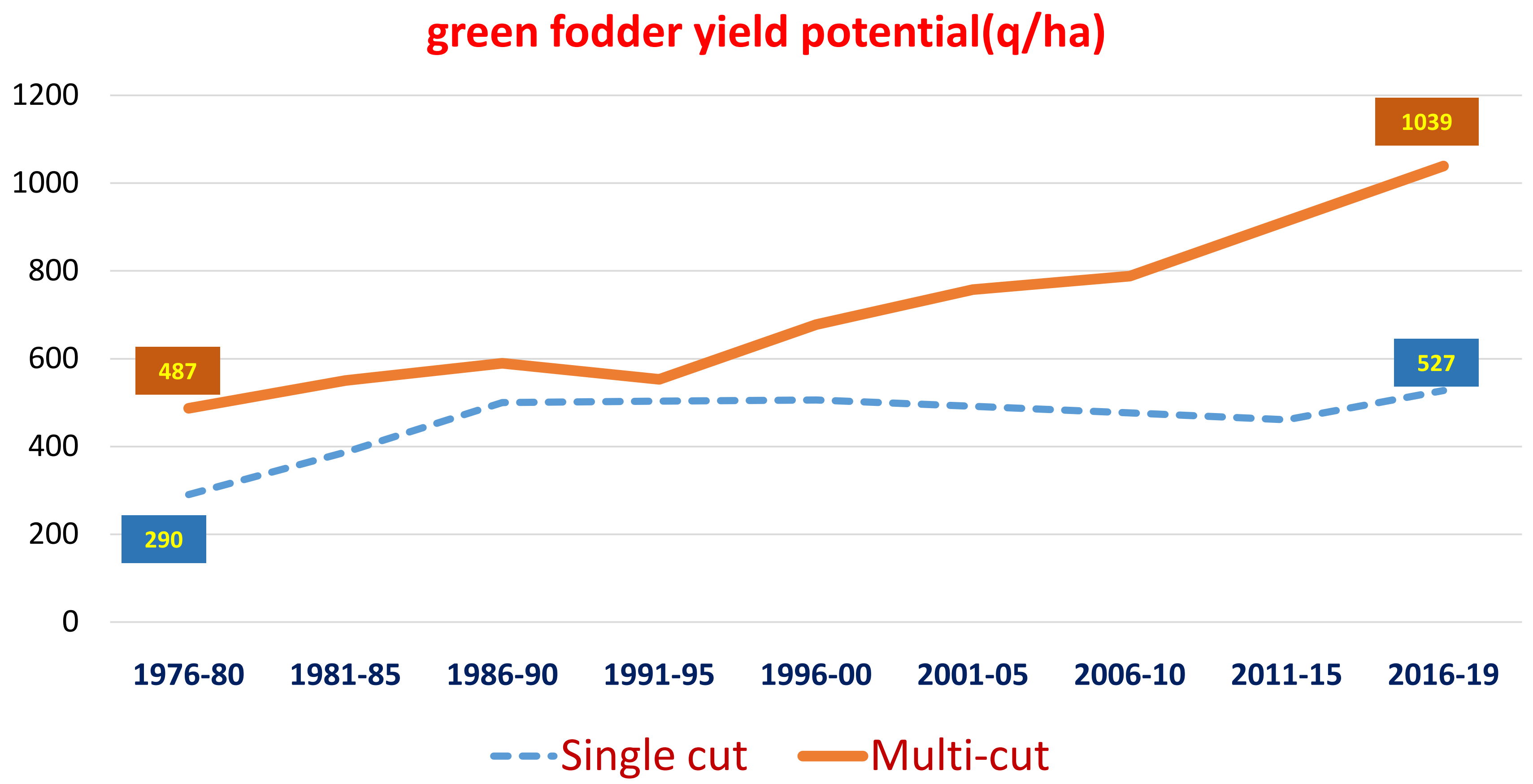
GRAIN SORGHUM- KHARIF VARIETIES



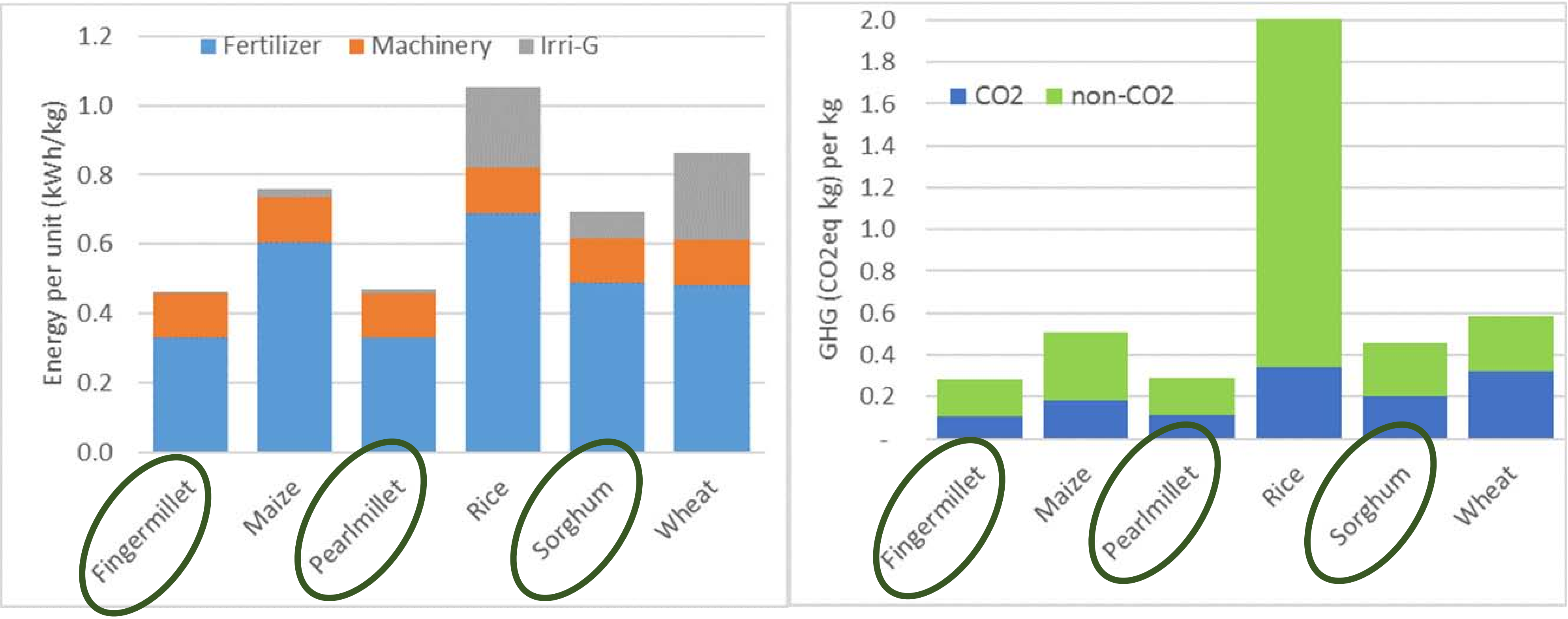
GRAIN SORGHUM- RABI VARIETIES



Fodder yield potential of forage sorghum cultivars developed under AICRP on Sorghum



Millets are Farmer and Environment Friendly Crops



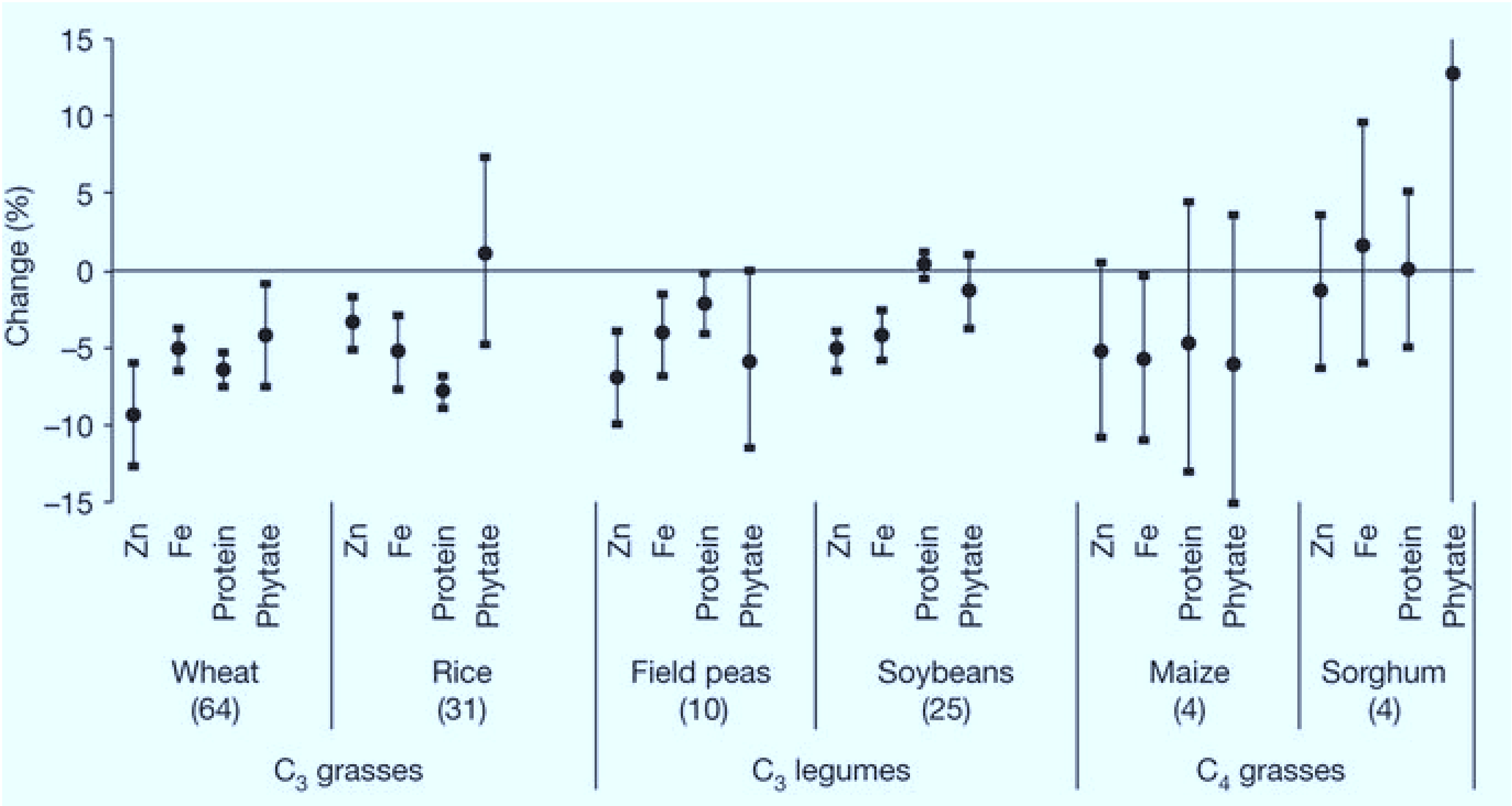
Rice is the most energy-intensive cereal, while millets are the least.

Fertilizer production & use dominates GHG emissions from all crops, contributing 52% of GHGs from cereals.

Replacing rice with other cereals has the potential to reduce energy consumption and GHGs

Rao ND, Poblete-Cazenave M, Bhalerao R, Davis KF, Parkinson S. (2019) Spatial analysis of energy use and GHG emissions from cereal production in India. *Sci Total Environ.* 654:841-849.

Nutrition is affected by climate change



Percent change in nutrients at elevated [CO2] relative to ambient [CO2]

Numbers in parentheses refer to the number of comparisons of a particular cultivar for which mean nutrient values are compared with identical cultivars under identical growing conditions except grown at ambient [CO2].

C3 grains and legumes have lower concentrations of zinc and iron when grown under field conditions at the elevated atmospheric CO2 concentration predicted for the middle of this century. C3 crops other than legumes also have lower concentrations of protein, whereas C4 crops seem to be less affected.

Myers et al. (2014)

Progress – AICRP Sorghum 2018-19

Trials execution summary 2018-19

Kharif trials

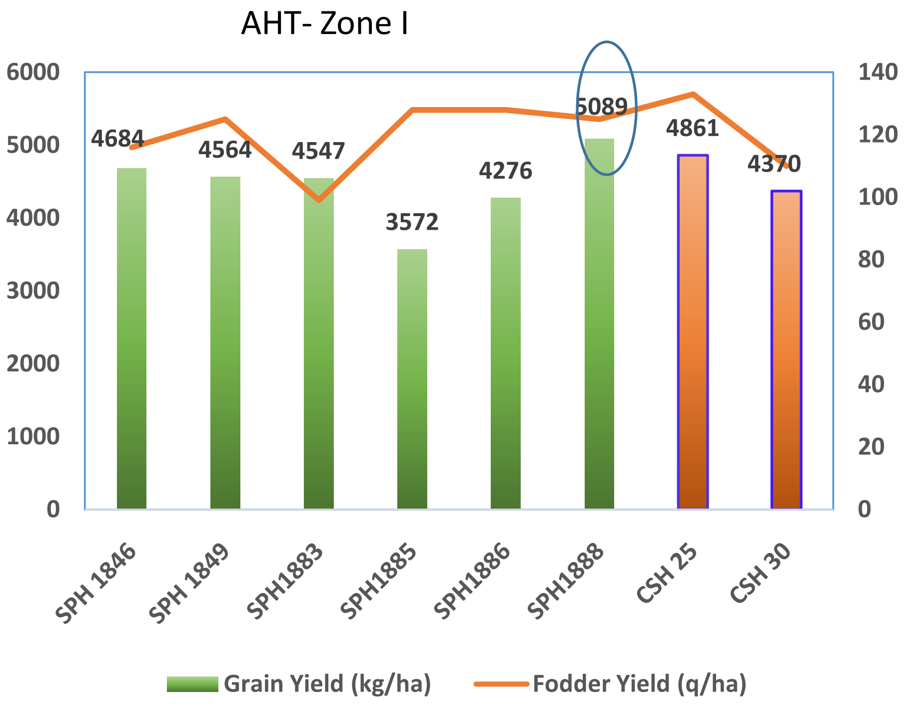
Discipline	Locations	Trials supplied	Success (%)
Breeding	45	165	97
Agronomy	14	7	86
Entomology	11	101	97
Pathology	9	11	100
Physiology	5	3	90
Total		287	94

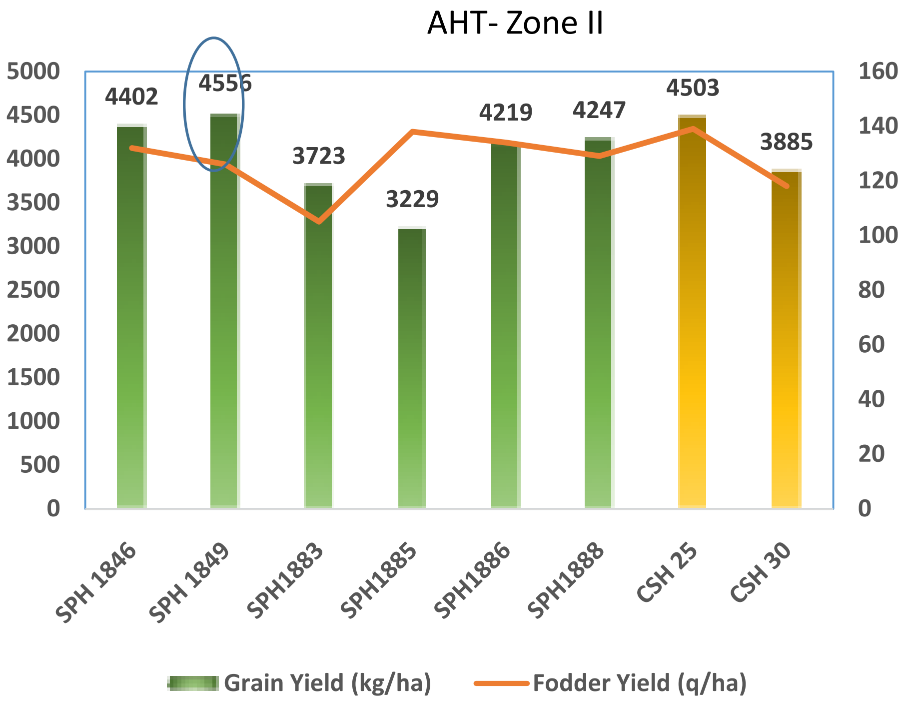
Rabi trials

Discipline	Locations	Trials supplied	Success (%)
Breeding	25	38	89
Agronomy	6	4	100
Entomology	7	25	100
Pathology	4	4	100
Physiology	6	5	100
Total		76	97.8

