

Sorghum pathology: Kharif 2016

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Executive summary

Pathology programme for the year 2016-17 consisted of applied as well as basic research components. Applied research dealt with multi-location testing of breeding materials for resistance against sorghum diseases at hot spot locations. A total 188 sorghum lines consisting of grain, forage and sweet sorghum entries were evaluated against panicle and foliar and systemic diseases in endemic areas (Coimbatore, Akola, Parbhani, Surat, Pantnagar and Ludhiana) spread over three sorghum growing zones. Basic and strategic research focused mainly grain mold, anthracnose and pokkah boeng.

Disease situations: Among panicle diseases grain mold was predominant in Telangana, Tamil Nadu, parts of Maharashtra and Gujarat. Sugary disease (ergot) was observed in Gujarat. Downy mildew in low to moderate form was noted in peninsular region. Among foliar diseases anthracnose, zonate leaf spot appeared in moderate to severe form in Pantnagar and Ludhiana on forage sorghum. Leaf blight, recorded in Coimbatore, and sporadically in Marathwada region of Maharashtra. Sporadic incidence of sooty stripe, rough, target and grey leaf spots was also noted in Parbhani and Akola, region. Location severity index (LSI) for various diseases indicated that materials under evaluation exhibited presence of some degree of resistance against diseases.

Grain mold: Location severity index for grain mold assessed over all the trials in the location indicated that grain mold pressure was moderate at Akola, Parbhani, Surat and Coimbatore. Grain mold severity ranged from 3.7 to 4.3 with mean 4.0 in grain sorghum (AHT, AVT, IHT and IVT), and 2.1 to 4.0 with mean 3.9 in sweet sorghum (IAVHT-SS). Among the advanced grain sorghum hybrids SPH 1813, SPH 1817, SPH 1779 and SPH1789 and among the varieties SPV2296, SPV 2307, SPV 2363 and SPV 2366 were moderately resistant to grain mold. Most promising entries in initial grain sorghum hybrid were SPH 1848, SPH 1852 and SPH 1853 and varieties were SPV 2427, SPV 2431 and SPV 2435. Promising sweet sorghum entries for grain mold resistance were SPH1798, SPH 1859 and SPV 2458.

Downy mildew: One hundred and seventeen grain and forage sorghum entries consisting of seven trials (AHT, AVT, IHT, IVT, IAVHT-MC, AVHT-SC and IVHT-SC) were evaluated for downy mildew resistance in sick-plot at Coimbatore. Location severity index showed that downy mildew was severe in sick-plot (Loc. mean all trial 20.5%) indicating inherent susceptible nature of the materials under optimum disease conditions. In non-sick plot incidence was low and sporadic. In Central and Northern India there was no report of downy mildew incidence. Among grain sorghum entries the advanced hybrid SPH 1813, the advanced variety SPV 2364 and the initial hybrids SPH 1847 and SPH 1848 were promising for downy mildew resistance ($\leq 10\%$). Forage sorghum entries SPH 1770 and SPH 1844 (IAVHT multi-cut), SPV 2383 (AVHT single cut) and SPH 1856, SPV 2443 and SPV 2452 (IVHT single cut) were promising for downy mildew resistance.

Sugary disease/ Ergot: Moderate incidence of sugary disease was recorded from Surat but not from any other locations. Incidence was highly sporadic and no significant differences were observed among the entries.

Foliar diseases: Forage and grain sorghum entries consisting of advanced and initial experimental hybrids and varieties were evaluated for resistance to foliar diseases in hot spot locations under natural conditions in Coimbatore, Pantnagar, Ludhiana and Surat. Anthracnose, zonate leaf spot and leaf blight were major foliar diseases during kharif 2016. Location severity index showed that anthracnose severity was moderate to high at Pantnagar, Ludhiana and Surat and low and sporadic in other locations. Zonate leaf spot was moderate at Pantnagar. Leaf blight appeared in moderate form at Surat. Other foliar diseases like rough, gray leaf spot and sooty stripe were recorded as low incidence sporadically in a few locations. Most promising entries for foliar disease resistance were as

follows: Forage hybrid- SPH 1806, SPH 1838, SPH 1841, SPH 1842, SPH 1857; varieties- SPV 2452, SPV 2383, SPV 2445, SPV 2448; sweet sorghum hybrid- SPH1859 and SPH1862; and varieties SPV2324 and SPV 2459; and grain sorghum hybrid- SPH 1778, SPH 1855, SPH 1847 and SPH 1849; varieties- SPV 2357, SPV 2370, SPV 2293 and SPV 2427.

Multiple resistances: In grain sorghum combined resistance against grain mold and downy mildew, grain mold and ergot and grain mold and foliar diseases are important for different growing regions. Grain sorghum hybrids SPH 1318 and SPH 1848 and variety SPV 2363 had moderately resistant to grain mold and downy mildew. Grain hybrids SPH 1813, SPH 1817, SPH 1848 and SPH 1853 and varieties SPV 2296, SPV 2307, SPV 2363 and SPV 2427 had combined resistant to grain mold and leaf diseases. Sweet sorghum hybrid SPH1798, SPH 1859 showed combined resistant to grain mold and leaf diseases. For forage varieties leaf disease resistance is of utmost importance. Multi-cut forage hybrid SPH 1838, SPH 1841 and SPH 1842 had combined resistant to anthracnose and zonate leaf spot and SPH 1806 had combined resistance to anthracnose and leaf blight. Single-cut variety SPV 2452 and hybrid SPH 1857 showed resistance to anthracnose and zonate leaf spot. Forage hybrids SPH 1844 and SPH 1856 and variety SPV 2452 showed combined resistance to downy mildew and foliar diseases and would be important for peninsular India.

Pokkah boeng: Pokkah boeng or twisted top disease was observed in Marathwada region of Maharashtra. Incidence varied from 2 to 10% sporadically on some entries in the research plot and also observed in farmers field.

Grain mold nursery: based on two years pooled analysis the entry GMN 14-6 (2.7) and RMP 42 (3.1) performed superior to other entries and were at par with the resistant check B58586 (2.6) for panicle grain mold resistance. Few other improved sorghum lines namely AKGMR111, GMN14-9 and GMN15-1 and germplasm lines IS20956, IS21425 and IS21645 also had improved grain mold resistance that were at par with the variety CSV 27 (3.8) and CSH 25 (3.9). AKGMR111 had grain mold resistance (4.0) combine with bold grain (2.9 g /100) and might be important as mold resistant variety. All these test entries were medium in duration (range 69 to 75 days) (except IS20956, which was late type 80 days).

Anthracnose nursery: Nineteen entries were evaluated at Pantnagar for identification of new sources of anthracnose resistance. Disease pressure was moderate to severe and none of the test entries were resistant. Sixteen entries (AKSV380, AKSV382, AKSV386, RSSH18, RSSH50, RSSV397, IS10302, IS20956, IS23521, IS23586, IS4731, CSB12012, ICSB12019, ICSB12021, ICSB467 and ICSB474) were moderately resistant to the disease.