Highlights of AICRP-Sorghum trials 2018-19

Kharif Grain sorghum

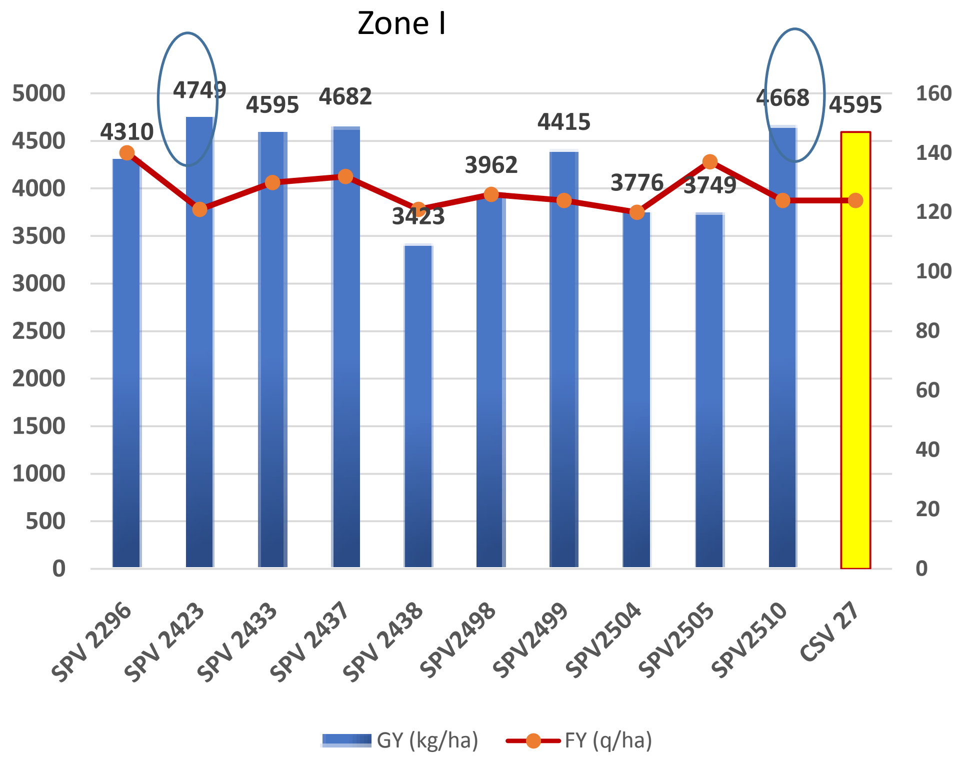


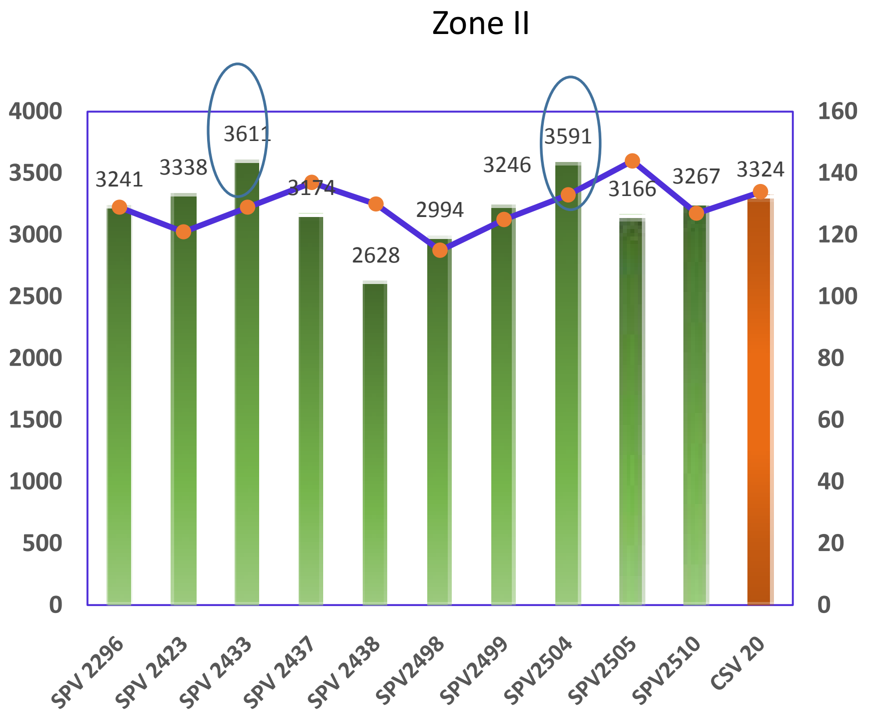


Entries- 6 (2+4)
Checks- 4
Locations-9

SPH 1888 in zone I and SPH 1849 in zone II were promising

Performance of kharif varieties in AVT

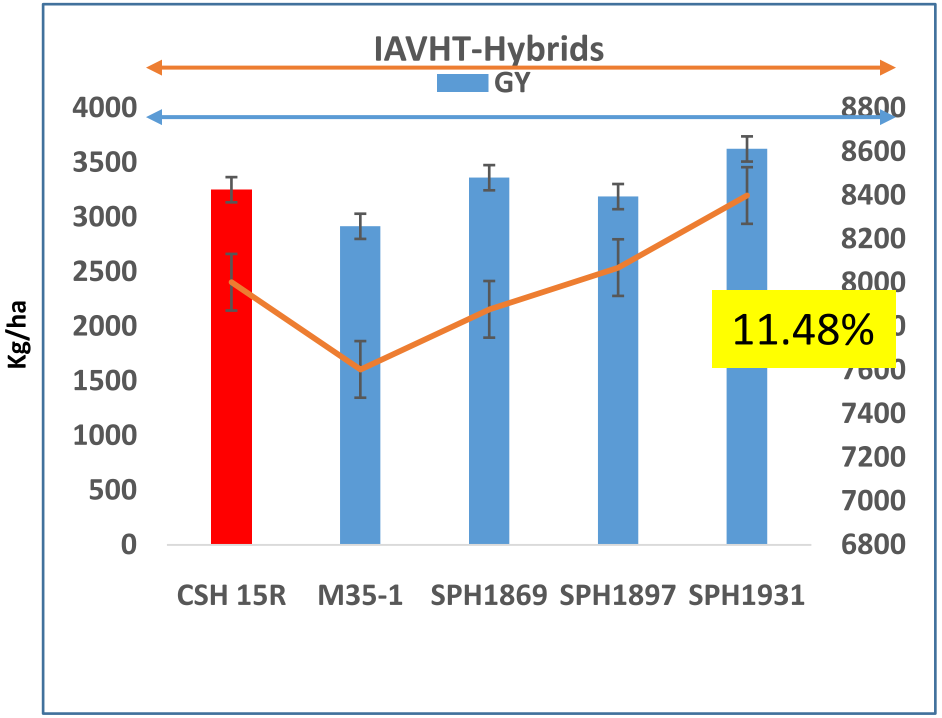


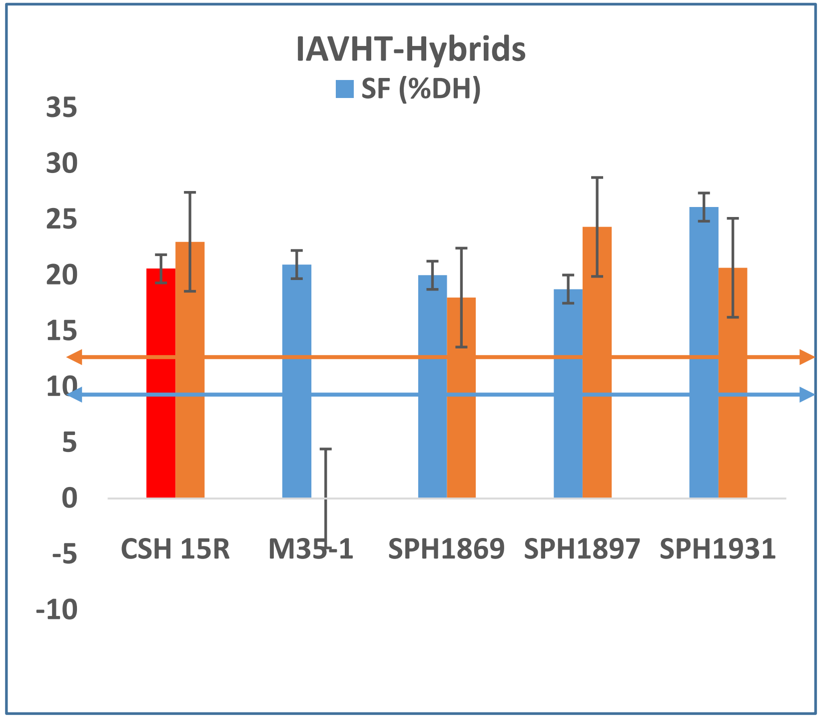


Entries- 10 (5+5)
Checks- 5
Locations-7

SPV 2423 and SPV 2510 in zone I and SPV 2433 and SPV 2504 in zone II were promising

Performance of Rabi Hybrids in IAVHT-Deep soil : Rabi 2018-19





SPH 1931 was promising with 11.5% grain yield superiority

Forage Sorghum Breeding

Single Cut- IVHT

All India

Promising hybrids (>20% higher fodder yield over check)

: 3 (SPH 1917, SPH 1918 and SPH 1919)

Promising varieties (>5% higher fodder yield over check)

: 3 (SPV 2581, SPV 2589 and SPV 2591)

Single Cut- AVHT

All India + Zone I + Zone II

Promising hybrids(>10% higher fodder yield): 2 (SPH 1890 and SPH 1891)

Multi-Cut- IAVHT

All India/Zone I/ Zone II

Promising hybrids (>5% higher fodder yield over check)

: 3 in AHT I (SPH 1877, SPH 1879 and SPH 1881)

: 3 in IHT (SPH 1904, SPH 1905 and SPH 1907)

Promising hybrids - >10% protein quality

: 1 in AHT (SPH 1879) and 1 in IHT(SPH 1906)

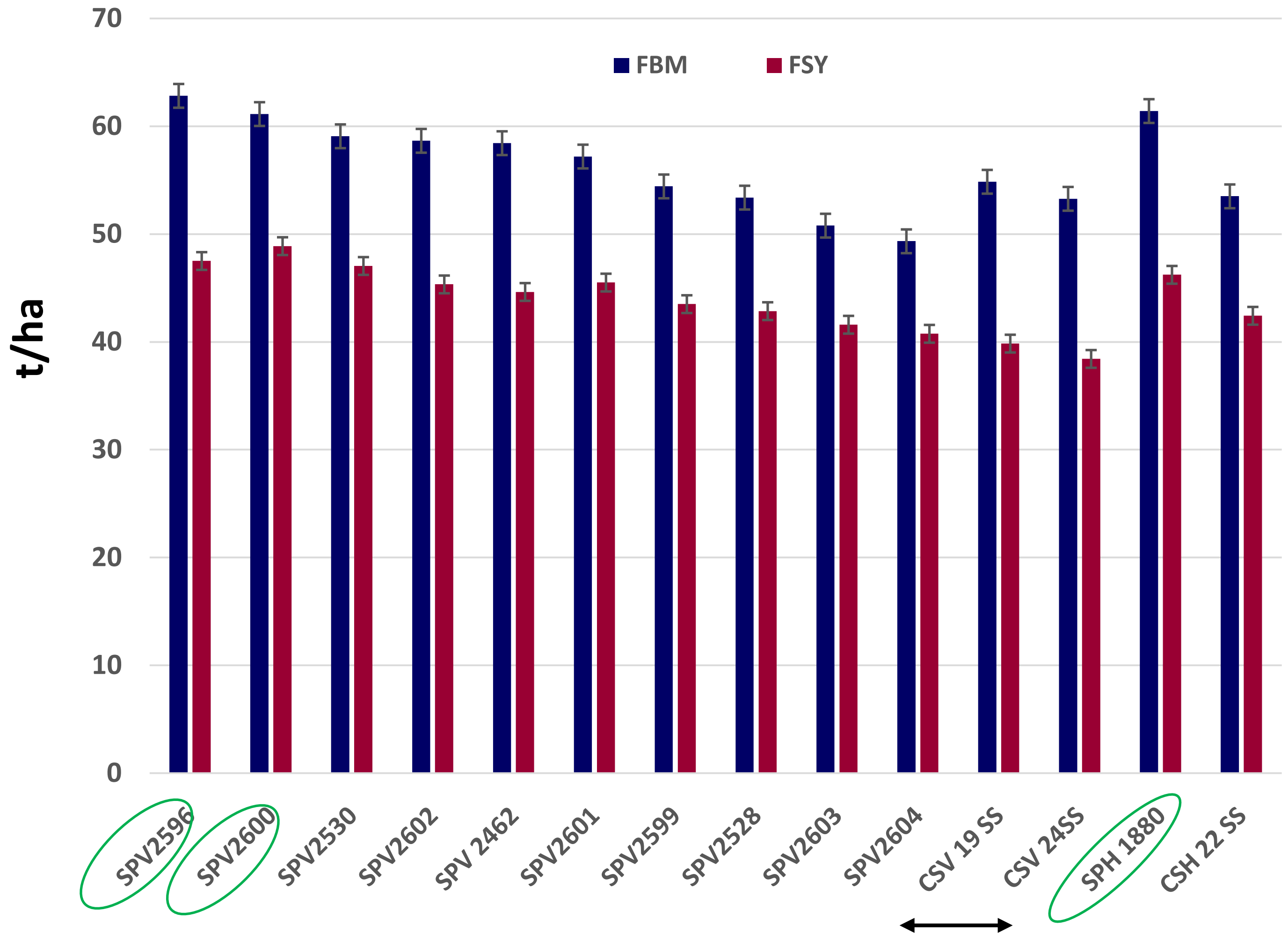
Forage sorghum - 3 years evaluation

		Green fodder yield (q)	Green fodder yield (kg/day)	Dry fodder yield (q)	Dry fodder yield (kg/day)	Protein (%)	IVDMD (%)
Single-cut variety SPV 2445	SPV 2445	490.7	633.4	120.5	101.3	7.5	52.2
% superiority over	CSV 30F	**7.10**	**7.68**	**10.23**	**13.53**	0.49	-0.60
	CSV 21F	**13.51**	**18.49**	-0.81	-36.94	-3.20	-1.12
Multi-cut hybrid SPH 1840	SPH 1840	905.4	6.3	206.3	1.5	8.0	53.4
% superiority over	CSH 24MF	0.6	-7.4	**9.3**	-0.7	**10.0**	-3.4

More than 5% superiority for fodder yield observed across 3 years in multi-location trials in qualifying single-cut and multi-cut test entries

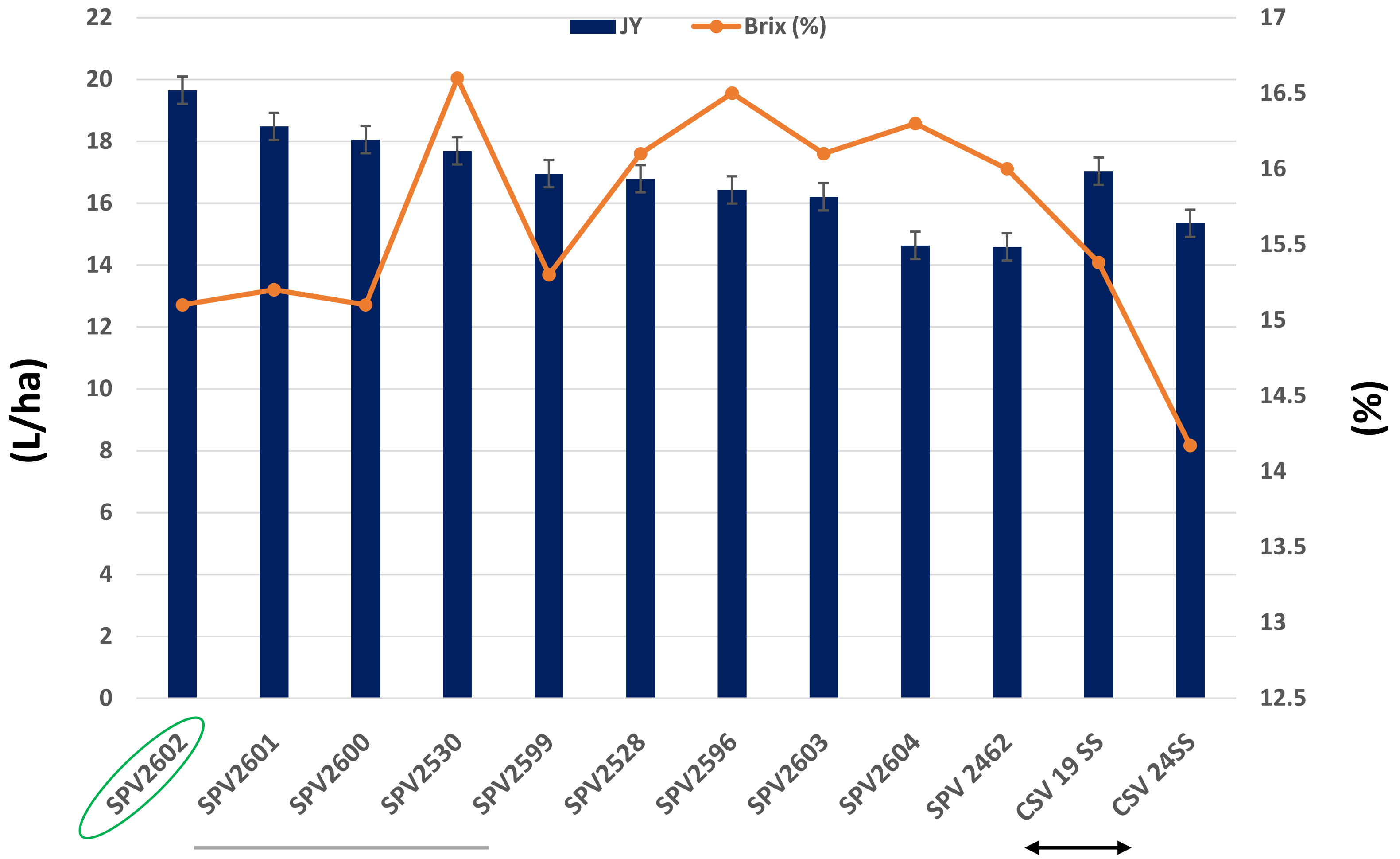
Sweet Sorghum Trials

Performance of test entries for stalk traits in IASSVHT-Kharif 2018



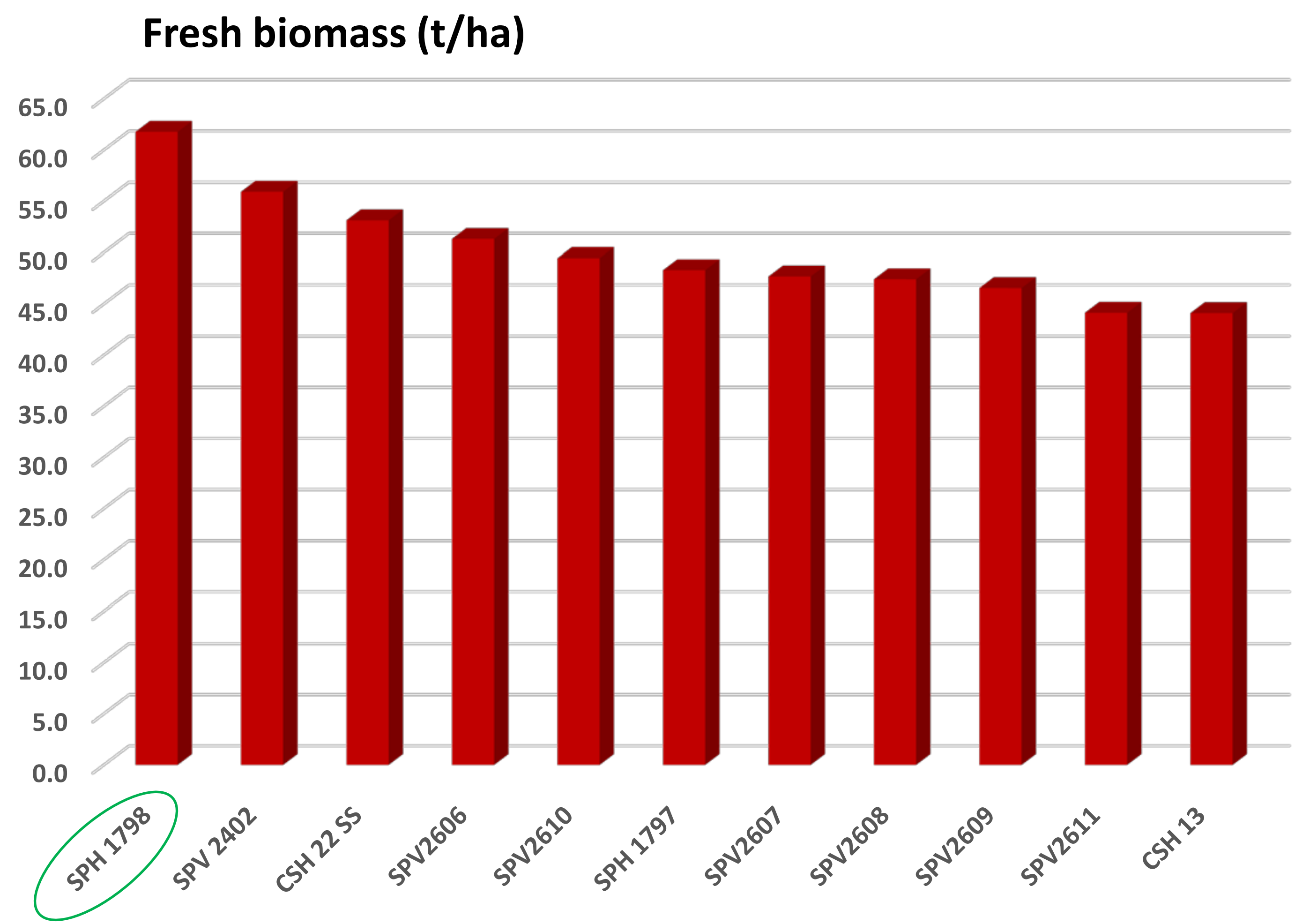
Promising entries for fresh biomass and stalk yields: SPH 1880, SPV 2596 and SPV 2600

Performance of test varieties for juice yield and brix content - Kharif 2018



Promising entry for brix and juice yields: SPV 2530

High biomass trial-Kharif 2018



Promising entry for fresh biomass: SPH 1798 (62 t/ha); 16% superiority over CSH 22 SS (53 t/ha)

भाकृअनुप ICAR

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Current Industrial Partners

Green Petal Infra & Resources Private Limited, Vijayawada, Andhra Pradesh

Sweet sorghum is being promoted as a feedstock for producing sorghum syrup and ethanol

Agronomy: Kharif

Forage sorghum

- Influence of soil moisture stress at later cuts in MC forage sorghum: Creating 7-day water stress prior to irrigation increased the total green fodder yield by 8 t/ha compared to no stress.
- Multi Cut forage sorghum response to Phosphorus & Potassium: Forage sorghum responded upto 30 kg P at Hisar and upto 15 kg at Surat, while in case of potassium the response was observed upto 15 kg ‘K’ ha^{-1} at both the centres.

Grain sorghum

- Response of advanced/pre-released grain sorghum to fertility levels in rainfed conditions: SPH 1849 (4.3 t ha^{-1}), SPH 1820 (3.9 t ha^{-1}) and SPH 1846 (3.8 t ha^{-1}) were superior for grain yields. In varietal trial, test variety SPV 2423 at Coimbatore & Dharwad and SPV 2437 across 4 locations were superior
- Organic fertilizer enrichment with Zn and Fe: FYM enriched with 15kg Zn and Fe recorded the highest grain yield of 5.3 t ha-1, compared to 5.1 t ha-1 with application of 15 kg ZnSo4.
- Response of grain sorghum to liquid bio-fertilizer seed treatment: Seed treatment with 4 ml Azospirillum (AZO) plus 4ml PSB resulted in better response as compared to the combination of 4ml plus 2ml treatment.

Agronomy: Rabi

Organic fertilizer enrichment with Zn and Fe: Micronutrient enrichment of organic fertilizer (Vermicompost enriched with 11.25 kg/ha $ZnSO_4$ and $FeSO_4$) recorded highest mean grain yield (3.56 t ha^{-1}), compared to 3.23 t ha^{-1} with 15 kg $ZnSO_4$ when applied to the soil along with RDF.

Response of grain sorghum to liquid bio-fertilizer seed treatment: Grain yield was more with the combination of 4ml Azo plus 4 ml PSB seed treatment (3.27 t ha^{-1}), when compared to powder form of biofertilizer (2.70 t ha^{-1}). The increase in grain yield was observed to an extant of 21%, due to liquid form of biofertilizer seed treatment over powder form.

Rabi sorghum response to organic fertilizer enrichment and irrigation: FYM @ 50 kg/ha enriched with 7.5 kg/ha $ZnSO_4$ plus $FeSO_4$ each significantly increased the grain yield by 15% over control, but there were no significant differences were seen in fodder yield. One irrigation at 30 days could enhance the grain yield by about one ton (59 % more than control), while two irrigations at 30 and 60 days increased the fodder yield by two tons/ ha

Physiology: Kharif

Physiological basis of assessing the genetic progress in yield potential of kharif sorghum cultivars:

- SPV 462 and CSV 20 still continue to maintain higher LAI than others.

Physiological basis of assessing the genetic progress of kharif sorghum parental lines:

- 296B continues to maintain higher LAI than recent ones. All R-lines had recorded higher LAI at flowering than B-lines.
- Specific leaf mass at flowering had shown high significant positive relationship ($P \leq 0.05$) with biomass, grains/m2 and grain yield.

Evaluation of sorghum elite lines (forage/sweet sorghum) for salinity tolerance:

- Plant height reduced by 26.8% and 34.3 % under 6dS/m and 8dS/m EC, res. compared to non-saline. SPH 2597 was more tolerant under 8dS/m Ec.
- SPV 2601 and CSH 22SS were superior under highest level of salinity.
- In forage sorghum, CSV 21F was tolerant followed by SPV 2445 and CSV 30F under 8dS/m level of salinity. CSV 30F and CSV 32F were superior for physiological traits
- RWC, total chlorophyll and SPAD values reduced by 17.1%, 20.2% and 23.8% at highest salinity level

Physiology: Rabi

Preliminary evaluation of diverse germplasm for rabi adaptation:

- EP 94, RSV 1837, RSV 1984, and CRS 73 maintained higher Photosynthesis rate (Pn) than check CSV 22R.
- RSV 2252, VJV 111, PVR 947, CRS 71 recorded high biomass, while VJV 112, PEC 23, PVR 950, and PVR 16-3 produced higher grain yield (21.0- 35.0 g/pl).