Publications and recognitions: The AICRP-Sorghum Pathology group was involved in publishing 22 different publications including 9 journal papers, 1 book, 4 book chapters, 4 popular articles, 1 information bulletin and two conference papers during 2016-17. Scientists from different centres participated in regional and national symposia. Dr. SN Chattannavar received best poster award in IPS South Zone meet and acted as examiner for Ph D Thesis.

Detailed report

I. Disease situations

Kharif sorghum is usually grown for grain, forage as well as sweet stalks in different parts of India that are mainly located in the states of peninsular India (Tamil Nadu, Karnataka & Telangana), Central and Western India (Maharashtra, Parts of Gujarat Madhya Pradesh and Rajasthan) and in parts of North India (Uttarakhand, Uttar Pradesh, Haryana and Punjab). Type of sorghum diseases and their severity differ based on the type of sorghum grown. Report of the survey conducted on disease incidence in farmers' fields and in research plots at different sorghum growing regions in the country is as given below.

(A) Peninsular India

Tamil Nadu: Major diseases observed in this region were grain mold and downy mildew. Apart from these, minor incidence of leaf blight was noted. Anthracnose was not reported this year from this region. Grain mold low to moderate and severity grade varied from 2.0 to 6.0 with mean 3.7 (1-9 scale). Downy mildew incidence was low and sporadic in farmers' field. In research plot (sick soil) incidence was moderate to severe and ranged from 4 to 60% on different sorghum. Occurrence of less rain during the late stage of the crop growth caused lower grain mold infection. **Karnataka:** Because of humid weather the peninsular region attracts almost all the foliar and panicle diseases including grain mold, downy mildew, rust and leaf spot diseases on kharif sorghum. Among the foliar diseases, the rust and leaf spots were noted. **Telangana:** Grain mold was common in this region and incidence was moderate to severe (5.0 to 9.0 on a 1-9 scale) in these areas because of high rainfall during this season. There was severe incidence of grain mold in the experimental trials. Incidence of foliar diseases viz., leaf blight, anthracnose and rust was low in local varieties. Sporadic incidence of bacterial soft rot caused by *Erwinia chrysanthemi*, and pokkah boeng caused by *Fusarium subglutinans* were noted on few entries in the experimental plot.

(B) Central & Western States

Maharashtra: In Maharashtra disease incidence on grain sorghum was low to moderate. In Vidarbha region including Akola, Buldana, Amravathi, and Wasim district low to moderate incidence of grain mold (3.0 to 5.2) was observed on local and improved cultivars in farmers' field. Among the foliar diseases leaf blight and sooty stripe appeared on some cultivars in low to moderate severity (3.0 to 5.0). Moderate incidence of leaf blight (3.8) was observed on sweet sorghum. In Marathwada region grain mold was low to moderate (Parbhani 3.0 to 5.0, Latur 3.0 to 4.0). Foliar diseases like anthracnose, zonate, gray and rough leaf spots were low and sporadic in nature (2.0 to 4.0) on many local varieties and hybrids in Parbhani and Latur districts. Low to moderate incidence of pokkah boeng was recorded in farmers as well as research fields. **Gujarat:** Disease incidence in the different sorghum growing areas of the state indicated that the grain mold (3.9), sugary disease, anthracnose and leaf blight were more or less common (~4.0) diseases in this region. In south Gujarat, grain mold and sugary disease were observed in moderate form on farmers' field. Under experimental conditions also these diseases appeared in moderate form. **Rajasthan:** Forage as well as dual purpose sorghum is grown in this area. Low to moderate infection of anthracnose, zonate leaf spot, gray leaf spot are observed on local land races of sorghum cultivars.

(C) Northern States

Punjab: The region is known for sorghum as forage crop and presence of high humidity attracts many foliar diseases on this crop. During kharif 2016 major leaf diseases observed were anthracnose, zonate leaf spot and grey leaf spot. Dominating leaf spot disease was anthracnose caused by *Colletotrichum* spp. Grey leaf spot caused by *Cercospora sorghi* and zonate leaf spot were observed in moderate to severe form. **Uttarakhand:** Disease situation was surveyed on several places in farmers' field in the districts of Dehradun, Nainital, US Nagar and Hardwar districts on improved and local cultivars, which are mostly grown for forage purpose. Anthracnose and zonate leaf spot were two major diseases in this region. Severity of these diseases was more on local (6.0 to 8.0) than improved cultivars (4.0 to 6.0). These two diseases along with target leaf spot occurred in moderate to severe intensity (grade 6 – 8.0) in almost all the genotypes grown in farmers' field.

In brief, among panicle diseases grain mold was predominant in Telangana, Tamil Nadu and Gujarat. Sugary disease (ergot) was observed in Gujarat. Downy mildew in low to moderate form was noted in peninsular region. Among foliar diseases anthracnose, zonate leaf spot appeared in moderate to severe form in Pantnagar, and Ludhiana on forage. Leaf blight, recorded in Coimbatore, and sporadically in Marathwada region of Maharashtra. Sporadic incidence of sooty stripe, rough, target and grey leaf spots was also noted in Parbhani and Akola, region. Location severity index (LSI) for various diseases indicated that materials under evaluation exhibited presence of some degree of resistance against diseases.

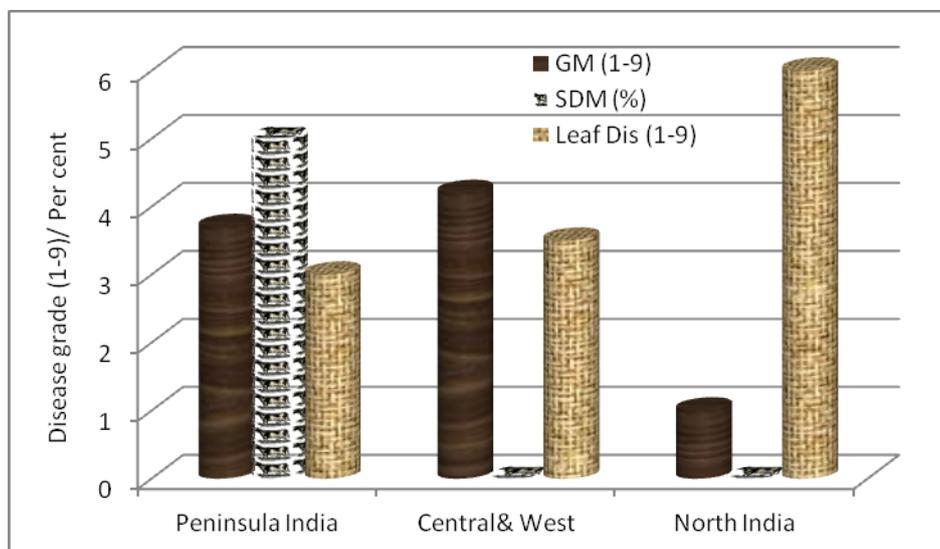


Table S1: Summaries of disease situation in sorghum growing states

States	Grain mold	Downy mildew	Sugary Disease	Leaf diseases	Dominant leaf diseases
Tamil Nadu	Low-moderate	Low	nr	Low	Leaf blight
Telangana	Severe	Traces	Traces	Moderate	Anthracnose & Leaf blight
Maharashtra	Low-moderate	nr	nr	Low-moderate	Leaf blight, Sooty stripe, Gray LS, Anthracnose, Zonate, Pokkah boeng
Gujarat	Low-moderate	nr	Moderate	Low-moderate	Anthracnose & Leaf blight
Uttarakhand	nr	nr	nr	Moderate-severe	Anthracnose & Zonate leaf spot
Punjab	nr	nr	nr	Moderate-severe	Anthracnose, Grey leaf spot

II. Evaluation of grain sorghum experimental varieties/ hybrids/ parental lines for resistance to major diseases

Fifty-one grain sorghum entries (excluding checks) consisting of advanced and initial experimental hybrids and varieties in four trials (Advanced Hybrid Trial, Advanced Varietal Trial, Initial Hybrid Trial and Initial Varietal Trial) were evaluated for resistance to grain mold, downy mildew and foliar diseases in hot spot locations (Akola, Parbhani, Surat, Coimbatore & Pantnagar) under natural conditions along with susceptible and resistant checks for different diseases. Panicle grain mold score (PGS) and threshed grain mold score (TGS) were recorded using 1-9 rating scale, where 1 = no mold and 9= >75% mold infected grains in Zone I and Zone II. Location severity index (LSI) for grain mold assessed over all the trials in the location indicated that grain mold pressure was moderate across locations and foliar disease pressure was high at moderate at Pantnagar.

Table S2: Grain mold severity index for different locations (LSI)

Location	AHT	AVT	IHT	IVT	LSI	Max Score	Total observations
Akola	4.6	3.9	4.3	4.2	4.3	8.0	291
Parbhani	3.9	4.4	5.0	3.5	4.1	8.3	291
Surat	3.9	4.2	3.3	4.0	3.9	5.7	291
Coimbatore	3.4	4.3	3.1	3.8	3.7	6.0	291

1. Advanced Hybrid Trial (AHT-GS)

AHT-GS trial was comprised of total 18 entries. They included 7 test entries, three hybrid checks, one local check from respective centre and seven pathology checks for comparing disease reactions.

Grain mold: Grain mold was recorded at four centres namely Akola, Parbhani, Surat & Coimbatore. Location severity index (LSI) for grain mold were 4.3 (Akola), 4.1 (Parbhani), 3.9 (Surat) and 3.7 (Coimbatore).

Panicle grain mold score (PGS): PGS is important for assessing genetic resistance against grain mold in an entry. Trials were laid at four locations and disease pressure was moderate to high. PGS ranged from 1.0 to 7.3 (resistance to susceptible reaction) over locations. Location means were 4.3 (Akola), 3.0 (Parbhani) and 3.9 (Surat). Coimbatore centre did not report PGS. Entries significantly differed in PGS scores in all the three locations (Table 1.1). At Parbhani PGS ranged from 1.0 to 6.7 with mean 3.0 and all the test entries were moderately resistant. At Akola PGS range was 2.3 to 7.3 with mean 4.3 and all the test entries were moderately resistant (≥ 4.0). At Surat PGS ranged from 2.3 to 5.7 with mean 3.9 and three test entries (SPH1813, SPH 1779 and SPH1778) showed resistance and rest four were moderately resistant (≥ 4.0). Pooled analysis of data showed that performance of test entries did not differ significantly from each other and they were moderately resistance to PGS. Best performing hybrid CSH 16 scored 2.9 and all the entries (except SPH1816) were at par with CSH 16. Top ranked three test entries were SPH1813, SPH 1779 and SPH1817 (Table 1.1).

Threshed grain mold score (TGS): TGS gives an indication of how much grain surface has been mold impacted and it is important to decide marketability of the grain. Trials were laid at four locations and TGS was reported from Akola, Parbhani and Coimbatore locations. Surat did not report. The disease pressure was moderate to high. TGS ranged from 1.0 to 8.0 (resistance to susceptible reaction) over locations. Location means were 4.9 (Akola), 4.7 (Parbhani) and 3.3 (Coimbatore). Entries significantly differed in TGS scores in all the three locations (Table 1.1). At Parbhani TGS ranged from 1.0 to 8.1 with mean 4.7 and all the test entries were moderately resistant. At Akola TGS range was 2.3 to 7.7 with mean 4.9 and all the test entries were moderately resistant (≥ 4.0). At Coimbatore TGS ranged from 1.7 to 5.0 with mean 3.4 and two test entries (SPH1813, and SPH1820) showed resistance and rest were moderately resistant. Pooled analysis of data showed that performance of test entries differed from each other and they were moderately resistance to TGS. Best performing hybrid CSH 25 scored 3.8 and all the entries were at par with CSH 25. Top ranked three test entries were SPH1813, SPH 1817 and SPH1789 (3.7 to 4.4).

Seed mycoflora: Studies of seed mycoflora of the harvested grain give an account of seed-borne microorganisms including grain mold fungi. These studies were carried out on harvested grains at Parbhani and Akola centres (Table 1.2). Frequency of infection of major grain mold fungi like *Fusarium* and *Curvularia* was estimated. Frequencies of *Fusarium* infection at different locations were 18.1% (Parbhani) and 18.8% (Akola) and that of *Curvularia* was 23.2% (Parbhani) & 27.2% (Akola). *Fusarium* and *Curvularia* infection significantly differed among the entries in both the locations. On national average *Fusarium* infection ranged from 11.1% (B58586) to 37.6% (296B) and *Curvularia* infection from 14.7% (PC4) to 46.3% (Bulk Y). Among the test entries *Fusarium* infection was less on SPH 1820, SPH 1813 and SPH 1817 (15 to 17%) and *Curvularia* on SPH 1813, SPH 1816 and SPH 1817 (19-24%). Data from two locations indicated that SPH 1813 was least affected by seed borne infection of mycoflora (17.6%). Based on results of PGS, TGS and seed mycoflora studies SPH 1813 and SPH 1817 were found promising for grain mold resistance and had semi-compact panicle structure (Table 1.1).

Downy mildew: Incidence of downy mildew was recorded in percentage. Standard method of resistance grading [i.e. R \leq 5%; MR=6 -10% S= 11-30%; HS= \geq 30%] was followed. Downy mildew was reported from peninsular India viz., Coimbatore with range 8.3 to 28.3% and mean incidence 16.6% in sick plot. The entries did not differ significantly on downy mildew reactions with susceptible check recording 13.2% incidence. Except SPH 1813, all other entries showed susceptible reactions (>10%) to downy mildew including hybrid checks (Table 1.2). Top three test entries were SPH 1813, SPH 1779 and SPH 1816 [7.7 to 14.2%].