Phenotyping advanced rabi sorghum entries for drought adaptation traits in medium and shallow soils:

- Plant height decreased by 16.6% in shallow soil over medium. Entries RSV 2138, BJV125, and BJV 129 recorded lower DSI for biomass and were stable.
- Entries, RSV 2121, CRS 65, and BJV 362 were superior for heat use efficiency
- Grain yield decreased by 52.8% in shallow soil over medium. CRS 66 (DSI=0.551), Phule Anuradha (DSI=0.655) and M35-1 (DSI=0.737) were relatively more stable under terminal drought and heat stress conditions.

Phenotyping sorghum for key root traits associated with drought adaptation:

- Fresh and dry root biomass, root length, volume and numbers declined by 42%, 47%, 46%, and 29%, respectively in rainfed condition than in irrigated.
- Entries RSV 1986, & CRS 57 in root length; CRS 66, CRS 57, & P Suchitra in root fresh and dry mass; BJV 125 & M35-1 in root volume; CRS 66, RSV2106 in root number at maturity were relatively superior across stress and non-stress conditions.

Entomology: Sources of pest resistance-Kharif 2018

Pest	Sources identified	Testing Centers	Check used
Shoot fly	SFRM-4 (36.3 % DH) SFRM-1 (39.8% DH)	Akol, Dhar, Pale, Ludh, Hisar, Parb, Rahu,	IS 18551 (RC)-28.2 % DH Swarna (SC) – 78.3 % DH
Stem borer	SPV 2498, SPV 2437, SPV 2438, SPH 1904, SPH 1905, SPV 2591, SPV 2592 (	Akol, Coim, Dhar, Ludh,Hisa, Parb,Rahu, Sura, Udai	IS 2205 (RC)- 12.3% DH Swarna (SC)- 35.4% DH

Major Sources of pest resistance- Rabi 2018-19

Pests	Identified lines	Testing Centers	Check used
Shoot fly	SPV 2643, SPV 2641, SPV 2644, SPV 2651, SPV 2654, SPV 2663, RSV 2115, SPV 2221	Akol, Dhar, Parb, Rahu, Solapur	Sels: <20% DH R- IS 18551- < 10%DH S- Swarna-56.8%DH
Stem borer	SPV 2653, SPV 2655, RSV 1988, SLV 169, RSV 2299, AKSV 282R, RSV 2289, RSV 2260, RSV 1885	Parb, Rahu, Bija, Kovi, Sola	R- IS 2205- <10% DH S- Swarna - 28.0%DH
Aphids	KR 191, M 35-1, ICSV 93046, RSV 2121, BRJ 67 RSV 1959, SLV 182	Bija, Dhar, Kovi, Parb, Rahu, Sola	Sels: < 4 DR R- TAM 428= 2.6 S- Swarna = 6.2
Shoot bug	SPV 2655, SPV 2660, RSV 1885, SLB 81	Bija,Rahu, Sola, Parb	Sel: < 3.0 DR R- Y 75 – 2.0 S- Hathikunta- 6.0

Pathology

To find out resistance status of popular cultivars to emerging diseases

Pokkah boeng, a new disease to sorghum

20 popular cultivars were evaluated under artificial inoculations

Three rabi (CSV18R, DSV4 and E36-1) and one sweet sorghum cultivars (CSV19SS) (DSI: 10-15), found to possess better resistance than others to the emerging disease 'pokkah boeng'

Disease Severity Index

<1.0% = highly resistant
1−10% = resistant
11−20% = moderately resistance
21−30 = susceptible
>30 = highly susceptible

Bio-management of sorghum diseases

Three bio-agents and their new strains were tested for anthracnose management

Seed treatment with *Trichoderma asperellum* significantly reduced (40% reduction over control) disease and increased green fodder yield

Leaf anthracnose is a major yield and quality limiting factors in forage cultivation in North India

Lines tolerant to multiple diseases

Entry	Diseases
SPH1846	Grain mold + downy mildew
SPV 2296 SPV 2433	Grain mold + foliar diseases
SPH1879 SPH1905	Anthracnose + Leaf blight

New source of resistance

The germplasm lines IS10302 and ICSV12021 are new anthracnose resistance sources suitable for multiple locations

Frontline demonstrations on sorghum

kharif FLDs

Focus of FLDs:

- Shootfly resistant
- Stemborer
- Grain mold

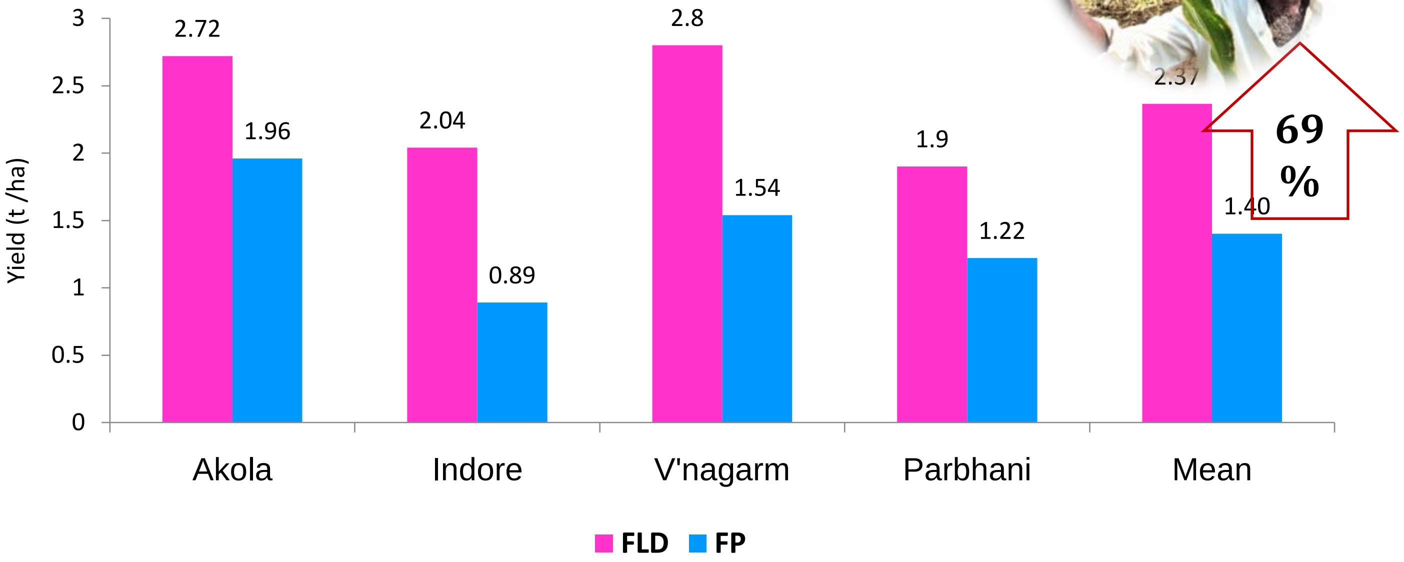
No. of FLDs: 196

Area : 80.4 ha

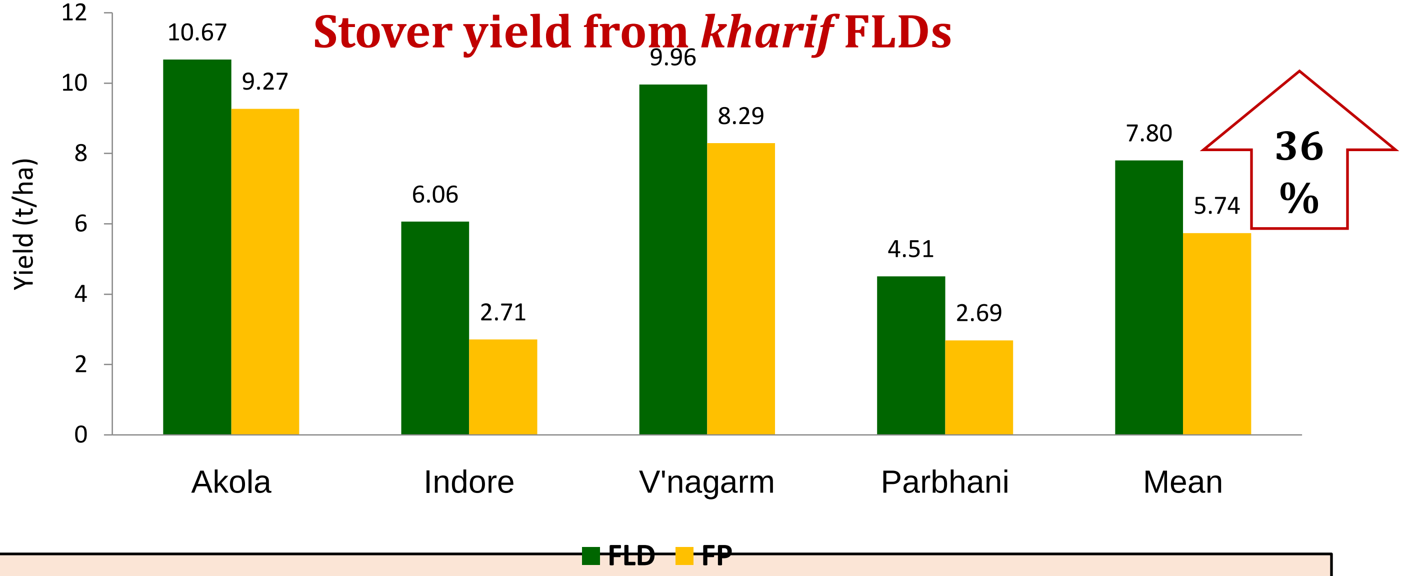
Cultivars (07) : CSV 27, CSV 23, CSV 17, CSH 14, SPH 1635, SPH 1641 and RVJ 1862

States : Maharashtra, Madhya Pradesh and Andhra Pradesh

Grain yield from *kharif* FLDs



Stover yield from *kharif* FLDs



Obtained 69% higher grain and 36% higher stover yield than the local checks

FLDs on *rabi* sorghum

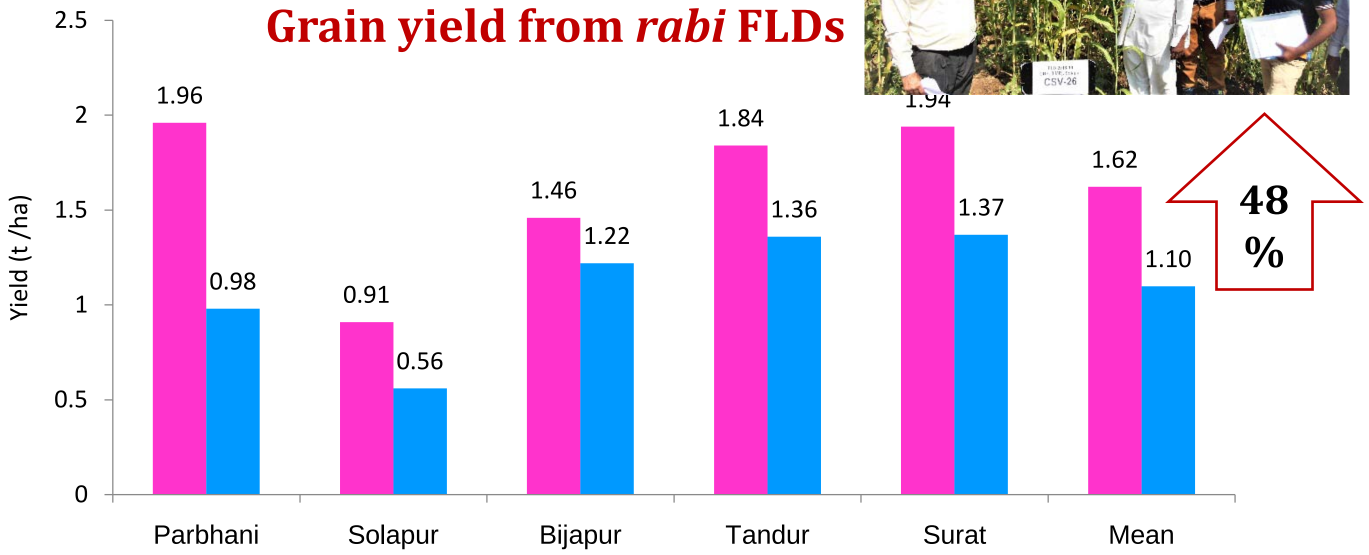
Focus of FLDs:
- Low productivity
- Soil-type based varieties
- Grain & fodder quality

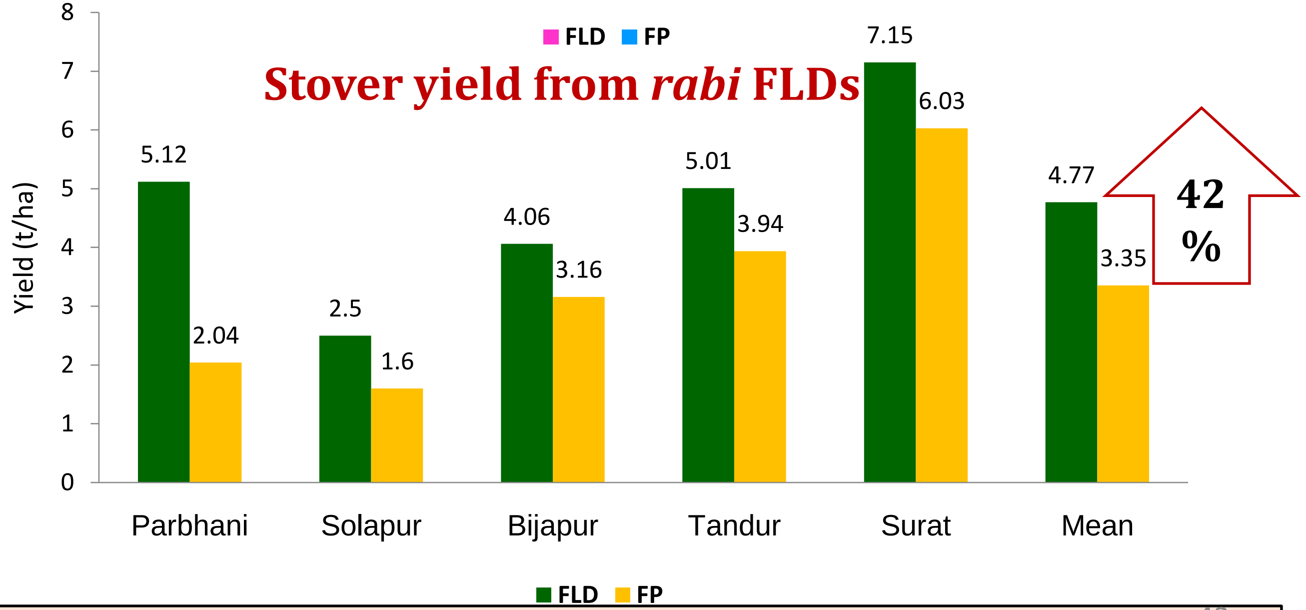
No. of FLDs: 294

Area : **121.6** ha

Cultivars (07) : CSV-29R, CSV 26R, CSV 18R, Parbhani Moti, Phule Revati, Phule Anuradha and Phule Suchitra

States : Maharashtra, Karnataka, Telangana and Gujrat





Obtained 48% higher grain and 42% higher stover yield than the local checks

Demonstrations under TSP 2018-19

No. of demos : 1164
Total area : 448 ha

Centres : 06 (AICRP-Sorghum, Akola, Parbhani, Vizi'ngaram, KVK, EG & MSSRF, TN & Odisha)

Technologies demonstrated

Cultivars : 14 (CSH 14, CSH 16, CSV 27, CSV 17, CSV 23, SPH 1635, SPH 1641, and small millets: GPU-66, GPU-28 Chilika, KMR-204, Bati Mandia, Jam Mandia and Arjun)

Check : Local cultivars

Recommended package of practices

- **The demonstrated cultivars gave 60% higher grain and 43% higher fodder yield than the local checks**
- **85% additional net return was obtained from the demonstrated cultivars than the local check**

Sorghum Breeder Seed Production 2018-19

	DAC indent	BSP I	Production
Breeder seed (q)	81	87	270
	Sub-Mission Nutricereals		
	Target->	194	208
Nucleus Seed (kg)		1399	1419*
Quality seed (q)			16135

IIMR's Supportive R&D in Sorghum

2018-19

Collection/Exploration of millet genetic resources

- ICAR-IIMR has undertaken 3 millets exploration programmes individually and in collaboration with ICAR–NBPGR (RS)
- Explorations: Tamil Nadu (62acc.), MP (56), Gujarat (37) and Telangana (19)
- 174 acc. of millets germplasm: Little millet 51 acc. followed by Sorghum (45 acc.), Finger millet (35 acc.), Pearl millet (27 acc.)
- Millet germplasm was collected from 16 tribal communities.
- The millet germplasm was with different maturity days, glume colour, grain colour, nutritional quality, number of finger etc.,

S.No.	Name of the millet	No. of acc.
1	Little millet	51
2	Sorghum	45
3	Finger millet	35
4	Pearl millet	27
5	Barnyard millet	8
6	Foxtail millet	7
7	Kodo millet	1
	Grand Total	174

S.No.	Ethinic group	No. of acc.
1	Blank	62
2	Malayali (Vellalar)	27
3	Malayali	24
4	Bilala	15
5	Kunbi	10
6	Barella	8
7	Varli	7
8	Bheel	5
9	Korku	5
10	Kukuna	3
11	Chaudhari	2
12	Sama	1
13	Gond	1
14	Dharbar	1
15	Malayali Koundar)	1
16	Kavit	1
17	Lambada	1
	Grand Total	174

Augmentation

- 11845 acc. from SAUs, AICRP on Pearl Millet, NGB-NBPGR and ICRISAT
- 4404 acc. of Sorghum, 2570 of Foxtail millet, 2365 of Pearl millet, 2034 of Finger millet was augmented.
- Max. millet germplasm augmented from NGB-NBPGR-New Delhi (9447) followed by AICRP on Pearl millet (2233)
-
- Category-wise millets augmented
- Facilitating SMTA: Facilitated three SMTAs to augment sorghum, pearl millet germplasm, wild relatives of millet.

S.No.	Name of the millet	No.of acc.
1	Sorghum	4404
2	Foxtail millet	2570
3	Pearl millet	2365
4	Finger millet	2034
5	Teff grass	288
6	Quinoa	130
7	Job's tear	47
8	Little millet	2
9	Kodo millet	2
10	Brown top millet	1
11	Proso millet	1
12	Barnyard millet	1
	Grand Total	11845

S.No.	Category of acc.	No. of acc.
1	Germplasm	4712
2	Indigenous/Exotic collections	4458
3	Mapping populations of economic importance	2233
4	Indigenous collections	351
5	Forage sorghum germplasm	78
6	Traditional varieties	13
	Grand Total	11845

Characterization

Sl. No.	Name of the Crop	No. of accessions characterized / multiplied	Date of sowing (From – to)	No. of descriptors	Date of harvesting (From – to)	Seed dispatch of data and seed material to NBPGR	
						Seed	Data
1	Sorghum New	2032	23rd Nov 2017	22	1-15th Mar 2018	1746**	Jun 2018
2	Sorghum un-germinated in Rabi 2016-17	2431	23rd Nov 2017	22	1-15th Mar 2018	1535**	Jun 2018
3	Sorghum less seed in Rabi 2016-17	699	23rd Nov 2017	22	1-15th Mar 2018	504**	Jun 2018
4	Finger millet	2013	11th Jun 2018	23	10th Nov – 10th Dec 2018	1737**	Jan 2019
5	Foxtail millet	2336	11th Jun 2018	23	4th Aug – 10th Oct 2018	1895**	Jan 2019
6	Sorghum New	4313*	17th Oct 2018	24	10th - 25th Feb 2019	3800*	In progress
	TOTAL	9511				7417	

**Characterization in progress*

***Seed packets of 7417 acc. of millets are kept ready at Millets Gene Bank-ICAR-IIMR-Hyderabad due to renovation at NGB-ICAR-NBPGR-New Delhi*

Sorghum Characterization under CRP-AB

Sorghum – New - 2032 acc. – Rabi 2017-18

Conservation

- 89,113 acc. of millets are conserved at MGB-IIMR
- Maximum contribution is by the sorghum genetic resources with 27,791 acc. as bulk samples followed by finger millet with 6,054 acc.
- In voucher samples, the maximum is by sorghum with 23,542 acc. followed by finger millet with 8,578 acc.