Sugary disease or ergot: Ergot Incidence was recorded in percentage (where, up to 10% resistant; 11-30% moderately resistant; 31-50% susceptible; and >50% highly susceptible). Moderate to high incidence of sugary disease was recorded from Surat but not from any other locations. Data not included because of high CV.

Foliar diseases: AHT entries were evaluated for foliar disease resistance under artificial/natural conditions in hot spots (Akola, Parbhani, Pantnagar, Surat and Coimbatore) locations. The disease severity was scored on a 1-9 rating scale. Anthracnose and zonate leaf spot were moderate in incidence. Minor and sporadic incidence of other leaf diseases including leaf blight, grey leaf spot, rough leaf spot and sooty stripe was noted in one or other locations (Table 1.4).

Anthracnose: Anthracnose was reported from Pantnagar, Akola and Surat (Table 1.3). Disease pressure was moderate at Pantnagar (5.3) and low-moderate at Akola (4.1) and Surat (4.1). Disease reactions of the entries significantly differed at all the locations but pooled analysis showed non-significant differences. All entries showed moderately resistant reactions with respect to the resistant check (4.8). Three top ranked entries were SPH 1778, SPH 1813, and SPH 1816 [3.2 to 4.1].

Zonate leaf spot: The disease was recorded in Pantnagar in moderate form (4.8) (Table 1.3) and in Parbhani and Akola as traces. No other centre reported the disease this year. The entries did not differ significantly on resistance. Three top ranked entries were SPH 1817, SPH 1778 and SPH1779 [4.5 to 4.5].

Leaf blight: Occurrence of leaf blight was reported from Parbhani (1.1), Akola (2.8), Surat (3.5) and Coimbatore (1.9) (Table 1.3). Disease incidence was low in all the above locations and entries behaved as resistance. Top three low scoring entries were SPH 1778, SPH 1779 and SPH 1789 [1.7 to 2.2].

Pokkah boeng: Minor incidence of pokkah boeng (2.0-8.7%) was recorded in few entries at Parbhani (Table 1.4).

Time to flowering: Days to 50% flowering was recorded at Parbhani, Akola, Surat and Coimbatore. Location means varied from 55.2 (Coimbatore) to 71.7 (Akola) days with national mean 66.7 days (Table 1.1). Data was significant at 5% level across locations except Surat. Among the test entries SPH 1813 was the earliest (62.0 days) and SPH 1817 was the latest (65.8 days) to flower.

Plant height: Plant height was recorded at Coimbatore. Mean plant height in this location was 129 cm (Table 1.4). Data was significant at 5% level. Among the test entries SPH 1820 was the shortest (127 cm) and SPH 1789 was the tallest (155 cm) in height.

Germination and seed weight: Germination ability of seed was tested in Parbhani and Akola centres (Table 1.2). Germination ranged from 43.2% (Parbhani) to 77.3% (Akola) with national mean 60.2%. Data was significant at 5% level across locations. Among the test entries germination was highest in SPH 1813 (72%) and lowest in SPH 1778 (57%). Seed weight (g/ 100) was recorded at Parbhani (1.5) and Akola (2.6) and entries differed significantly on pooled analysis (range 1.0 to 3.0). All the test entries wear at par with the checks.

2. Advanced Varietal Trial (AVT-GS)

AVT-GS trial was comprised of total 26 entries. They included 14 test entries, four varietal checks, one local check from respective centre and seven pathology checks for comparing disease reactions.

Grain mold: Grain mold was recorded at four centres namely Akola, Parbhani, Surat and Coimbatore. Location severity index (LSI) for grain mold were 4.3 (Akola), 4.1 (Parbhani), 3.9 (Surat) and 3.7 (Coimbatore).

Panicle grain mold score (PGS): PGS is important for assessing genetic resistance against grain mold in an entry. Trials were laid at four locations and disease pressure was moderate to high. PGS ranged from 1.0 to 6.7 (resistance to susceptible reaction) over locations. Location means were 3.9 (Akola), 2.7 (Parbhani) and 4.2 (Surat). Coimbatore centre did not report PGS. Entries significantly differed in PGS scores in all the three locations (Table 2.1). At Parbhani PGS ranged from 1.0 to 6.7 with mean 2.7 and all the test entries were moderately resistant. At Akola PGS range was 2.3 to 7.7 with mean 3.9 and the test entries were resistant or moderately resistant (except SPV 2372 and SPV 2373 were susceptible). At Surat PGS ranged from 3.0 to 5.7 with mean 4.2 and the test entries showed resistance and moderately resistant reactions. Pooled analysis of data showed that performance of test entries differed significantly from each other and they were resistant or moderately resistance to PGS. Because of overall low disease pressure six entries showed resistant and rest

were moderately resistant. Best performing variety CSV 20 scored 3.3, and all the entries were at par with CSV 20. Top ranked five test entries were SPV2296, SPV 2307, SPV 2363 and SPV 2366 [2.9 to 3.2] (Table 2.1).

Threshed grain mold score (TGS): TGS gives an indication of how much grain surface has been mold impacted and it is important to decide marketability of the grain. Trials were laid at four locations and TGS was reported from Akola, Parbhani and Coimbatore locations. Surat did not report TGS. The disease pressure was moderate to high. TGS ranged from 1.0 to 8.3 (resistance to susceptible reaction) over locations. Location means were 3.9 (Akola), 4.4 (Parbhani) and 4.3 (Coimbatore). Entries significantly differed in TGS scores in all the three locations (Table 2.1). At Parbhani TGS ranged from 1.0 to 8.3 with mean 4.4 and all the test entries were moderately resistant. At Akola TGS range was 2.3 to 6.7 with mean 3.9 and the test entries were resistant or moderately resistant (except SPV 2372 and SPV 2373 were susceptible). At Coimbatore TGS ranged from 2.7 to 6.0 with mean 4.3. Because of high CV, CD was also high and entries behaved differently based on resistant and susceptible checks. Few entries (SPV 2293 and SPV 2357) seemed susceptible (6.0). Pooled analysis of data showed that performance of test entries differed from each other and they were moderately resistance to TGS and a few were susceptible (e.g., SPV 2372). Best performing hybrid CSV 27 scored 3.8 and all the entries were at par with CSV 27. Top ranked few test entries were SPV2296, SPV 2307, SPV 2363 and SPV 2366 [3.1 to 4.0] (Table 2.1).

Seed mycoflora: Studies of seed mycoflora of the harvested grain give an account of seed-borne microorganisms including grain mold fungi. These studies were carried out on harvested grains at Parbhani and Akola centres (Table 2.2). Frequency of infection of major grain mold fungi like *Fusarium* and *Curvularia* was estimated. Frequencies of *Fusarium* infection at different locations were 16.6% (Parbhani) and 22.2% (Akola) and that of *Curvularia* was 17.0% (Parbhani) and 21.0% (Akola). *Fusarium* and *Curvularia* infection significantly differed among the entries in both the locations. On national average *Fusarium* infection ranged from 11% (B58586) to 34% (Bulk Y) and *Curvularia* infection from 12% (SPV 2307) to 38% (Bulk Y). Among the test entries *Fusarium* infection was less on SPV 2296, SPV 2307, SPV 2362 and SPV 2366 ($\leq 16\%$) and *Curvularia* on SPV 2296, SPV 2307, SPV 2357 and SPV 2364 ($\leq 15\%$). Data from two locations indicated that SPV 2307 was least affected by seed borne infection of mycoflora (13%). Based on results of PGS, TGS and seed mycoflora studies were SPV2296, SPV 2307, SPV 2363 and SPV 2366 were found promising for grain mold resistance and had semi-compact panicle structure (Table 2.1).

Downy mildew: Incidence of downy mildew was recorded in percentage. Standard method of resistance grading [i.e. R $\leq 5\%$; MR=6 -10% S= 11-30%; HS $\geq 30\%$] was followed. Downy mildew was reported from peninsular India viz., Coimbatore with range 4 to 44% and mean incidence 20.7% in sick plot. Original CV of the experiment was extremely high (68.5%) that became 42% after transformation, indicating extreme variation between replications. The entries differed significantly on downy mildew reactions but data was rejected due to high CV (Table 2.2). Only test entry with less than 10% disease was SPV 2363 (7%). Top five test entries were SPV 2293, SPV 2296, SPV 2358, SPV 2364 and SPV 2373 ($< 15\%$).

Sugary disease or ergot: Ergot Incidence was recorded in percentage (where, up to 10% resistant; 11-30% moderately resistant; 31-50% susceptible; and $> 50\%$ highly susceptible). Moderate to high incidence of sugary disease was recorded from Surat but not from any other locations. Data not included because of high CV.

Foliar diseases: AHT entries were evaluated for foliar disease resistance under artificial/natural conditions in hot spots (Akola, Parbhani, Pantnagar, Surat and Coimbatore) locations. The disease severity was scored on a 1-9 rating scale. Anthracnose and zonate leaf spot were moderate in incidence. Minor and sporadic incidence of other leaf diseases including leaf blight, grey leaf spot, rough leaf spot and sooty stripe was noted in one or other locations (Table 2.4).

Anthracnose: Anthracnose was reported from Pantnagar, Parbhani and Surat (Table 2.3). Disease pressure was moderate at Pantnagar (5.3) and low at Parbhani (1.6) and Surat (5.3). Disease reactions of the entries significantly differed at Pantnagar and Surat and not at Parbhani. On pooled analysis most of the entries showed moderately resistant reactions with respect to the resistant check (3.7) while SPV 2293, SPV 2308, SPV 2372 and SPV 2373 were susceptible. Top ranked 4 entries were SPV Nos. 2357, 2358, 2370 & 2364 (< 4.0).

Zonate leaf spot: The disease was recorded in Pantnagar in moderate form (4.6) (Table 2.3) and in Parbhani and Akola as traces. No other centre reported the disease this year. The entries did not differ significantly on resistance. Three top ranked entries were SPV 2293, SPV 2296, SPV 2301 and SPV 2307 (4.5).

Leaf blight: Occurrence of leaf blight was reported from Parbhani (1.1), Akola (2.6), Surat (3.7) and Coimbatore (2.9) (Table 2.3). Disease incidence was low in all the above locations and entries behaved as resistant to moderately resistant one. Top four low scoring entries were SPV 2370, SPV 2373, SPV 2363 and SPV 2357 [2.1 to 2.3].

Pokkah boeng: Minor incidence of pokkah boeng (4-12%) was recorded in few entries at Parbhani (Table 2.4).

Time to flowering: Days to 50% flowering was recorded at Parbhani, Akola, Surat and Coimbatore. Location means varied from 59.2 (Coimbatore) to 74.6 (Surat) days with national mean 70.3 days (Table 2.1). Data was significant at 5% level across locations except Surat. Among the test entries SPV 2373 was the earliest (66 days) and SPV 2296 was the latest (73 days) to flower.

Plant height: Plant height was recorded at Coimbatore. Mean plant height in this location was 136 cm (Table 2.4). Data was significant at 5% level. Among the test entries SPV 2370 was the shortest (111 cm) and SPV 2296 was the tallest (163 cm) in height.

Germination and seed weight: Germination ability of seed was tested in Parbhani and Akola centres (Table 21.2). Germination ranged from 55.1% (Parbhani) to 77.9% (Akola) with national mean 66.5%. Data was significant at 5% level across locations. Among the test entries germination was highest in SPV 2307 (81%) and lowest in SPV 2373 (60%). Seed weight (g/ 100) was recorded at Parbhani (2.0) and Akola (2.7) and test entries differed significantly on pooled analysis (range 2.1 to 2.6). All the test entries wear at par with the checks.

3. Initial Hybrid Trial (IHT-GS)

IHT-GS trial was comprised of total 21 entries. They included 10 test entries, three hybrid checks, one local check from respective centre and seven pathology checks for comparing disease reactions.

Grain mold: Grain mold was recorded at four centres namely Akola, Parbhani, Surat & Coimbatore. Location severity index (LSI) for grain mold were 4.3 (Akola), 4.1 (Parbhani), 3.9 (Surat) and 3.7 (Coimbatore).

Panicle grain mold score (PGS): PGS is important for assessing genetic resistance against grain mold in an entry. Trials were laid at four locations and disease pressure was moderate. PGS ranged from 1.0 to 7.7 (resistance to susceptible reaction) over locations. Location means were 4.1 (Akola), 3.2 (Parbhani) and 3.4 (Surat). Coimbatore centre did not report PGS. Entries significantly differed in PGS scores in all the three locations (Table 3.1). At Parbhani PGS ranged from 1.0 to 6.7 with mean 3.2 and all the test entries were moderately resistant. At Akola PGS range was 2.0 to 7.7 with mean 4.1 and the test entries were resistant or moderately resistant. At Surat PGS ranged from 2.0 to 5.0 with mean 3.4 and the test entries were resistant or moderately resistant. Pooled analysis of data showed that performance of test entries did not differ significantly from each other and they were moderately resistance to PGS. Best performing hybrid CSH 25 scored 3.3 and all the entries were similar with CSH 25 for mold reactions. Top ranked four test entries were SPH1847, SPH 1848, SPH 1852 and SPH1855 (≤ 3.2) (Table 3.1).