S. No	Name of the crop	2018-19 (As on 31st March 2019)			Augmented in 2018-19	New collections during 2018-19
		No. of acc.	Bulk	Voucher		
1	Sorghum	51333	27791	23542	4404	45
2	Finger millet	14632	6054	8578	2034	35
3	Foxtail millet	8353	3746	4607	2570	7
4	Pearl millet	6599	2238	4361	2365	27
5	Barnyard millet	3418	1197	2221	1	8
6	Proso millet	2890	1234	1656	1	
7	Kodo millet	654	236	418	2	1
8	Little millet	642	218	424	2	51
9	Brown top millet		25	30	1	
10	Teff grass	345	47	298	288	
11	Quinoa	143	11	132	130	
12	Jobs tear	49	1	48	47	
		89113	42798	46315	11845	174

भाकृअनुप
ICAR

IIMR
भारतीय कदन्न अनुसंधान संस्थान
ICAR-Indian Institute of Millets Research

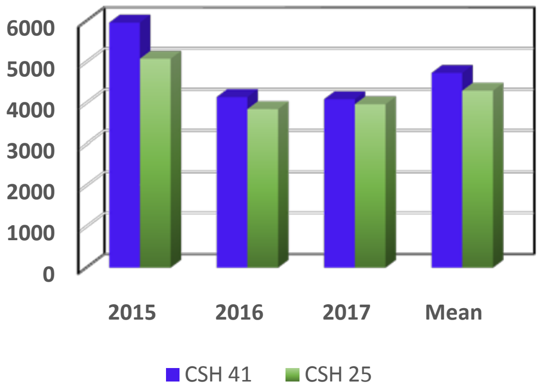
Sorghum Germplasm Field Day

30th January 2019 at ICAR-IIMR-Hyderabad

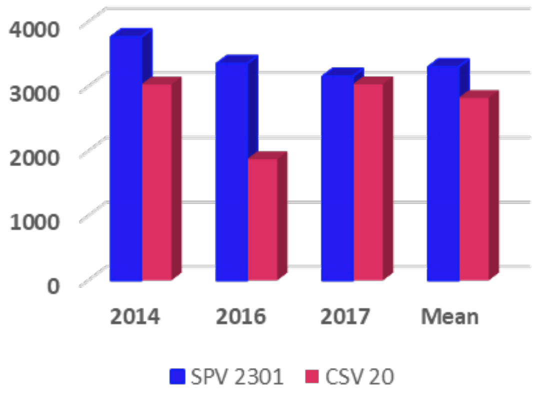
Kharif sorghum improvement program at IIMR

Khaif cultivars notified during 2018

CSH 41



CSV 36



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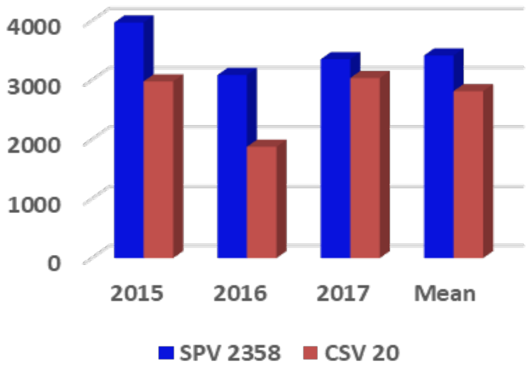


Progress in hybrid development

Evaluated 125 Experimental hybrids (27MS and 14R) in RCBD, Checks- CSH 25, CSH 30

	Hybrid/Check	DTF	GY (kg/ha)	Advantage CSH 25/30 (%)	Plant ht (cm)	GMS (1-9)
1	1114A x NR38-15	69.0	5779	26.8	202.0	5.00
2	151A x CB11	68.0	5718	25.4	196.3	5.83
3	461Ax CB33	72.5	5715	25.3	234.0	4.50
4	1097Ax NR 35-15	70.5	5679	24.6	197.0	5.25
5	4414A x C43	62.5	5173	20.1	168.0	5.25
6	4414A x NR43-15	64.5	4794	11.3	187.0	5.25
7	1111A x NR40-15	63.3	4766	10.7	170.3	6.50
8	9216A x AKR150	64.0	4759	10.5	162.5	7.00
	CSH 25 (Check)	74.8	4558	-	203.0	6.5
	CSH 30 (Check)	61.0	4307	-	191.0	6.13
	CD (0.05)	3.85	1068		13.4	1.2

32 were early maturing with DTF ranging from 56-65 days

Hybrids for different situations

- 12 experimental hybrids evaluated on farmers' fields near Tenali under zero tillage in rice fallows
- Farmer preference was based on plant stature. Most preferred cultivars were RFSH 2, 5, 10, 11, 12.

Hybrids in rice fallows

Hybrids for high density planting

Progress in colored sorghum development

Sl. No.	Hybrid	Seed color	GY (g/pl)	DTF	DTM	PH	GW
1	PVR 945	Yellow	38.1	68	108	261	3.09
2	PYPS 15	Yellow	37.0	68	109	275	2.75
3	IIMR red1	Red	40.2	68	109	220	2.60
4	PYPS 1	Yellow	35.2	69	110	270	2.74
5	PYPS 4	Yellow	33.0	68	110	267	2.57
	CSV 20	White	41.8	69	108	240	2.82
	C 43	White	37.3	69	108	155	2.96
	CD(5%)		15.3	4	4	39	0.39
	CV (%)		220	4.63	2.06	11.94	8.44

GY: grain yield (kg/ha), DTF: Days to flower, DTM: days to maturity; PH: plant height (cm), GW: 100 grain weight (g)

Colored lines : 10 (3 red, 5 yellow, 2 brown)
Checks : 2
Design : RCBD with 3 replications

IIMR red- CSV 15 x IS 23514

Progress in Grain mold resistance breeding

➢165 Population breeding derivatives with 5 checks evaluated in augmented design

Entry No.	Days to flowering	TGS (1-9)	Panicle structure	Glume cover (%)	Plant height (cm)	Seed size (g/100)
GM066	73	2.7	SC	90	230	1.95
GM075	67	3.7	L	90	230	2.5
GM077	71	3.7	SC	100	190	2.51
GM078	66	5.3	SC	50	200	3.9
GM087	68	3.2	SC	55	280	1.78
GM094	74	3.0	SC	60	235	2.0
GM097	76	3.7	SC	42	300	2.59
GM112	56	3.2	SL	45	140	1.9
C43	69	5.3	SC	30	130	2.93
27 B	66	6.4	SL	45	162	2.38
B58586 (R)	72	3.9	L	100	190	1.78
296 B (S)	69	6.8	SC	37	182	2.30
SE	0.70	0.22			8.03	0.07

➢30 derivatives recorded <5GMS of which eight were early with less than 65 DF

➢Seven entries recorded grain weight >2.5g/ 100 seed

➢GM112 has less glume cover and short height

Progress- Breeding for Shoot fly resistance- Fine mapping

QTL for LG-10

Marker	DH28	GS	SH	Egg21	Wax
Unnhsbm150					3.02
Xtxp331		3.40			
Xcup67		3.84			
XnhsbSFCILP2		5.10			
SB5435_10	15.32		3.00	11.90	
Xnhsbm1006_10		4.00		5.50	1.20
Xnhsbm1011_10	3.60	5.40	6.14	10.46	3.30
Xnhsbm1027		10.74	4.81	10.50	
Xnhsbm1033		9.49		5.95	
Xnhsbm1043_10		5.87		5.12	3.50
MS-IIMR-SB10-3334	7.25	15.06	7.76	11.11	
SB5511_10	6.15	15.41	4.57	11.79	
Xcup16_10	7.41	17.10		10.32	
XnhsbSFCILP29				2.88	
XnhsbSFCILP30_10	6.58	16.16	3.34	9.87	
XnhsbSFCILP33_10	8.54	20.32	4.46	13.60	
SB5514_10	7.30	18.29	4.60	13.83	
Unnhsbm250	3.98	8.32	3.23	11.10	
Total (PV%)	21.20	33.92	22.90	32.00	18.60

QTL for LG-10

Marker	DH28	GS	SH	Egg21	Wax
SB3055_05				5.88	
SB3075_05					
MS-IIMR-SB05-451					
MS-IIMRS-SB05-567				2.8	
MS-IIMR-SB05-571	3.84			3.11	
Total				8.4	

Lines ready for registration

- RBSV-50 (BNV364)-(44% DH) to shoot fly over two years in Entomology Trials (AICRP-S).
- RBSV-35 (BNV349) on par with IS2205 for stem borer resistance - 9.3% ST and 16.7% DH (AICRP-S).

NRCSFR 09-3 (INGR 17071) registered with NBPGR

Progress in SF resistance breeding

F_3 families of elite x wild crosses

S. No	Interspecific crosses	No. of derivatives	Deadhearts (%)		
			Elite Parent	Wild parent	Interspecific derivatives
1	27B x *S. versicolor* (IS 18941)	54	69.6	38.2	25.6 - 37.5
2	126B x *S. versicolor* (IS 18941)	50	52.2	38.2	20.0 - 37.9
3	27B x *S. purpureosericeum* (IS 18944)	32	69.6	9.1	24.4 - 90.0
4	126B x *S. purpureosericeum* (IS 18944)	14	52.2	9.1	26.7- 100.0
5	27B x *S. australiense* (IS 18955)	28	69.6	36.0	28.6 - 35.7
6	SSV84 x *S. australiense* (IS 18955)	22	73.9	36.0	34.2

Inter-specific progeny (BC_1F_2) for shoot fly screening during K2018

Pedigree	No
27B x *S. versicolor*, IS18926	7
126B x *S. versicolor*, IS18926	4
27B x *S. purpureosericeum*, IS18944	22
126B x *S. purpureosericeum*, IS18944	5
27B x *S. australiense*, IS18955	38
SSV84 x *S. australiense*, IS18955	4

Sorghum mutants for shoot fly

- **Thirteen mutants out of 20 in M5 generation** tested in five AICSIP locations (Akola, Palem, Parbhani, Rahuri and Hyderabad) were found to be consistently superior than the resistant check (IS18551) for shoot fly resistance
- These mutants' showed **10-25% improvement over resistant check in terms of deadheart %**
- Four mutants (M4-65-1-P, M4-98-1-H, M4-92-1-H and M4-77-2-H) were contributed for AICSIP testing during 2018-19
- Mutants developed in C43 and 296B were screened for shoot fly resistance at Hyderabad in M3 generation
- 104 out of 370 mutants of C43 and 45 out of 109 mutants of 296B showed 10-55% improvement over resistant check in terms of deadheart %

Rabi breeding: Material developed

S. No.	Type of material	Material developed/identified	Special features
1)	F1s or crosses synthesized	60 crosses (Inter-varietal and using landrace/ exotic germplasm)	Better grain type, High yielding, Charcoal rot tolerance
2)	Double crosses	Set 1: 4 DCs Set 2: 50 DCs	100 Seed weight, Long and compact panicles
3)	Inter-mated Double cross derivatives	IDC: 25 (Strategy –I) – 10 IPS (Rabi traits) IDC: 20 (Strategy –II)	Most of the rabi adaptive traits targeted in the project
4)	Segregating populations (F_2 s & F_3 s & Selection of desirable transgressive segregants	Individual plant selections: F_2 s: 49 populations (Different crosses) 1) F_3 -I : 85 (CSV-216R × CRS-4) 2) F_3 -II : 5 (M35-1 × CSV-29R) 3) F_3 -III : 5 (DSV 5 × Sel. 3) 4) F_3 -IV : 90 (Parbhani Moti × CRS-20)	1. Panicle length: 25 cm; 2. Flowering: 60-65 days; 3. Bold and lustrous grain; 4. Compact-semi compact panicles, 5. Low charcoal rot disease incidence
5)	Promising germplasm	70 promising landraces 11 exotic lines	Early duration, better panicle exertion, plant phenology

Genetic diversification for new plant architecture

1. R x R/ V x R : 11 F1s

1. (M35-1 x IS18343) D-C
2. (RS585 x IS18343)
3. (CSV-22 x IS18343)
4. (CSV-29 x IS 18343)
5. (RS585 x Gidda maldandi)
6. (CSV-216R x CS3541)
7. (CSV-22 x CS3541)
8. (CSV-22 x IS18656) C
9. (CSV-26 x IS18656)
10. (CSV-29 x IS18656)
11. (CSV-216R x IS18344) D

2. B x B : 2 F1s

1. [(104B x (296B x N178B)-66)]
2. [(104B x (296B x N178B)-20)]

3. BC1F1 progenies : 4 crosses

1. [(RS585 x C43) x RS585]
2. [(CSV-29 x 296B) x CSV-29]
3. [(CSV-29 x C43) x CSV-29]
4. [(104B x 296B) x 104B]

4. F3 families developed : dwarf and earliness

Crosses	Type	No.	To look for
M35-1 x 296B	R x K	68	Dwarf
CSV-22 x C43	R x K	123	Dwarf
CSV-22 x CS3541	R x K	107	Dwarf
RS585 x CS3541	R x K	61	Dwarf
M35-1 x CSV-17	R x K	84	Earliness
CSV-216R x CSV-17	R x K	100	Earliness
RS585 x CSV-17	R x K	85	Earliness
M35-1 x SSV74	R x K	183	GY, Stalk
104B x 279B	R x K	32	Earliness, GY

5. Mutation breeding: M35-1

- **216 M6** progenies
- Isolated mutants with
  - brown midrib,
  - chlorophyll variegation,
  - dwarf stature,
  - absence of bloom,
  - loose panicles
  - Awn/Awnless

Hybrids development, A /B lines, CMS diversification

New hybrids developed

271 F_1 hybrids on rabi CMS lines

- 129 F1s of 104A (17 F_1s of M6)
- 142 F1s of SLA22 (127F_1s of M6)

Maintenance Breeding:

A/B pairs : 37
R lines : 58
Varieties : 125
Landraces: 55
IS lines : 243

CMS diversification:

New CMS lines stabilized

- ✓ A3-M35-1 (RBSA1)
- ✓ A4-M35-1 (RBSA2)
- ✓ A3-CSV-19SS (RBSA18)
- ✓ A3-CSV-216R (RBSA19)
- ✓ A4-CSV-216R (RBSA20)
- ✓ A4-Mangalweda Maldandi (RBSA50)

New hybrids on A3 cytoplasm:

A3-M35-1 x 21 lines :

BRJ62, SLV190, SLV213, CRS7, SLR10, SLV81, SLV173-1, SLV185-1, SLV188-1,, SLV193-1, SLV195-1, RSLG2241, IS 18474, IS 18482, IS 26981, IS 4592, IS 4895, PR3178-3, IS 14880, SLR31, SLR67

Status of introgression lines with stay green trait through MAS

Entry	Stage	Lines		
CRS4	BC1F5	22		
	BC1F6	42		
	BC2F4	90		
	BC2F5	126		
	BC3F5	510		
	BC4F4	201		
		991		
RSLG262	BC1F5	30		
	BC1F6	54		
	BC2F4	74		
	BC2F5	69		
	BC3F5	111		
	BC4F4	192		
		530		
Trial	Stage	Total	CRS4	RSLG262
MLT (HST)	BC3F4	13	8	5
ICRISAT	BC3F4	123	74	49

2018: BC2F4s : MPKV Rahuri
- CRS4 : 140
- RSLG262 : 78

2018:
MLT trials :
IIMR, Solapur, Bijapur, Mohol

Phenotyping of stay-green introgressed BC products in rabi adapted backgrounds (IIMR-ACIAR proj.- Ph II)

1. Field evaluations:

2016-17: Hyd;
2017-18: MLT (Hyd, Solapur , Bijapur)

2. Evaluations in Lysimeters at IIMR

Experiments

- 3 Replications
- 2 Treat (WW & WS)
- Split plot design

Traits :

- ✓ Phenology, growth parameter
- ✓ Phys. Traits (GLAR , RWC , SPAD)
- ✓ Yield components (Grain & stover yield)

Plant Material: BC_3F_4s of CRS4 & RSLG 262

- ➢ 8 in CRS-4 background
- ➢ 5 in RSLG 262 background

CRS 4*B 35; RSLG 262* B35:
RPs: CRS 4 (SPV1671); RSLG 262 (*Phule Maulee*); SG donor: B35 (BTx642)-Conv. IS12555

Phenotyping stay green introgression lines……

- **Phenotyping SG QTL introgression lines led to significant improvement in GLAR, GY, STY, WE and TE in both the genetic backgrounds particularly under WS conditions**

- **Yield components improved more with CRS4 (Gy-54%, STY-63%) than RSLG 262 background (Gy-35%, STY-47%) under WS.**

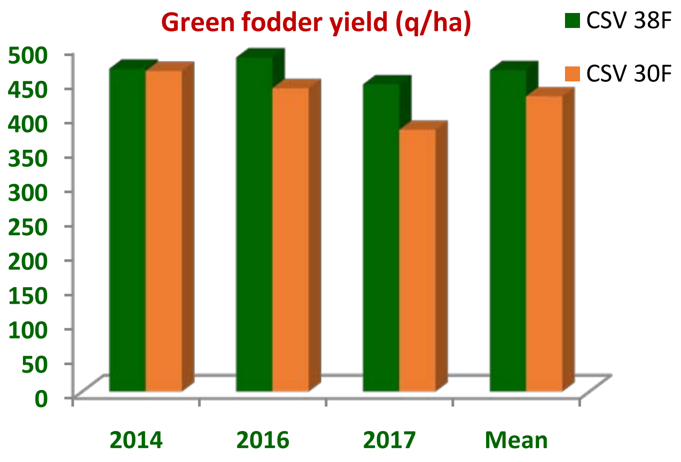
- **Enhancement in GLAR and yield components seems to be due to improvement in WE and TE.**

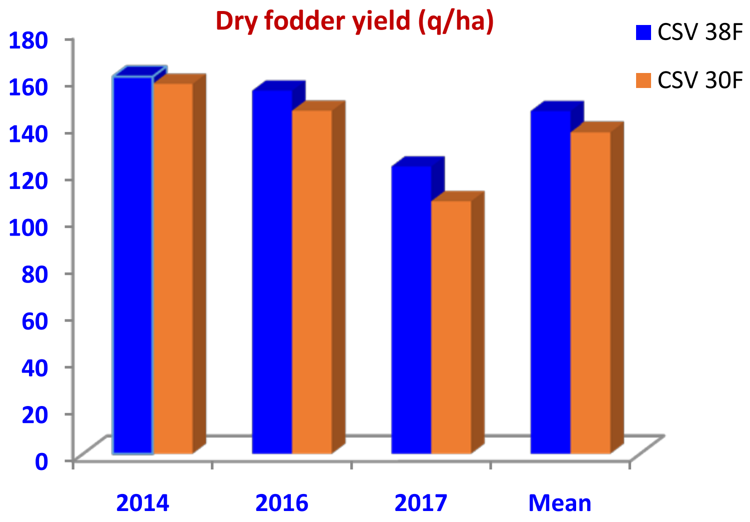
- **Improvement in WE was more in RSLG 262 than CRS 4 and vice-versa for TE**

- **SG QTL ILs such as C3 & C7 with CRS4, and R3 with RSLG262 backgrounds, respectively are promising and needs further evaluation at more target rabi environments**

CSV 38F- A single cut forage cultivar released by IIMR

CSV 38F (Zone II)





Genetic improvement of forage sorghum

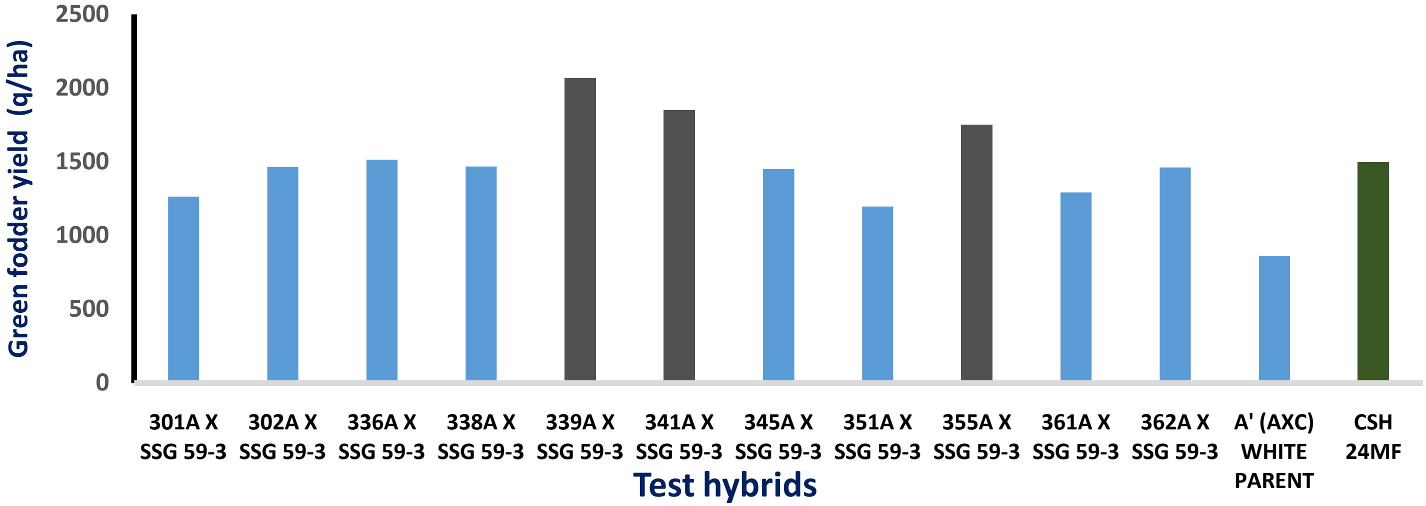
New parental lines for multi-cut sorghum hybrids

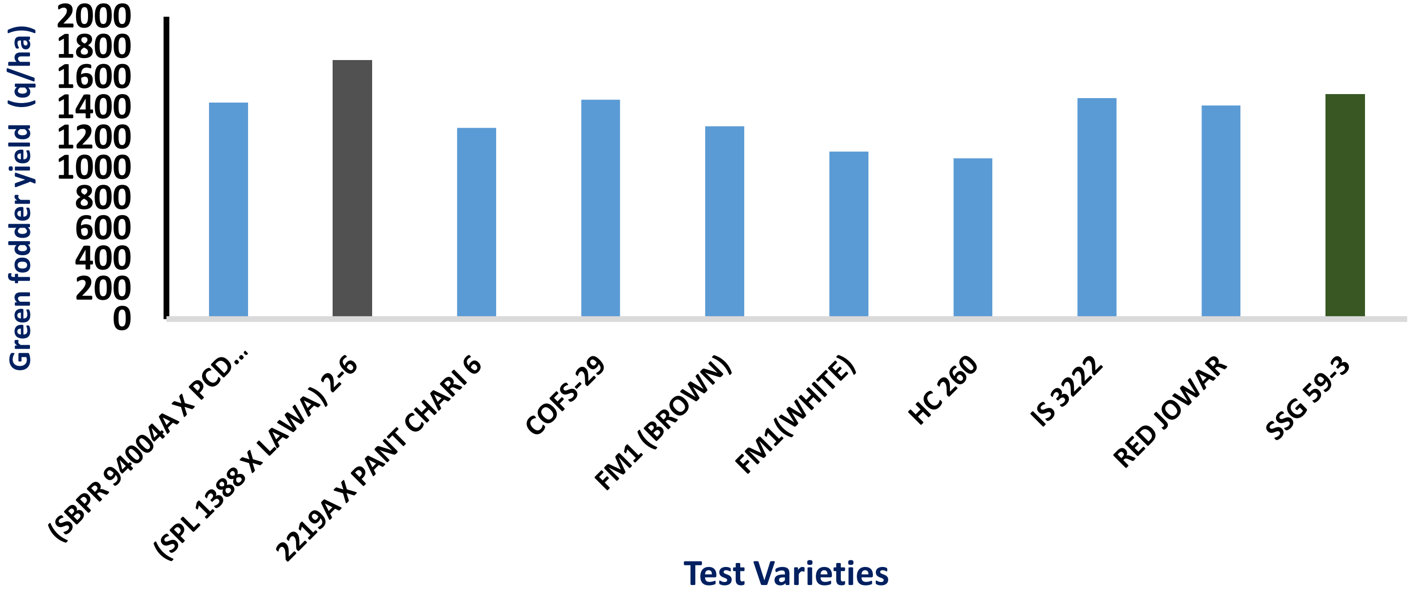
- **20 A/B pairs developed** with synchrony in flowering, good seed set and stable male sterility expression.
- **BxB crosses for new female parents**
  - 20 BC4 lines conversion in progress
  - 32 BC4s were converted to A lines
- **Sweet sorghum x sudan grass crosses- Progeny advancement**
  - 91 selections from 25 crosses reached F6 & F7- Multiplication for evaluation
  - 320 F4 families selected and advanced to F5- from 81 crosses
- **New MS pairs multiplied – 72**
- **Mapping populations for fodder quality traits**
  - Fodder quality RIL populations – genotyping and phenotype data for two seasons completed.
  - One derivative from 4-way cross identified for single-cut forage
- **grain x sweet sorghum** B lines: **118 selections made from 21 Crosses** between the.
- **forage x forage** and **sweet sorghum x forage** crosses: **150 selections from 13 crosses** involving were effected.
- **40 new crosses** were made to develop **R lines** (male lines) for hybrids.

Forage sorghum multi-cut hybrid development

- **3 hybrids recorded >10% improvement in fodder yield over the check CSH24MF.**
- **One test variety recorded >10% improvement over the check SSG 59-3**

Performance of forage sorghum multi-cut hybrids and varieties

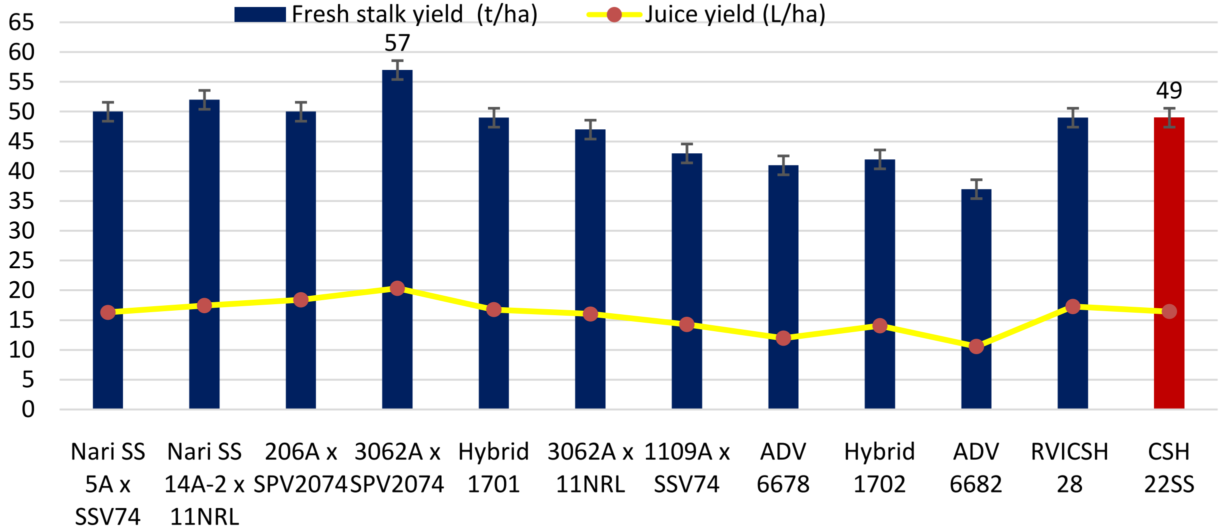




ICAR

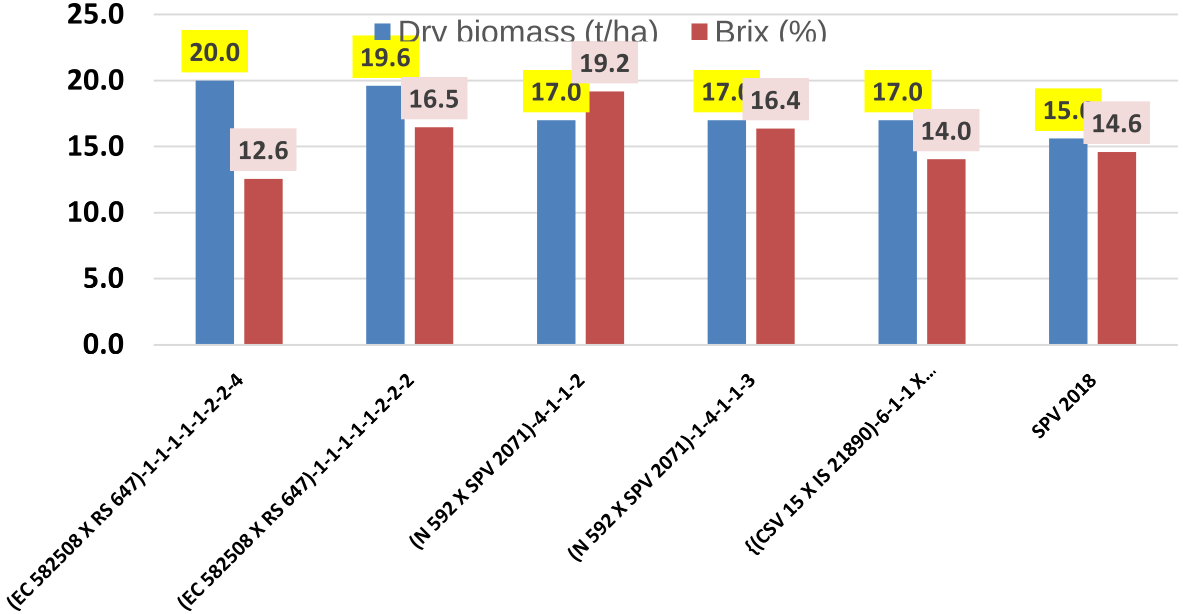
IIMR
भारतीय कदन्न अनुसंधान संस्थान
ICAR-Indian Institute of Millets Research

Performance of sweet sorghum hybrids for stalk and juice yields



3062A x SPV 2074

Performance of *bmr* varieties for biomass yields

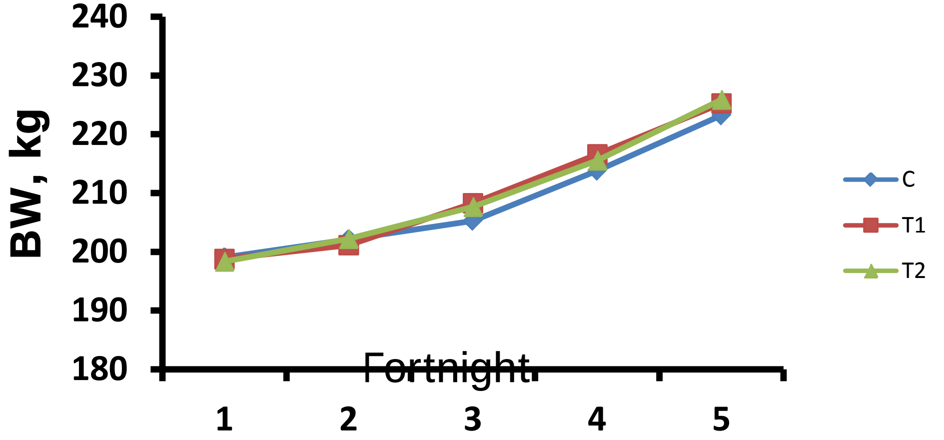


EC 582508 x RS 647

Nutrient digestibility (%) in buffalo calves fed with three different sorghum cultivars

(IIMR-CIRB collaborative project)

Attributes	Treatments			SEM	p Value
	MP Chari	CSH 24 MF	SPV 2018		
Dry matter	66.92^{a}± 2.11	68.14^{a}± 1.16	**73.70^{b}± 0.38**	1.92	0.002
Organic matter	68.79^{a}± 2.07	69.99^{a} ± 1.01	**75.75^{b} ± 0.90**	0.66	0.002
Crude protein	68.37 ± 4.60	67.91 ± 2.65	**73.89 ± 1.03**	2.28	0.103
Ether Extract	65.25 ± 7.53	64.30 ± 2.88	64.37 ± 4.18	2.67	0.891
Neutral Detergent fibre	59.15^{a} ± 2.61	60.16^{a} ± 1.20	67.05^{b} ± 0.74	2.31	0.003
Acid detergent fibre	55.38^{a} ± 3.09	54.31^{a} ± 0.74	62.61^{b} ± 1.19	2.46	0.004



(14.0% increase in Body Weight in 60 days)

Stalk sugar content in sweet sorghum mutants

- A total of 258 new mutants developed in SSV84 background were screened in M3 generation for high stalk sugar content
- 60 mutants showed an improvement of 10-34% in BRIX (%)
- The average BRIX in control was 17%, in mutants 19-23%
- Out of 1554 plants tested, 13% (198) plants showed the BRIX in the range of 22-27

S.No	Sweet sorghum mutant	Brix (%) Ave	Brix (%) Range	% Imp.
1	SSV84	17	7-20	
2	M34-1	20	14-24	16
3	M34-26	21	17-26	25
4	M34-36	22	19-24	28
5	M34-42	23	18-25	34
6	M34-48	20	16-25	16
7	M34-50	21	17-24	23
8	M34-84	20	15-26	18
9	M34-90	20	16-23	19
10	M34-91	20	18-25	20
11	M34-93	19	15-25	13
12	M34-94	21	15-24	21
13	M34-143	21	13-25	22
14	M34-193	20	16-24	16
15	M34-234	21	19-27	25
16	M34-248	21	16-26	22
17	M34-265	19	16-25	14
18	M34-272	20	14-23	15

Sorghum genotypes for biofuel production through marker-assisted gene pyramiding

Recurrent Parents (Dual-purpose varieties)

CSV 20

CSV 27

Markers for foreground selection

Genes	Markers	Reference
bmr2	CAPS *bmr2*	Saballos et al. 2012
bmr6	CAPS *bmr6*	Sattler et al. 2009
Bmr12	CAPS *bmr12*	Bout and Vermerris 2003

Donor Parents (Brown midrib lines)

OKY-11 (*bmr2*)

Atlas-*bmr6*

Atlas-*bmr12*

Recovery of recurrent parent genome in positive plants

BC_2F_1	Recovery of recurrent genome (%)
(CSV 20 × OKY 11-*bmr2*) // CSV 20	79 – 93
(CSV 27 × OKY 11-*bmr2*) // CSV 27	78 – 95
(CSV 20 × Atlas-*bmr6*) // CSV 20	81 – 94
(CSV 27 × Atlas-*bmr6*) // CSV 27	83 – 96
(CSV 20 × Atlas-*bmr12*) // CSV 20	77 – 93
(CSV 27 × Atlas-*bmr12*) // CSV 27	80 – 93

Biofortification in Sorghum

Selection of candidate genes for Fe and Zn

Deoxymugineic Acid Synthase
Formate Dehydrogenase
Ferritin
Heavy Metal-associated
Iron Deficiency-responsive
Acireductone Dioxygenase
Iron Deficiency-specific 3
Iron-related Transcription Factor
Iron-regulated Transporter
Nicotianamine Synthase
Nicotianamine Aminotransferase
NAC Domain-containing Protein
Natural Resistance-associated Macrophage Protein
Vacuolar Iron Transporter
WRKY Transcription Factor 80
Yellow Stripe 1-like
Zinc Transporter
Heavy Metal ATPase
Zinc-induced facilitator-like
ABC Transporter Oligopeptide Transporter

Selection of candidate genes of Fe and Zn based on the reports in major cereals

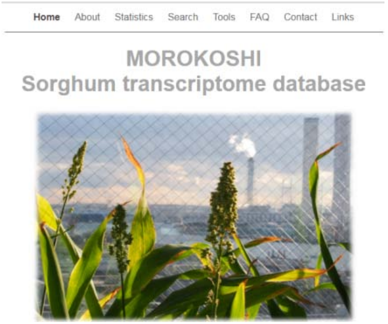
Identification of SNP in the candidate genes for Fe and Zn

Selection of candidate genes – Literature

↓

1. Retrieval of gene sequences – NCBI, Phytozyme
2. Orthologue search against Rice, Maize, Sorghum, Arabidopsis, etc. - RGAP

↓



Retrieval of candidate gene IDs from *MOROKOSHI* database using "SEARCH" tool

↓

Retrieval of candidate gene SNP using "COMPARE" tool from SorGSD database by comparing the available germplasm accessions in database

SNPs selected at a minimum of 100bp intervals

↓

5' [Target allele(SNP)/Reference allele] 3' with 50 base flanking sequence

↓

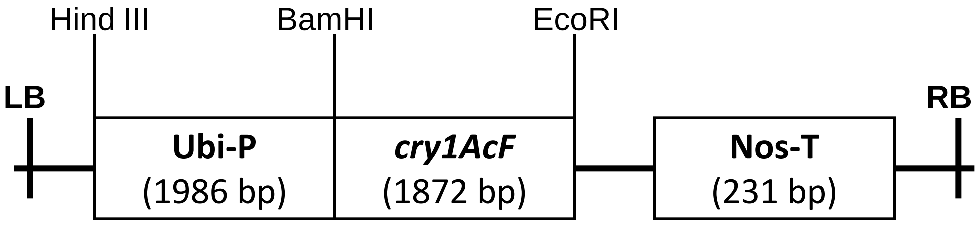
KASP Assay

Sorghum Transgenics for Stem Borer Resistance

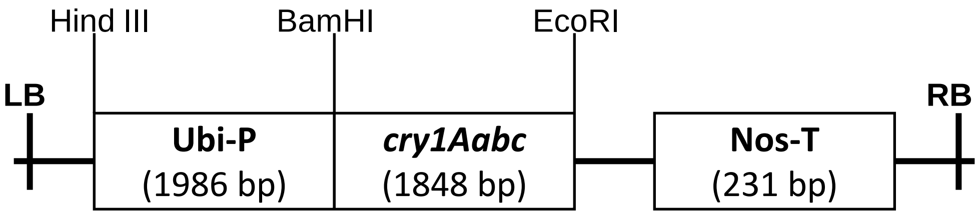
- **Three genes (*cry1AcF*, *cry1Aabc* and *cry2Aa*) received from Dr. Rohini Sreevathsava, ICAR-NRCPB through MTA were cloned individually into pCAMBI0390 binary construct under the control of monocot specific maize ubiquitin promoter.**

3 Gene Constructs

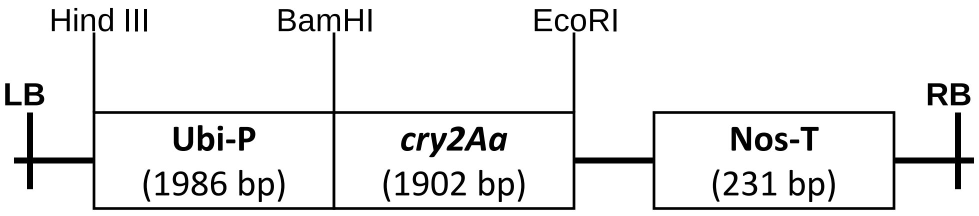
***cry1AcF* gene construct**
pCAMBIA390-Ubi:*cry1AcF*:NosT
(10653 bp)



***cry1Aabc* gene construct**
pCAMBIA390-Ubi:*cry1Aabc*:NosT
(10629 bp)

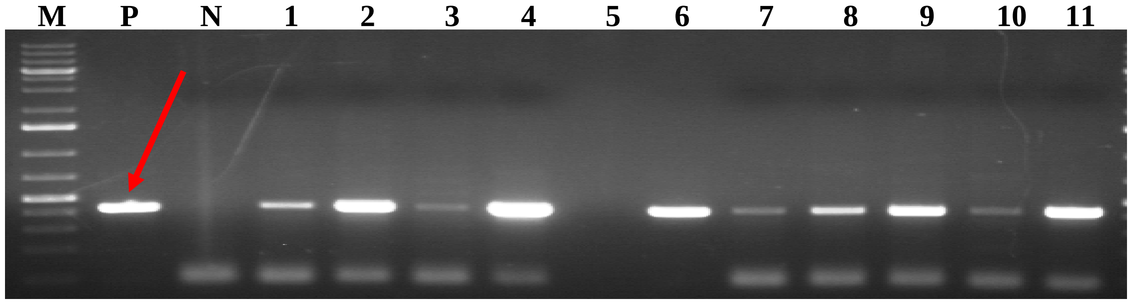


***cry2Aa* gene construct**
pCAMBIA390-Ubi:*cry2Aa*:NosT
(10683 bp)



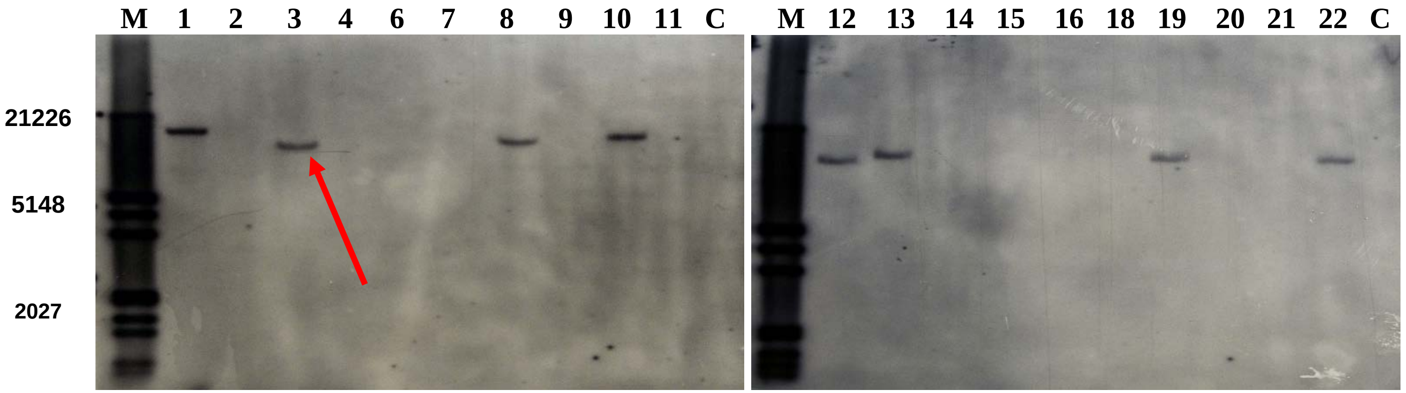
Confirmation of Gene Integration

PCR amplification: **Twenty** out of 22 events showed **412 bp** fragment of ***bar*** gene T_0 generation transgenics of C43 genotype.



M 100 bb DNA ladder, **P** plasmid DNA, **N** DNA from non-transgenic control plant, **1-11** DNA from transgenic plants.

Southern blot analysis: **Eight** out of 20 transgenic events carrying ***bar*** gene showed **single copy insertion** in the sorghum genome in different positions



M DNA molecular weight marker III DIG-Labeled (Roche), **1-22** Transgenic sorghum plant DNA carrying *bar* gene, **C** Non-transformed sorghum plant DNA.