Threshed grain mold score (TGS): TGS gives an indication of how much grain surface has been mold impacted and it is important to decide marketability of the grain. Trials were laid at four locations and TGS was reported from Akola, Parbhani and Coimbatore locations. Surat did not report. The disease pressure was moderate to high. TGS ranged from 1.0 to 8.3 (resistance to susceptible reaction) over locations. Location means were 4.3 (Akola), 5.0 (Parbhani) and 3.1 (Coimbatore). Entries significantly differed in TGS scores in all the three locations (Table 3.1). At Parbhani TGS ranged from 1.0 to 8.3 with mean 5.0 and all the test entries were moderately resistant. At Akola TGS range was 2.3 to 7.7 with mean 4.3 and all the test entries were moderately resistant. At Coimbatore TGS ranged from 2.0 to 4.7 with mean 3.1. Data was not considered as CV was quite high. Pooled analysis of data showed that performance of test entries did not differed from each other and they were moderately resistance to TGS. Best performing hybrid CSH 25 scored 3.9 and all the entries were similar with CSH 25 for mold reactions. Top ranked 3 test entries were SPH1848, SPH 1852 and SPH1853 (Table 3.1).

Seed mycoflora: Studies of seed mycoflora of the harvested grain give an account of seed-borne microorganisms including grain mold fungi. These studies were carried out on harvested grains at Parbhani and Akola centres (Table 3.2). Frequency of infection of major grain mold fungi like *Fusarium* and *Curvularia* was estimated. Frequencies of *Fusarium* infection at different locations were 16.3% (Parbhani) and 23.1% (Akola) and that of *Curvularia* was 21.5% (Parbhani) and 22.5% (Akola). *Fusarium* and *Curvularia* infection significantly differed among the entries in both the locations. On national average *Fusarium* infection ranged from 11.7%

(DMS652) to 37.7% (296B) and *Curvularia* infection from 10% (Kekri Local) to 34.8% (Bulk Y). Among the test entries *Fusarium* infection was less on SPH 1846 and SPH 1853 ($\leq 15\%$) and *Curvularia* on SPH 1850 ($\leq 15\%$). Data from two locations indicated that SPH 1853 was least affected by seed borne infection of mycoflora (17.5%).

Based on results of PGS, TGS and seed mycoflora studies SPH 1848, SPH 1852 and SPH 1853 were found promising for grain mold resistance and had compact panicle structure (Table 3.1).

Downy mildew: Incidence of downy mildew was recorded in percentage. Standard method of resistance grading [i.e. R $\leq 5\%$; MR=6 -10% S= 11-30%; HS $\geq 30\%$] was followed. Downy mildew was reported from peninsular India viz., Coimbatore with range 10 to 34% and mean incidence 18% in sick plot. The entries differed significantly on downy mildew reactions with susceptible check recording 15% incidence. Except SPH 1847 and SPH 1848, all other entries showed susceptible reactions ($>10\%$) to downy mildew including hybrid checks (Table 3.2). Top three test entries were SPH 1847, SPH 1848 and SPH 1855 [10 to 14%].

Sugary disease or ergot: Ergot Incidence was recorded in percentage (where, up to 10% resistant; 11-30% moderately resistant; 31-50% susceptible; and $>50\%$ highly susceptible). Moderate to high incidence of sugary disease was recorded from Surat but not from any other locations. Data not included because of high CV.

Foliar diseases: AHT entries were evaluated for foliar disease resistance under artificial/natural conditions in hot spots (Akola, Parbhani, Pantnagar, Surat and Coimbatore) locations. The disease severity was scored on a 1-9 rating scale. Anthracnose and zonate leaf spot were moderate in incidence. Minor and sporadic incidence of other leaf diseases including leaf blight, grey leaf spot and sooty stripe was noted in one or other locations (Table 3.3, 3.4).

Anthracnose: Anthracnose was reported from Pantnagar, Parbhani and Surat (Table 3.3). Disease pressure was moderate at Pantnagar (5.3) and low-moderate at Surat (3.7) and low at Akola (1.2). Disease reactions of the entries significantly differed at Pantnagar and Surat but not at Parbhani. Pooled analysis showed non-significant differences. All entries showed moderately resistant reactions with respect to the hybrid checks (3.2). Three top ranked entries were SPH 1855, SPH 1846, and SPH 1849 [3.0 to 3.2].

Zonate leaf spot: The disease was recorded in Pantnagar in moderate form (4.6) (Table 3.3) and in Parbhani and Akola as traces. No other centre reported the disease this year. The entries differed significantly on resistance at Pantnagar. Three top ranked entries were SPH 1855, SPH 1853 and SPH1847 (2.2).

Leaf blight: Occurrence of leaf blight was reported from Parbhani (1.4), Akola (3.1), Surat (3.1) and Coimbatore (2.5) (Table 3.3). As disease incidence was low in all the above locations the entries behaved as resistance. Top three low scoring entries were SPH 1847, SPH 1848, and SPH 1849 [1.8 to 1.9].

Pokkah boeng: Minor incidence of pokkah boeng (1.7-4.3%) was recorded in few entries at Parbhani (Table 3.4).

Time to flowering: Days to 50% flowering was recorded at Parbhani, Akola, Surat and Coimbatore. Location means varied from 56 (Coimbatore) to 73 (Parbhani) days with national mean 67 days (Table 3.1). Data was significant at 5% level across locations. Among the test entries SPH 1849 was the earliest (65 days) and SPH 1851 was the latest (70 days) to flower.

Plant height: Plant height was recorded at Coimbatore. Mean plant height in this location was 129.5 cm (Table 3.4). Data was significant at 5% level. Among the test entries SPH 1850 was the shortest (1127 cm) and SPH 1847 was the tallest (141 cm) in height.

Germination and seed weight: Germination ability of seed was tested in Parbhani and Akola centres (Table 3.2). Germination ranged from 52.3% (Parbhani) to 73.4% (Akola) with national mean 62.8%. Data was significant at 5% level across locations. Among the test entries seed germination was highest in SPH 1851 (71.5%) and lowest in SPH 1847 (57.7%). Seed weight (g/ 100) was recorded at Parbhani (1.8) and Akola (2.6) and entries did not differ significantly on pooled analysis (range 2.07 to 2.53). All the test entries wear at par with the checks.

4. Initial Varietal Trial (IVT-GS)

IVT-GS trial was comprised of total 32 entries. They included 20 test entries, 4 varietal checks, 1 local check from respective centre and 7 pathology checks for comparing disease reactions.

Grain mold: Grain mold was recorded at four centres namely Akola, Parbhani, Surat and Coimbatore. Location severity index (LSI) for grain mold were 4.3 (Akola), 4.1 (Parbhani), 3.9 (Surat) and 3.7 (Coimbatore).

Panicle grain mold score (PGS): PGS is important for assessing genetic resistance against grain mold in an entry. Trials were laid at four locations and disease pressure was low to moderate. PGS ranged from 1.0 to 7.3 (resistance to susceptible reaction) over locations. Location means were 3.5 (Akola), 2.5 (Parbhani) and 4.0 (Surat). Coimbatore centre did not report PGS. Entries significantly differed in PGS scores in all the three locations (Table 4.1). At Parbhani PGS ranged from 1.0 to 5.3 with mean 2.5 and all the test entries were moderately resistant. At Akola PGS range was 2.0 to 7.3 with mean 3.5 and the test entries were resistant or moderately resistant. At Surat PGS ranged from 3.3 to 4.7 with mean 4.0 and the test entries showed resistance and moderately resistant reactions. Pooled analysis of data showed that performance of test entries differed significantly from each other and they were resistant or moderately resistance to PGS. Because of overall low disease pressure most of the entries showed resistant reactions. Best performing variety CSV 27 scored 3.3, and all the entries were at par with CSV 27. Top ranked test entries were SPV 2435, SPV 2427, SPV 2425 and SPV 2432 [2.7 to 2.9] (Table 4.1).

Thresholded grain mold score (TGS): TGS gives an indication of how much grain surface has been mold impacted and it is important to decide marketability of the grain. Trials were laid at four locations and TGS was reported from Akola, Parbhani and Coimbatore locations. Surat did not report TGS. The disease pressure was low to moderate. TGS ranged from 1.0 to 7.7 (resistance to susceptible reaction) over locations. Location means were 3.4 (Akola), 4.2 (Parbhani) and 3.8 (Coimbatore). Entries significantly differed in TGS scores in all the three locations (Table 4.1). At Parbhani TGS ranged from 1.0 to 7.0 with mean 4.2 and all the test entries (except SPV 2434, susceptible) were moderately resistant. At Akola TGS range was 2.0 to 7.0 with mean 3.4 and the test entries were resistant or moderately resistant. At Coimbatore TGS ranged from 2.0 to 5.7 with mean 3.8. Because of high CV, CD was also high and entries behaved differently based on resistant and susceptible checks. The entry SPV 2423 seemed susceptible (>5.0). Pooled analysis of data showed that performance of test entries differed from each other and they were moderately resistance to TGS. Best performing hybrid CSV 27 scored 3.6 and all the entries were at par with CSV 27. Top ranked few test entries were SPV 2430, SPV 2431, SPV 2334 and SPV 2435 [2.9 to 3.3] (Table 4.1).

Seed mycoflora: Studies of seed mycoflora of the harvested grain give an account of seed-borne microorganisms including grain mold fungi. These studies were carried out on harvested grains at Parbhani and Akola centres (Table 4.2). Frequency of infection of major grain mold fungi like *Fusarium* and *Curvularia* was estimated. Frequencies of *Fusarium* infection at different locations were 18.5% (Parbhani) and 21.0% (Akola) and that of *Curvularia* was 17.3% (Parbhani) and 18.9% (Akola). *Fusarium* and *Curvularia* infection significantly differed among the entries in both the locations. On national average *Fusarium* infection ranged from 12% (DMS652) to 37% (296B) and *Curvularia* infection from 10% (Kekri Local) to 37% (Bulk Y). Among the test entries *Fusarium* infection was less on SPV 2427, SPV 2429 and SPV 2439 ($\leq 15\%$) and *Curvularia* on SPV 2423, SPV 2426, SPV 2431, SPV 2437 and SPV 2440 ($\leq 15\%$). Data from two locations indicated that SPV 2440 was least affected by seed borne infection of mycoflora (14.5%).

Based on results of PGS, TGS and seed mycoflora studies were SPV 2427, SPV 2431 and SPV 2435 were found promising for grain mold resistance and had semi-compact to compact panicle structure (Table 4.1).

Downy mildew: Incidence of downy mildew was recorded in percentage. Standard method of resistance grading [i.e. R $\leq 5\%$; MR=6 -10% S= 11-30%; HS= $\geq 30\%$] was followed. Downy mildew was reported from peninsular India viz., Coimbatore with range 4 to 51% and mean incidence 27.8% in sick plot. Original CV of the experiment was extremely high (76%) that became 47% after transformation, indicating extreme variation between replications. The entries differed significantly on downy mildew reactions but data was rejected due to high CV (Table 4.2). None of the test entries had less than 10% disease. Top five test entries with less than 20% SDM were SPV 2425, SPV 2428, SPV 2429 and SPV 2437.

Sugary disease or ergot: Ergot Incidence was recorded in percentage (where, up to 10% resistant; 11-30% moderately resistant; 31-50% susceptible; and >50% highly susceptible). Moderate to high incidence of sugary disease was recorded from Surat but not from any other locations. Data not included because of high CV.

Foliar diseases: AHT entries were evaluated for foliar disease resistance under artificial/natural conditions in hot spots (Akola, Parbhani, Pantnagar, Surat and Coimbatore) locations. The disease severity was scored on a 1-9 rating scale. Anthracnose and zonate leaf spot were moderate in incidence. Minor and sporadic incidence of other leaf diseases including leaf blight, grey leaf spot, and sooty stripe was noted in one or other locations (Table 4.4).

Anthracose: Anthracnose was reported from Pantnagar, Parbhani and Surat (Table 2.3). Disease pressure was moderate at Pantnagar (5.4) and low at Parbhani (1.3) and Surat (5.1). Disease reactions of the entries significantly differed at all the locations. On pooled analysis most of the entries showed moderately resistant reactions with respect to the resistant check (3.5). Top ranked entries were SPV 2427, SPV 2423, S PV 2430 and SPV 2432 (3.3 to 3.7).

Zonate leaf spot: The disease was recorded in Pantnagar in moderate form (4.7) (Table 4.3) and in Parbhani and Akola as traces. No other centre reported the disease this year. The entries differed significantly on resistance. Top ranked entries were SPV 2293, SPV 2296, SPV 2301 and SPV 2307 (4.5).

Leaf blight: Occurrence of leaf blight was reported from Parbhani (1.1), Akola (2.6), Surat (3.7) and Coimbatore (2.9) (Table 2.3). Disease incidence was low in all the above locations and entries behaved as resistant to moderately resistant one. Top four low scoring entries were SPV 2438, SPV 2439, SPV 2440 and SPV 2441 (2.2).

Pokkah boeng: Minor incidence of pokkah boeng (1 to 4%) was recorded in few entries at Parbhani (Table 4.4).

Time to flowering: Days to 50% flowering was recorded at Parbhani, Akola, Surat and Coimbatore. Location means varied from 57.3 (Coimbatore) to 77.5 (Akola) days with national mean 71.5 days (Table 4.1). Data was significant at 5% level across locations. Among the test entries SPV 2442 was the earliest (68 days) and SPV 22426 was the latest (76 days) to flower.