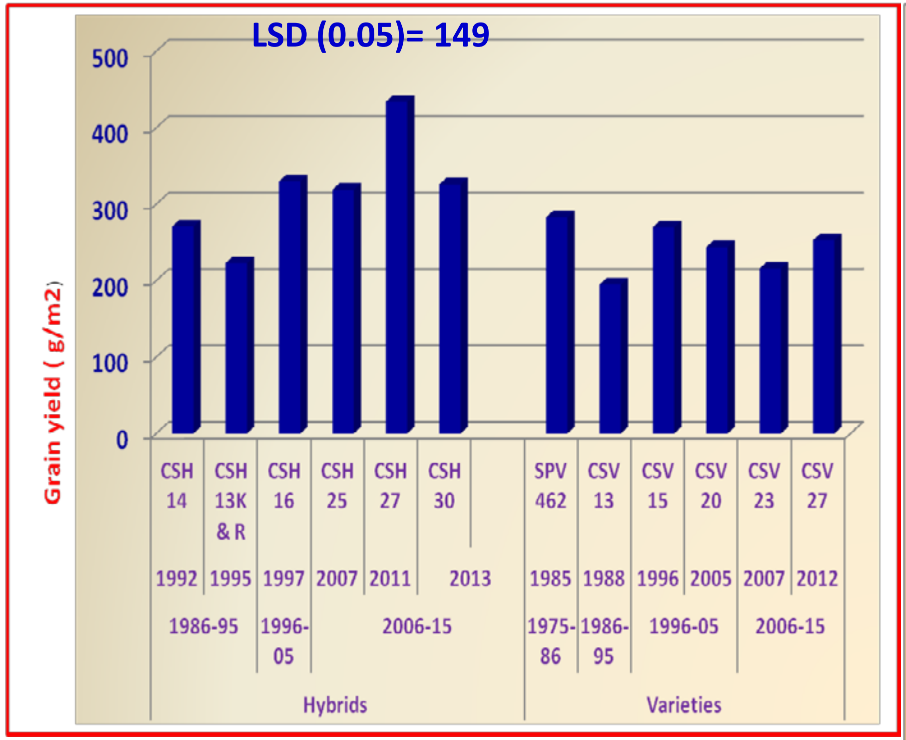
Status of *Bt* transgenic development



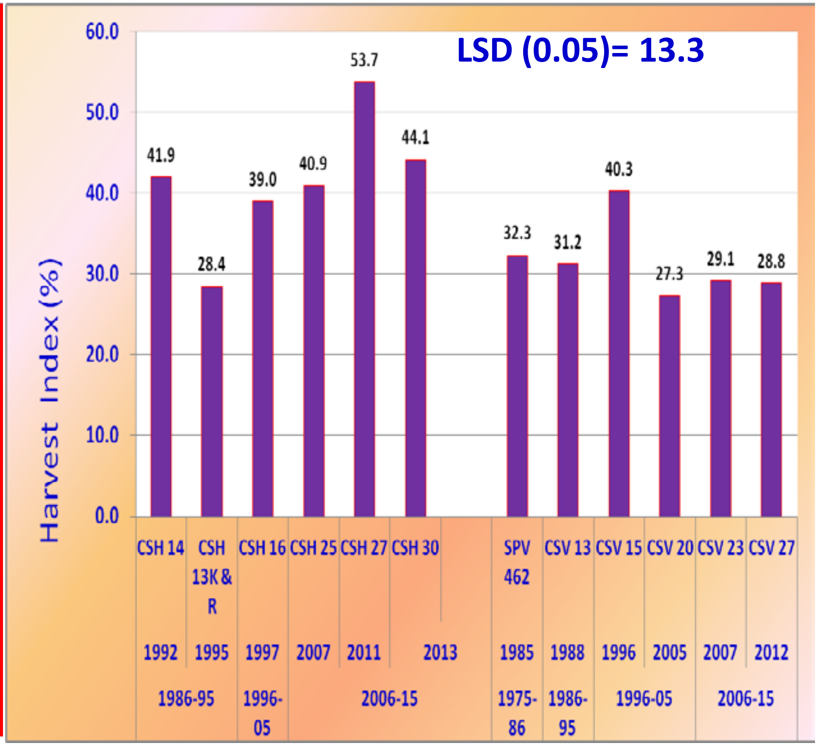

Method	*cry1Aacf*	*cry1Aabc*	*cry2Aa*
Method of genetic transformation	*Agrobacterium LBA4404*	*AgrobacteriumLBA4404*	*Agrobacterium*LBA4404
Variety(ies) used for transformation	SSV84	SSV84	SSV84
No. of explants transformed	400	400	400
No. of independent transformants at T_0	100	66	61

Physiological basis of assessing the genetic progress in yield potential of *kharif* historical releases -contd----

Grain yield

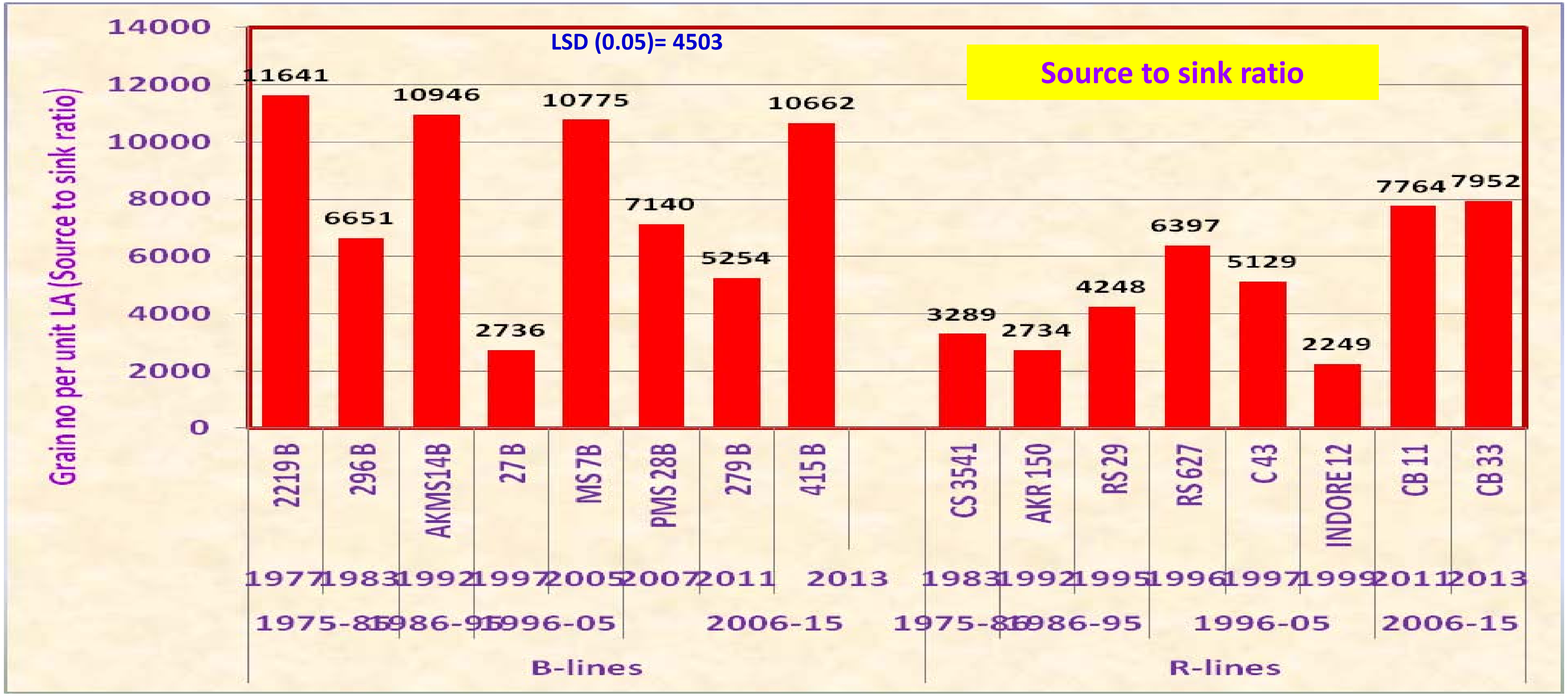


Harvest Index



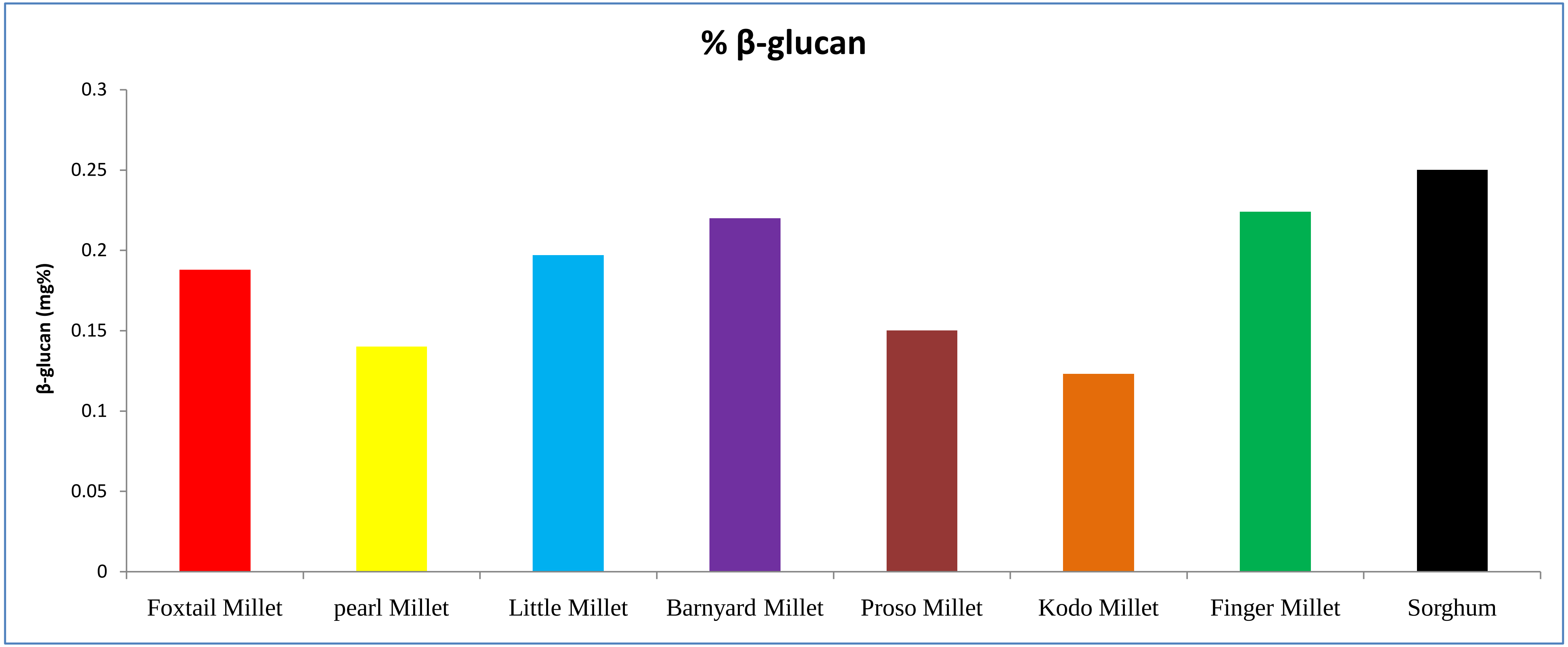
- **Modern hybrids produced higher grain and had greater HI than older ones.**
- **In general, hybrids were superior for grain yield and HI than varieties**

Physiological basis of assessing the genetic progress of kharif sorghum parental lines (old and new) for yield potential



1. In source to sink ratio, B-lines in general were superior to R-lines
2. Older B-lines still continue to maintain superiority

β-Glucan in whole grain of various millets



Reference Standards

Oats - 8 %

Barley - 4%

Summer Sorghum

Cultivar	Grain Yield (t/ha)	Rank	Fodder Yield (t/ha)	Rank
CSH 13	**5.07^{A}**	**1**	**21.23^{BC}**	3
CSH 14	**4.75^{AB}**	**2**	**16.94^{DE}**	6
CSH 16	**4.69^{AB}**	**4**	**16.90^{DE}**	8
CSH 25	**4.70^{AB}**	**3**	**18.00^{D}**	5
CSH 30	**3.07^{C}**	10	**11.98^{F}**	10
CSV 15	**3.98^{ABC}**	8	**16.91^{DE}**	7
CSV 20	**3.99^{ABC}**	7	**13.97^{EF}**	9
CSV 23	**3.68^{BC}**	9	**27.55^{A}**	1
CSV 27	**4.41^{AB}**	**5**	**23.60^{B}**	2
SPV 462	**4.20^{ABC}**	**6**	**19.12^{CD}**	4
p-Value	<.0001		<.0001	
CV (%)	8.6		5.37	
SE(d)	0.259		0.707	
Tukey's HSD at 1%	0.9279		2.5352	

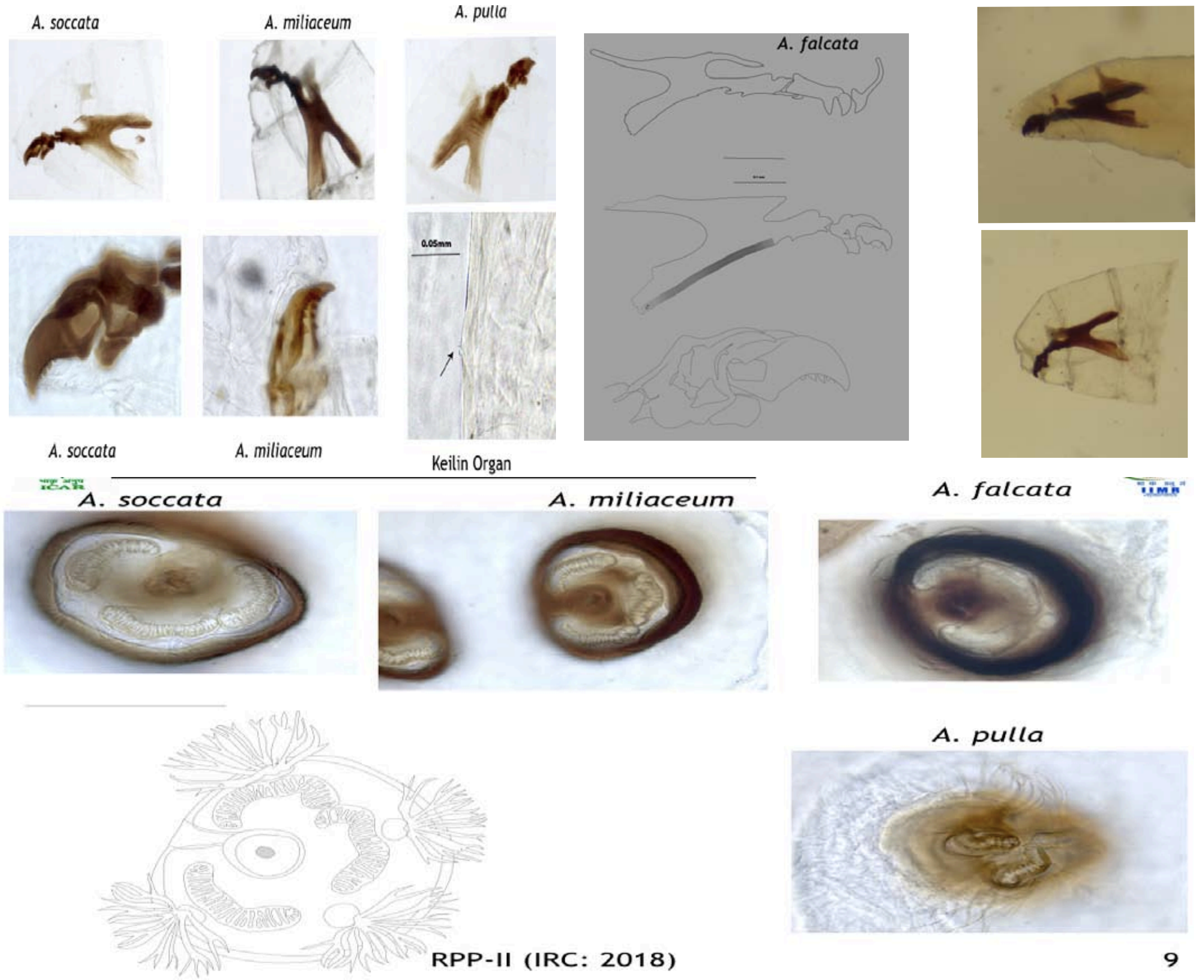
Sorghum under Zero Tillage

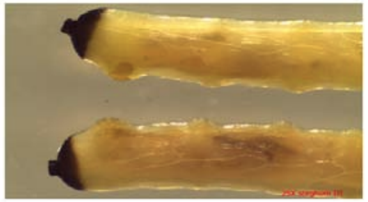
Benefit : Cost Ratio

Particular	Cost (Rs. /ha)
Seed quantity 10 kgs/ha	1125
Seed sowing	5250
Fertilizers' cost + its application	5875
Herbicide cost + its application (Atrazine+ Paraquat)	2000
Pesticides cost + its application	6250
Irrigation water and labour charges	7137
Harvesting	3750
Threshing	6250
Drying / Bagging	1500
Total cost of production	39137
Gross returns* Grain Rs 1650/ quintal	99000
Net returns	59863
Benefit : Cost ratio	2.54

Identification of shoot fly at immature stages: Cephalopharyngeal structural variations

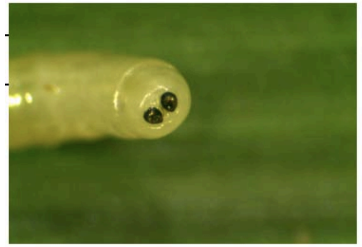
Dentures, size & shape of mouth hook vary with species



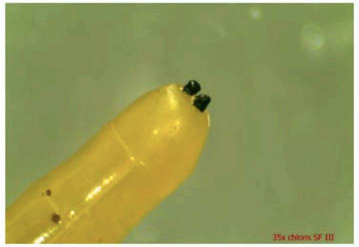


A.soccata III (male, female)

A. soccata II, III



A. punctata III

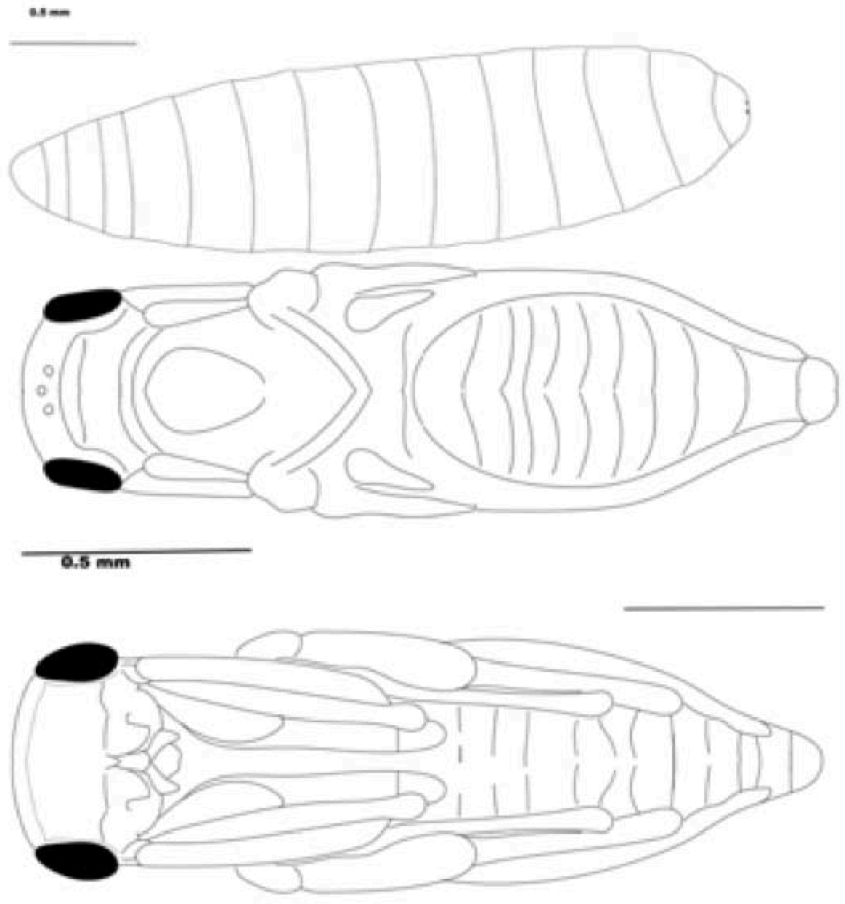


A. miliaceae III

Three species of *Neotrichophoroides* identified and taxonomically described

Neotrichophoroides nyemitawus

Koinobiont endoparasitism (Hymenoptera: Eulophidae: Tetrastichinae)



N. nyemitawus

N. beonus

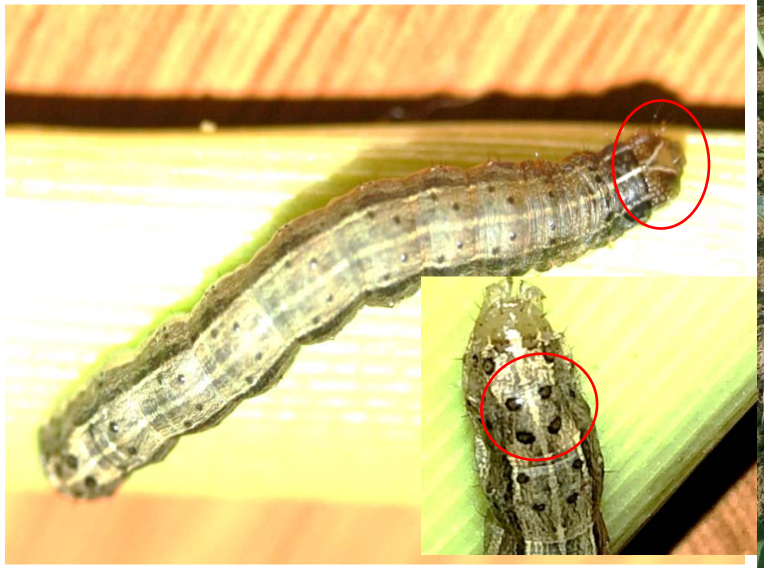
N. viridimaculatus

- All the three species occur abundantly in the field
- Efficiency as biocontrol agents are being studied

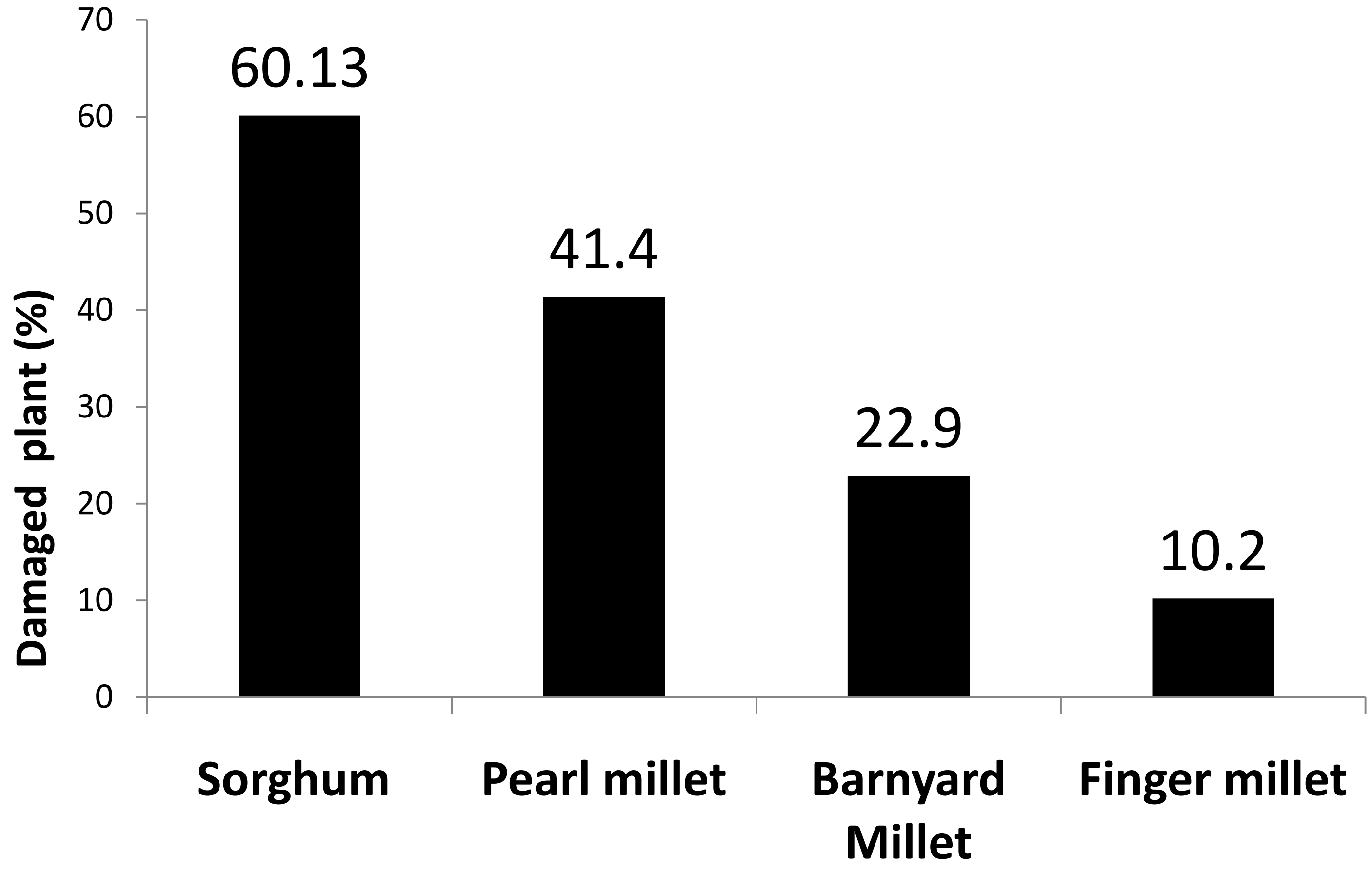
Invasive pest Fall Army worm, *Spodoptera frugiperda*








Incidence of Fall army worm in Millets (Rabi, 2018, IIMR, Hyderabad)



DDG Crop Sciences, ADG PP, Director IIMR
visiting Maize & Sorghum
fields affected by FAW at Mahboobnagar

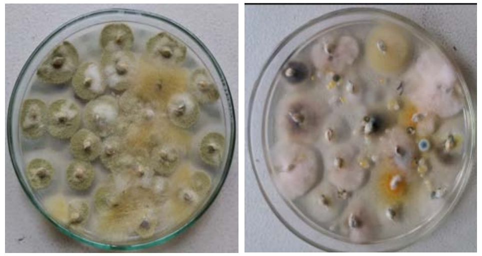
Grain Mold Management

***Trichoderma harzianum* (liquid)** significantly reduced fungal infection and grain mold score

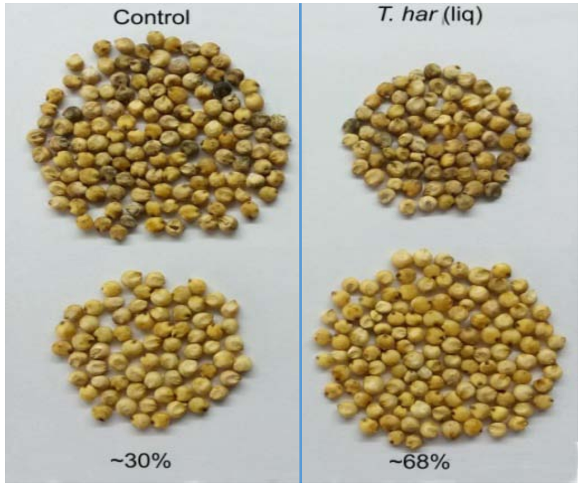
Treatments	Fusarium (%)	Curvularia (%)	TGS (1-9)
T. harzianum (wp)	27(30.9)*	18(25.2)	8.5
***T. harzianum* (liq)**	**23(28.1)**	**35(35.1)**	**4.5**
T. harzianum (pc)	27(30.9)	23(28.2)	6.5
T. viride (wp)	22(27.1)	43(41.2)	8.0
T. viride (liq)	15(22.8)	48(44.0)	5.5
T. viride (pc)	7(14.8)	8(16.6)	6.5
Bio-mix (wp)	17(24.0)	68(55.9)	5.0
Bio-mix (liq)	10(18.4)	35(36.2)	6.0
Control (water)	23(28.8)	35(36.2)	8.0
CD at 5%	(4.5)	(8.1)	0.9
Probability	0.024	0.009	0.018

Re-isolation on 10-th day

CSH25



Treated Control



Charcoal Rot Management

Reduction over untreated control

Seed treatment with *Trichoderma viride* formulation (@8g/Kg seed) → **37.4%**

Drenching with Carbendazim + Mancozeb → **40.6%**

Evaluation of parental lines advanced materials

Six advanced varieties **(SLV-104, SLV-41, SLV-169, SLV-181, SLV-182 and SLV-212** with CRI between 11.6 and 24.3) were **moderately resistant to charcoal rot**.

New charcoal rot rating Index

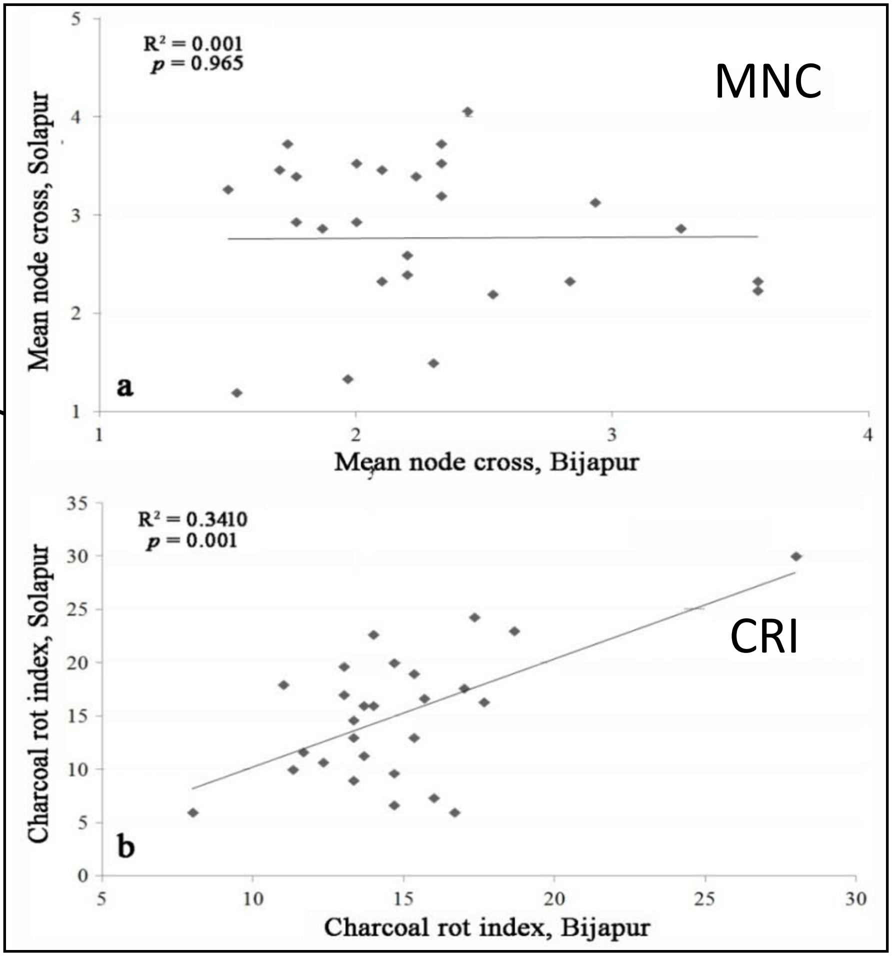
Developed a new charcoal rating index (CRI) for accurate and reliable assessment of charcoal rot resistance in multilocation trials

The Index: CRI = CRP × 0.4 + MLS × 0.6, where CRP= CR %, MLS= mean length of lesion cm

Accuracy

Genotype	MNC (Old scale) Bijapur	MNC (Old scale) Solapur	CRI (New scale) Bijapur	CRI (New scale) Solapur
G1	MR	S	MR	MR
G2	MR	S	MR	MR
G3	MR	S	MR	MR
G4	R	S	MR	MR
G5	R	R	MR	R
G6	S	MR	MR	MR
G7	R	S	MR	MR
G8	R	MR	MR	MR
G9	MR	R	MR	R
G10	MR	MR	MR	MR
G11	MR	MR	MR	MR
G12	R	R	MR	R
CSH 15R	MR	S	MR	MR
CSV 29R	MR	MR	MR	MR
M35-1	S	MR	MR	R
CSV 8R	S	MR	S	S
E36-1	R	HR	R	R

Reliability

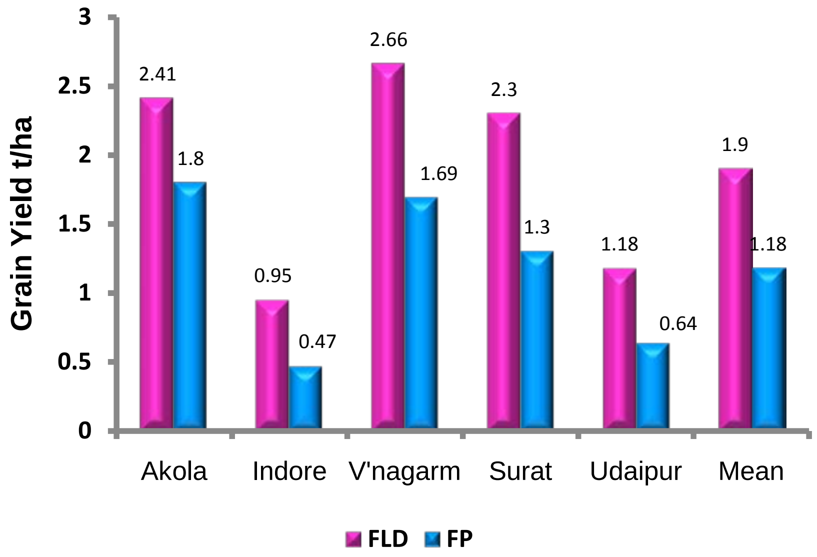


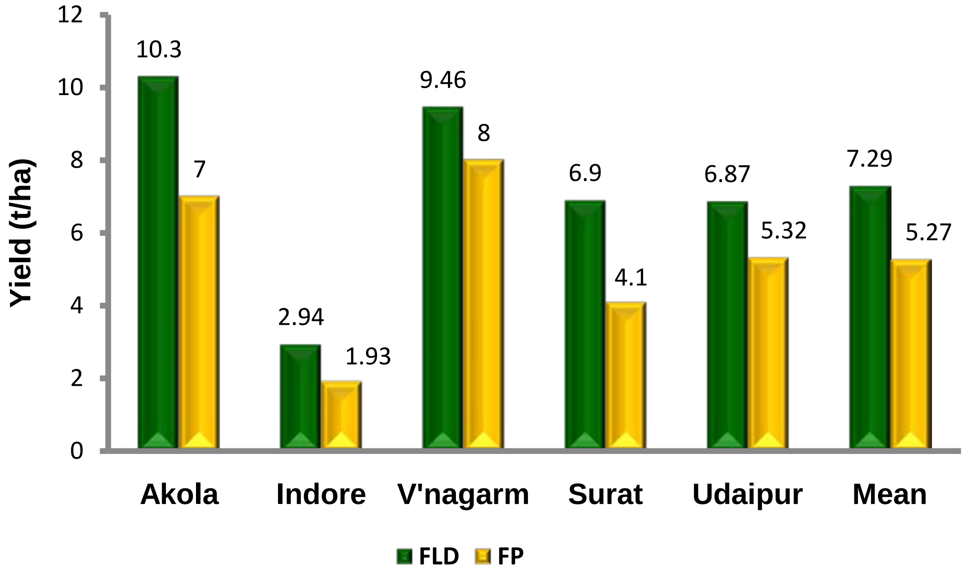
Regression showing repeatability of two scales

Frontline demonstrations on sorghum

FLDs on sorghum	Area (ha)	No. FLDs	Technology demonstrated
***Kharif* season**			
Grain and dual purpose sorghum	90.40	241	CSV 20, PDKV Kalyani, CSH 16, CSV 27, RVJ 1862, CSV 23
Forage sorghum	20.40	67	UTFS 85, UTFSH 2, Pant Chari 5, Pant Chari 6, UTMC 539, UTMC 552, UTMC 554, CSH 20MF, CSH 24MF, HC 136, HC 171, HC 308, HJ 513, HJ 541, SSG 59-3
***Rabi* season**			
Dual purpose sorghum	204.00	436	CSV 29R, CSV 26R, BJV 44, Phule Suchitra, Phule Revati and Parbhani Moti
Forage sorghum	10.00	25	CSV 33MF
Total	**324.80**	**769**	**29**

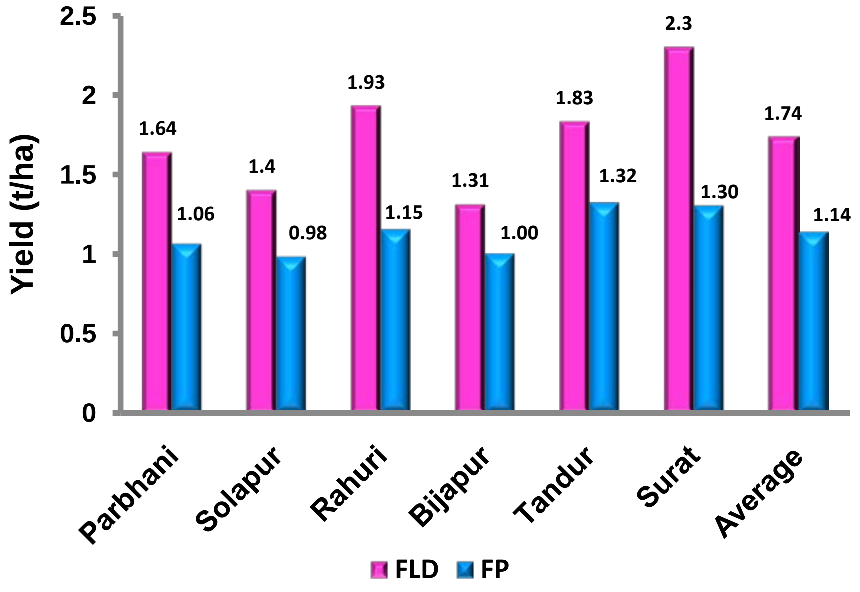
Grain yield and Stover yield in *kharif* FLDs

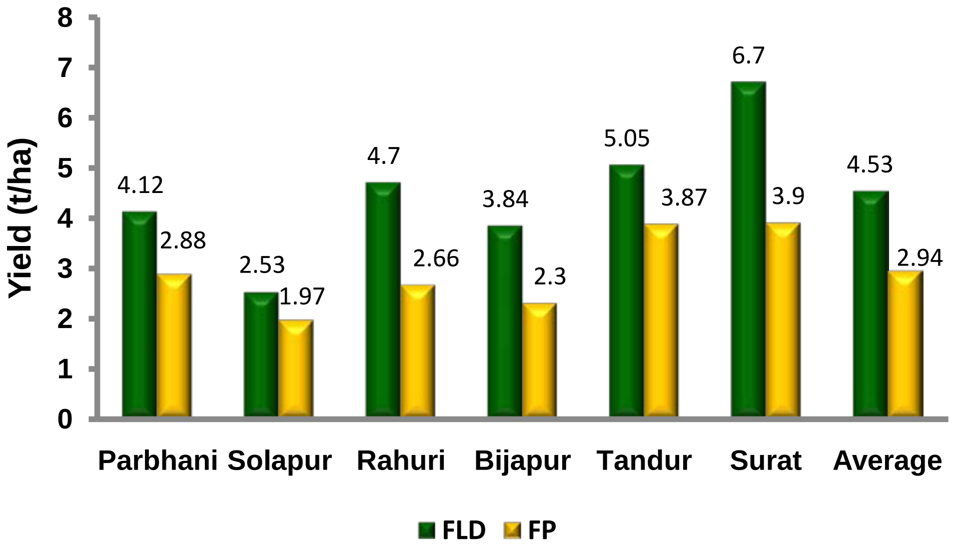




- The demonstrated eight varieties gave **71% higher grain yield** than the local checks which is resulted into **67% higher net returns**
- The demonstrated sorghum varieties gave **43% higher stover yield** than the local checks

Grain yield and Stover yield in *rabi* FLDs





- The demonstrated seven varieties gave <u>55% higher grain yield</u> than the local checks
- The demonstrated sorghum varieties gave <u>52% higher stover yield</u> than the local checks

Economic benefits

FLD Centre	Cost of cultivation (Rs. ha^{-1})	Net return (Rs. ha^{-1})		B:C ratio	
		FLD	LC	FLD	LC
Akola	24565	40511	26550	1.65	1.31
Indore	8450	12680	7152	2.49	1.52
Vizianagaram	16745	28550	16396	2.71	2.16
Surat	26502	46651	23542	1.76	1.29
Udaipur	17570	32968	22913	1.94	1.88
Mean	18766	32272	19311	2.11	1.63

The demonstrated varieties could earn net returns of Rs.32,272/- on the cost of Rs.18,766/- per ha, which is 67% higher than the farmer's practice (LC)

Value addition, Value chains, Entrepreneurship and Policy Development

FPOs KVKs

SAUs

Industry

National Sub-Mission on Millets & National Year of Millets 2018-19

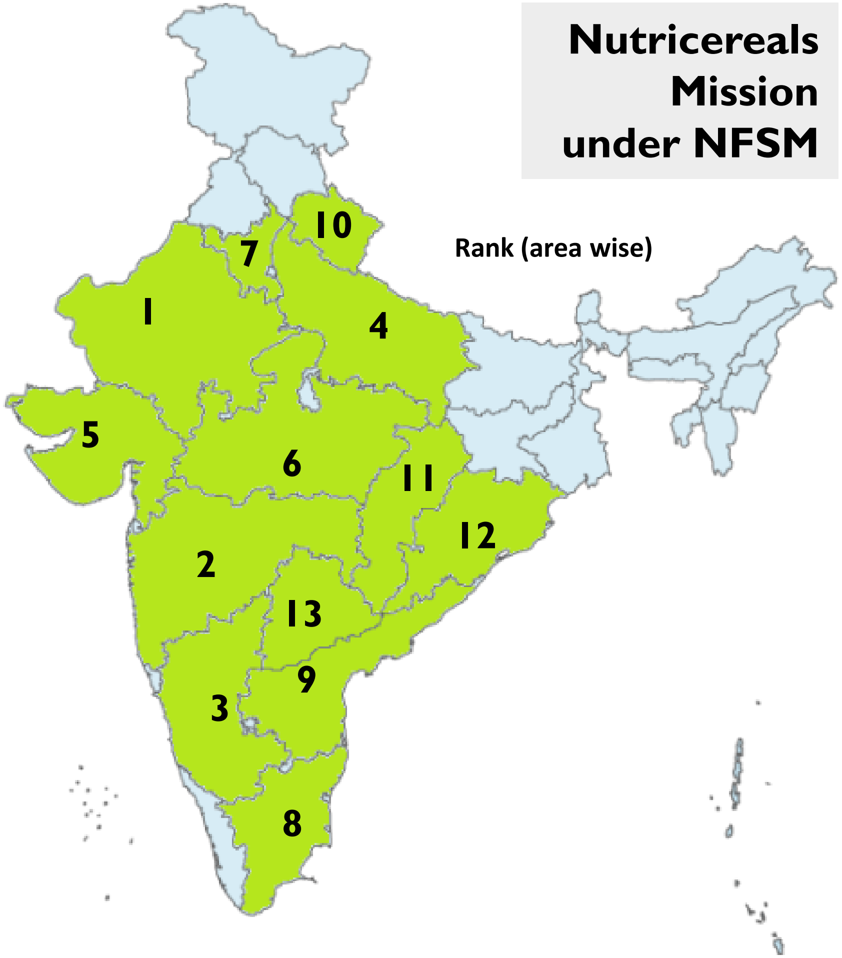
Ensuring Legitimate Place For Millets in Global Food Basket

Policy Push for Millets

- Indian Government declared 2018-19 as National Year of Millets
- Indian government has proposed to UN for declaring a year as “International Year of Millets” Now agreed for 2023
- National mission on millets (nutricereals)- US$ 21m for 5 years(2018-22) initiated; road map in place
- With linking millet farmers to markets and enhanced consumer awareness about health benefits, increase in millets crop area and utilization contemplated;
- With the government, industry and farmers taking a fresh look at promoting millets, there is a great momentum

States Included under NFSM Nutricereals

State/UT	Total Area
Rajasthan	4948.25
Maharashtra	4160.60
Karnataka	2093.20
Uttar Pradesh	1107.20
Gujarat	775.60
Madhya Pradesh	687.24
Haryana	488.20
Tamilnadu	458.55
Andhra Pradesh	337.38
Uttarakhand	183.06
Chhattisgarh	135.58
Orissa	83.25
Telangana	35.20



- Total 13 States (1st Year), 193 districts and 1600 clusters identified
- Traditional Millet Producing States with over 30000 ha area under millet cultivation
- Other states can be recommended for inclusion for next year program under NFSM
- A total of 21 states + Non traditional states with malnutrition

PROMOTION OF NUTRICEREALS

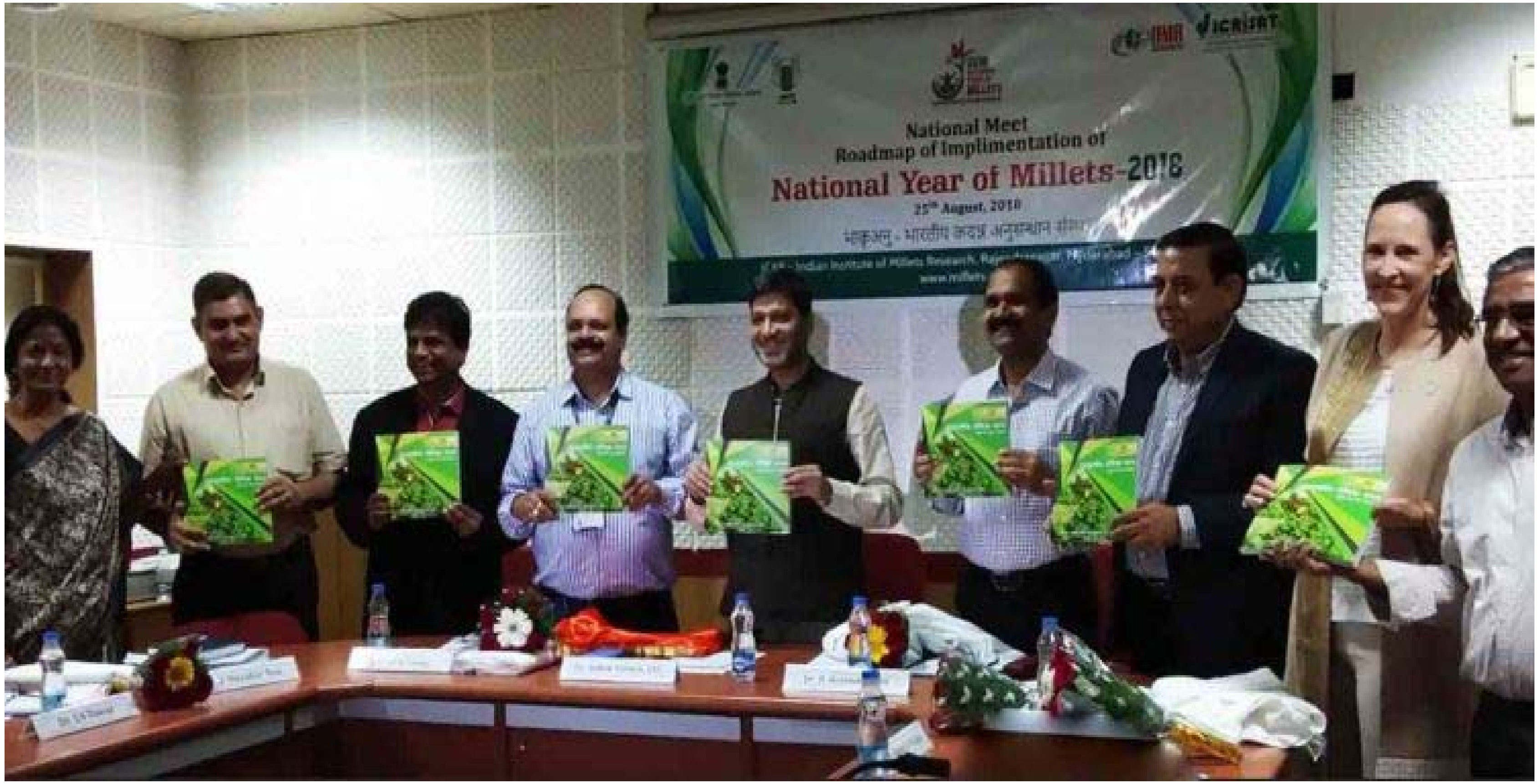
- Production
- Farmgate Processing
- Value chains
- Market Linkage
- Supply chains
- Value addition
- Enhancing Farmers income
- Awareness programs
- Millets for Export

Nutri cereals Conclave 2018

- **Organized Nutri cereal conclave 2018 at Hyderabad, to provide a platform for start-ups to witness business opportunities technologies and investment potential in the area of nu- tricereals (millets).**

Promotion of Millets

International Millet Trade Fair, Bangalore (Jan, 2018)



National Meet on Road map on Celebration of National year of Nutricereals [15-Aug 2018]

IIMR INCUBATEES @ RASHTRAPATHI BHAVAN

Two IIMR startups M/s Fountain foods, and M/s Inner being) at Festival of innovation and entrepreneurship at Rastrapathi Bhavan, New Delhi.

National Level Workshop on Nutricereals (Sep 2018)

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National Level Workshop on Nutricereals (Sep 2018)

MoU with Odisha Government (November, 2018)

Accelerating End of Malnutrition and Zero Hunger
Bangkok – Global Event – FAO, IFPRI (Dec, 2018)

Agri Business Incubation & Zonal Technology Management Centers

1. To facilitate technology commercialization & undertake last mile scale-up from pilot level of value chain in collaboration with stakeholders
2. To promote base for entrepreneurship in value added millet technologies
3. To undertake capacity building to prospective entrepreneurs, consultancies & promote or facilitate agri-business development.
4. To explore, develop & adopt value added technologies including grassroots innovation

MoU for Technology transfer/consultancy

1. M/s Milletify, Bangalore
2. M/S VisishtaTej Industries (p) Ltd. Hyderabad
3. M/s. RICH foundation, Hyderbad
4. M/s Indira-craft Foods Pvt Ltd, Hyderabad
5. M/s Nandini Pickles, KIADB Auto Nagar, Naubad, Bidar
6. M/s. Sresta Organics- Hyderabad (TS)
7. M/s. My Green Mart- Bengaluru (KA)
8. M/s. Ganaay Millets Pvt Ltd- Vijayawada (AP)
9. M/s. Rich Millets- Hyderabad (TS) and
10. M/s. Boinpallys Agro Food Products Private Limited -Hyderabad (TS)
11. M/s Borne Technologies Pvt. Ltd, Dindigul for collaborative refinement of machinery and capacity building.
12. Dr. MS Ramaiah medical college, Bngaluru and ICAR-IIMR for sharing research programme on value added technologies of millets.

Other Value added Millet Technologies – Offered for technology licensing

All Millet Flakes

- Proso millet flakes
- Barn yard millet flakes
- Pearl millet flakes
- Finger millet flakes
- Sorghum flakes
- Little millet flakes
- Foxtail millet flakes
- Kodo millet flakes

Other Products Technologies in Pipeline

Sorghum Pizza Base

Sorghum Noodles

Sorghum based energy Bars

Sorghum Khakra

Branding

eatrite™

Eat Jowar – Stay Healthy

Indian Institute of Millets Research Brand

Product Development

Packaging & Labelling

eatrite™

Eat Jowar - Stay Healthy

Millet extruded products

- **Extruded Snacks/Flakes** are prepared using millet based formulation
- Extruded through twin screw hot extruder using various die.

Advantages and Uniqueness of technology/Product

- Utility as evening snacks, breakfast cereals and inflight snacks.
- They are rich in **protein, fibre, iron, zinc and magnesium**.
- The shelf life of the product was 6 months
- Variants available masala coated and essence based

Millet bakery products

- **Millet Cookies/bread and cake** are popular ready-to-eat products
- **Millet cookies/ cake** is prepared using 100% millet flour blended with other ingredients and **bread** is prepared by replacing 50% wheat with millet flour.

Ragi cookies

Advantages and Uniqueness of technology/Product

- Utility as breakfast food
- Pure Millet biscuits are fibre rich and beneficial for all age groups.
- It is rich in **magnesium, zinc, iron, dietary fibre and protein.**

Millet Cookies

Millet Bread

Millet Cake

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Entrepreneurship training & Capacity building

1. Trainings
2. Capacity building measures
3. Demonstrations
4. Hands on experience
5. Entered MoU for technology
6. Licensing

Clientele:

Rural women- 2200
Urban entrepreneurs-300
SHG's -3300
Farmers-6000

Topics:

- Primary food processing
- Secondary food processing
- Retrofitting of machinery
- Handling on operations
- Recipe making
- Packing & Nutritional labelling
- Marketing & Creation of awareness
- Trouble shooting

Number of trainings:

- INSIMP -16 trainings, **NFSM – 7 Trainings** (upto March 2016) for 1500 stake holders from AP, Karnataka, Tamilnadu and Maharashtra
- Exposure visits >1000 nos

Locations:

In house at IIMR

Other locations

Parbhani, Adilabad, Mahabubnagar, Solapur & Nanded

other locations

Agri Business Incubation

A selective, comprehensive service offering that aims to accelerate the growth of SMEs

Services		Value to the Entrepreneur
Business Services:	*Registration, licenses, QM, technology transfer, accounting, strategy, marketing, export/import, etc.*	Accelerates business development activities, saves time and money
Financing:	*Brokering financial services and/or providing them i.e. equity, credit, guarantees, etc.*	Leveraging the credibility of the incubator & the portfolio of entrepreneurs to overcome financing gaps
"Networking and capacity building"	*Mentoring, coaching and networking with fellow entrepreneurs (a micro cluster), market linkages*	Learning, exchange of ideas, partnerships, business relationships etc.
Infrastructure:	*Lab and production facilities, Office space, meeting rooms, electricity, phone, Internet, etc.*	Economies of scale decreases the cost of starting a business

Success story IIMR partnership with Industry and other stakeholders

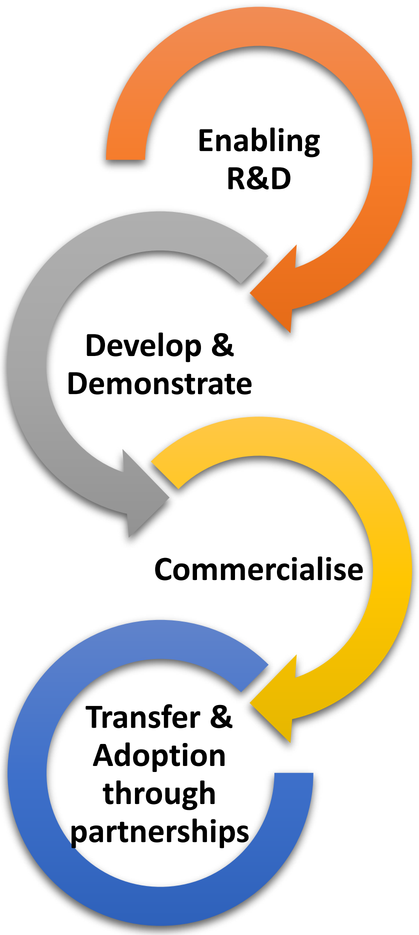
Partnership with stakeholders and industries has lead to :

More than Rs 100 Cr business

With more than 300 start ups engaged

+ Bigger Private players

- Created demand for sorghum through diversification in sorghum/millet food processing technologies and their commercialization.
- Creating awareness among the urban and rural households on value added RTE products of sorghum/millet.
- Many entrepreneurs to take up sorghum/millet processing.
- Ensuring sustainability and availability of sorghum products in the markets.
- Increasing employment potential in the rural economy



IIMR partnership with Industry

Turn over and revenue of IIMR's physical and virtual incubates

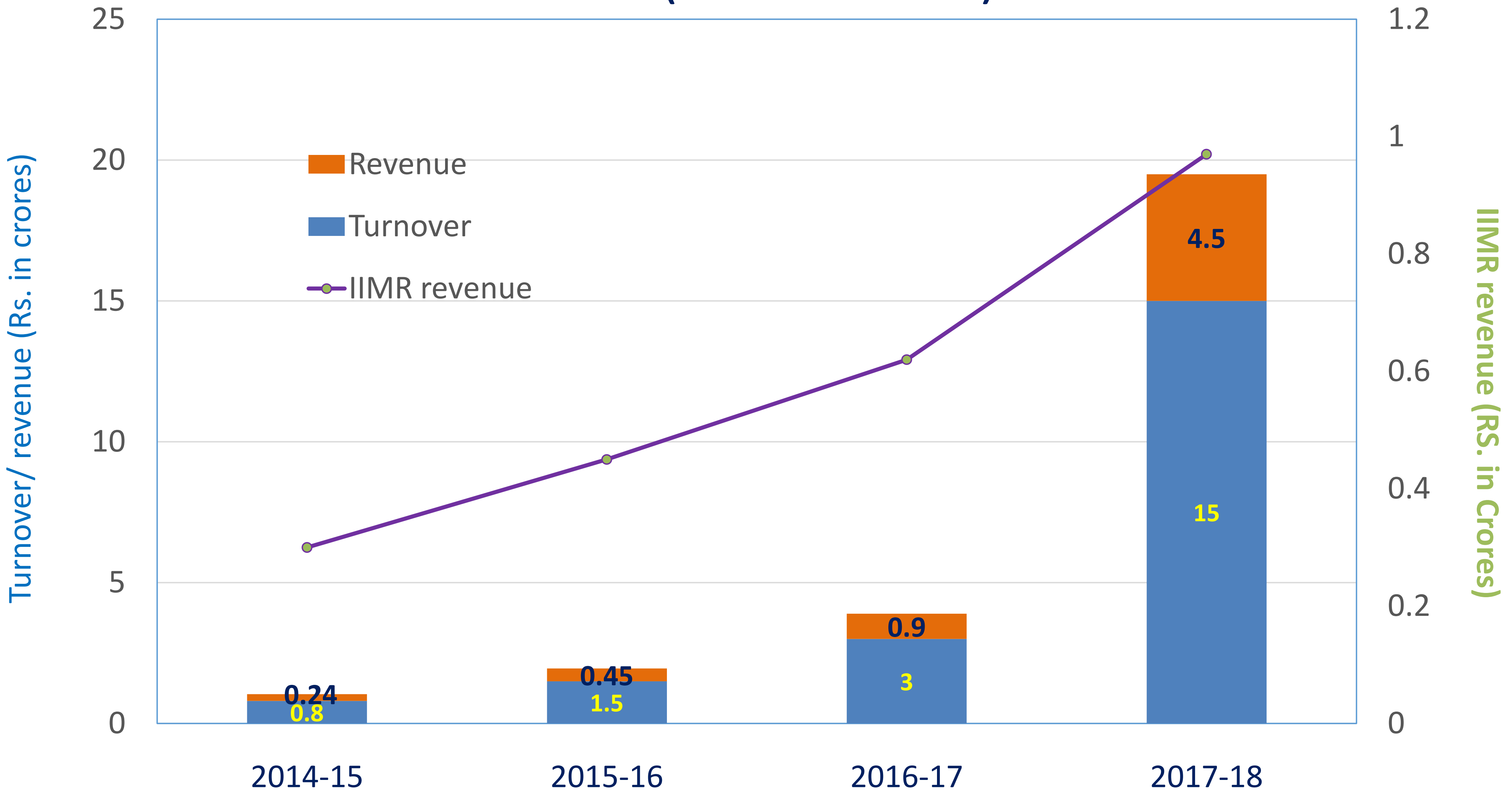
(Rs. in Crores)

ICAR-Indian Institute of Millets Research					
Year Wise	Startups Turnover in Cr		Startups revenue in Cr		IIMR Revenue in Cr
	Physical Incubatees	Virtual Incubatees	Physical Incubatees	Virtual Incubatees	Commercialization *
2014-15	_	0.8Cr	–	0.24Cr	0.3Cr
2015-16	_	1.5Cr	–	0.45Cr	0.45Cr
2016-17	_	3.0Cr	–	0.90Cr	0.62Cr
2017-18	7.0Cr	15.0Cr	2.1 Cr	4.50Cr	0.97Cr

*Through Technology licensing and Supporting Agribusiness Incubation

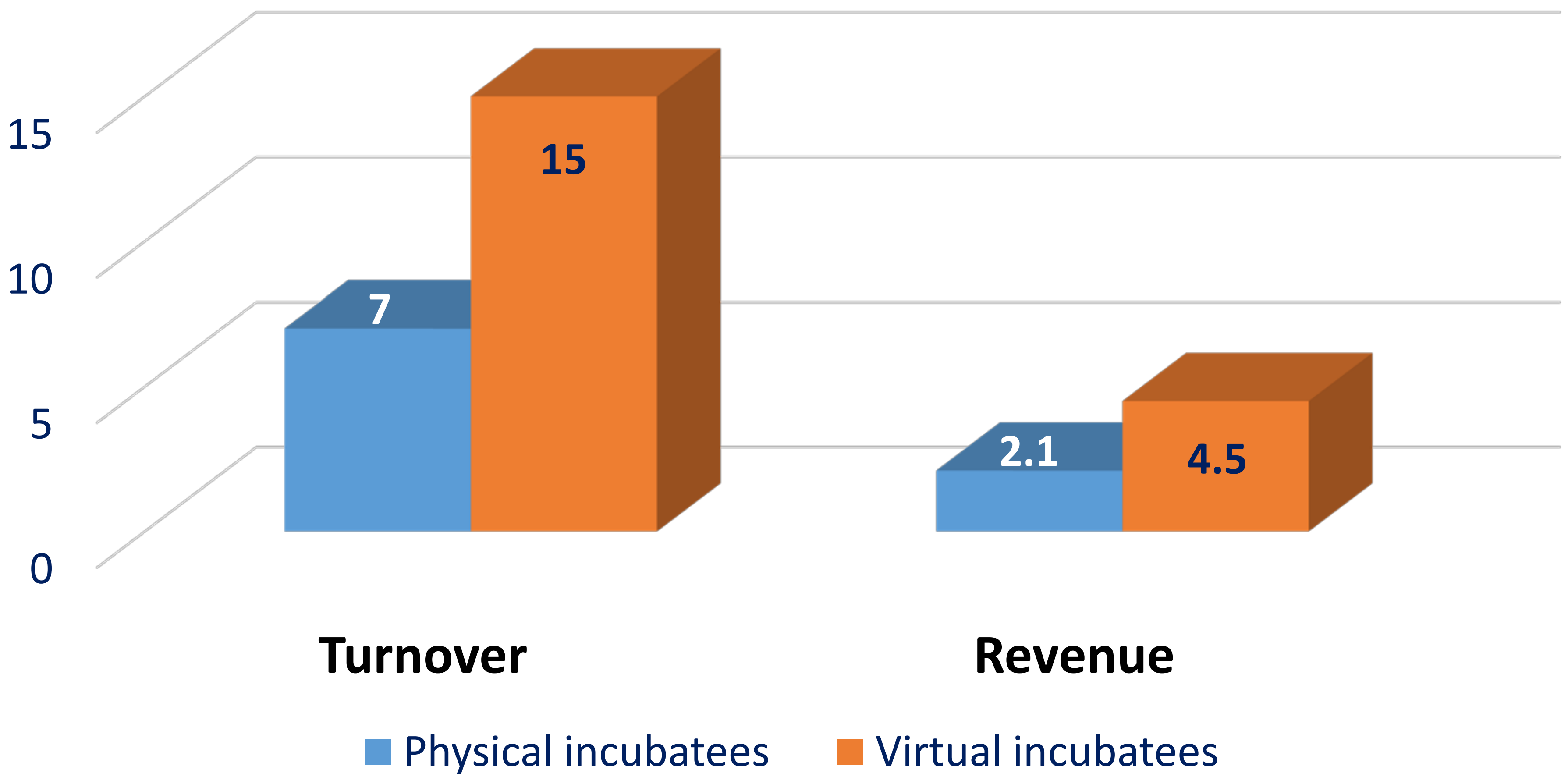
Startup's (Virtual incubates) Turn over and revenue of ICAR-IIMR (2014-18)

(Rs. in Crores)



Turn over and revenue of IIMR's Physical and Virtual incubates (2017-18)

(Rs. in Crores)



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GOLDEN JUBILEE OF SORGHUM RESEARCH

50
YEARS

AICRP on Sorghum

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2018
NATIONAL
YEAR OF
MILLETS
Nutricereals For Nutritional Security

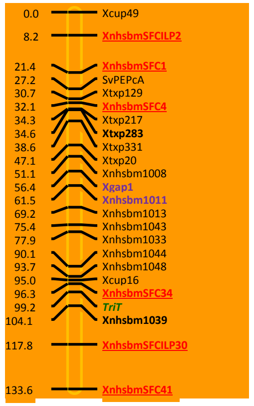
2023
International Year
of Millets






SORGHUM: For Food, Feed, Fodder, Fuel and Health



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Thanks