Plant height: Plant height was recorded at Coimbatore. Mean plant height in this location was 134 cm (Table 4.4). Data was significant at 5% level. Among the test entries SPV 2439 was the shortest (118 cm) and SPV 2428 was the tallest (170 cm) in height.

Germination and seed weight: Germination ability of seed was tested in Parbhani and Akola centres (Table 4.2). Germination ranged from 57.9% (Parbhani) to 77.7% (Akola) with national mean 67.8%. Data was significant at 5% level across locations. Among the test entries germination was highest in SPV 2428 (80%) and lowest in SPV 2430 (63%). Seed weight (g/ 100) was recorded at Parbhani (1.8) and Akola (2.6) and test entries did not differ significantly on pooled analysis (range 2.0 to 2.7). All the test entries wear at par with the checks.

III. Evaluation of forage sorghum experimental varieties/ hybrids/ parental lines for resistance to diseases

Forty-six forage sorghum entries (excluding checks) consisting of advanced and initial experimental hybrids and varieties in three trials (Initial and Advanced Varietal and Hybrid Trial Multi-cut, Advanced Varietal and Hybrid Trial Single-cut and, Initial Varietal and Hybrid Trial Single-cut) were evaluated for resistance to, downy mildew and foliar diseases in hot spot locations under natural conditions in Coimbatore, Pantnagar, Ludhiana and Surat along with susceptible and resistant checks for different diseases. Foliar diseases destroy active leaf area required for photosynthesis, adversely affect accumulation of sugar in stalk and thus interfere with the quantity and quality of fodder. Most of the foliar diseases of grain sorghum also occur in forage sorghum. Anthracnose, leaf blight, rust, zonate leaf spot and few other leaf diseases occurs almost regularly either in moderate or severe form in various parts of India. They are more seen on forage sorghum as they are purple type than grain sorghum which is mostly tan type. Foliar disease severity index for different locations are given below.

Table S3: Foliar disease severity index for different locations

Trial	Anthracose		Zonate leaf spot		Leaf blight		Leaf diseases
	PAN	SUR	PAN	SUR	COI	SUR	LUD
IAVHT-MC	5.4	5.0	4.1	1.0	1.7	4.1	7.5
AVHT-SC	5.5	4.5	4.7	1.0	1.8	3.5	7.6
IVHT-SC	5.2	5.0	4.6	1.0	2.0	3.1	7.7
Location severity Index (LSI)	5.4	4.8	4.5	1.0	1.8	3.6	7.6
Max Score	6.5	6.0	5.2	1.0	3.3	5.0	8.3
Total observations	207	207	207	207	207	207	207

1. Initial and Advanced Varietal and Hybrid Trial Multi-cut (IAVHT-MC)

Downy mildew: Downy mildew was reported from Coimbatore with location mean 20.5%. Incidence was recorded in percentage. Standard method of resistance grading [i.e. $R \leq 5\%$; $MR=6-10\%$ $S=11-30\%$; $HS \geq 30\%$] was followed. Incidence was highly sporadic and CV was high and data were not considered (Table 5.2). Only two entries recorded less than 10% (SPH 1844 and SPH 1780) and all others were susceptible under sick plot condition.

Foliar diseases: IAVHT entries were evaluated for foliar disease resistance under artificial/natural conditions in hot spots (Ludhiana, Pantnagar, Surat and Coimbatore) locations. The disease severity was scored on a 1-9 rating scale.

In Ludhiana the zonate leaf spot was in traces. The grey leaf spot also started in August but later on anthracnose became predominant. All these diseases were recorded together on a 1-9 scale as 'foliar diseases' at the time of 50% flowering. Disease pressure in this location was severe and all the entries were susceptible scoring more than 6.3 (Table 5.1).

In Pantnagar, Surat and Coimbatore score was recorded on individual disease such as Anthracnose, zonate and leaf blight, each of which are described below.

Anthracnose: Anthracnose was recorded in Pantnagar, Surat (Table 5.1). Disease pressure was moderate at both the locations Pantnagar (5.4) and 4 Surat (5.1). Disease reactions of the entries significantly differed Pantnagar but not at Surat. The entries SPH 1768, SPH 1806, SPH 1838, SPH 1841 and SPH 1842 were moderately resistant (<4.9) like the check CSH 24MF and SPH 1770, SPH 1809, SPH 1840, SPH 1844, SPV 2353 and SPV 2421 were susceptible (>5.6) at Pantnagar. Based on pooled analysis top four entries were SPH 1806, SPH 1838, SPH 1841 and SPH 1842 [4.5 to 5.2].

Zonate leaf spot: The disease was recorded in Pantnagar in low-moderate form (4.1) (Table 5.1). No other centre reported the disease this year. The entries differed significantly on resistance and SPH 1838, SPH 1841 and SPH 1842 were the best performing entry (3.8) when susceptible check was 4.5.

Leaf blight: The disease was recorded in forage sorghum at Surat in moderate form (4.1) and at Coimbatore in traces (1.7) (Table 5.1). No other centre reported the disease this year on forage. Because of low-moderate disease pressure the entries did not differ significantly at any of these locations. Based on pooled analysis top five entries were SPH 1844, SPH 1806, SPH 1843, SPH 1838 AND SPV 2353 [2.5 to 2.7].

Time to flowering: Days to 50% flowering was recorded at Coimbatore and Surat. Location means were 58.4 (Coimbatore) and 77.6 (Surat) days with national mean 68 days (Table 5.1). Data was significant at 5% level at both the locations and all the test entries were at par with checks. Among the test entries SPH 1841 was the earliest (65 days) and SPH 1770 was the latest (74 days) to flower.

Plant height: Plant height was recorded at Coimbatore. Mean height was 133 cm with range 108 to 163 cm (Table 5.2). Height differences were not significant at 5% level. Among the test entries SPH 1842 was the shortest (108 cm) and SPH 1845 was the tallest (163 cm) in height.

2. Advanced Varietal and Hybrid Trial Single-cut (AVHT-SC)

Downy mildew: Incidence of downy mildew was recorded in percentage. Standard method of resistance grading [i.e. $R \leq 5\%$; $MR=6-10\%$ $S=11-30\%$; $HS \geq 30\%$] was followed. Downy mildew was reported from Coimbatore with mean incidence 22.2%. Incidence was highly irregular and CV was high (even after transformation) and data were not considered (Table 6.2). Except SPV 2383, all entries recorded more than 10% downy mildew including checks. Entries with less than 15% downy mildew were SPV 2383, SPV 2391, CSV21F and CSV 30F (9 to 13%).

Foliar diseases: AVHT-SC entries were evaluated for foliar disease resistance under artificial/natural conditions in hot spots (Ludhiana, Pantnagar, Surat and Coimbatore) locations. The disease severity was scored on a 1-9 rating scale.

In Ludhiana the grey leaf spot started in August but later on anthracnose became predominant. The zonate leaf spot was in traces. All these diseases were recorded together on a 1-9 scale as 'foliar diseases' at the time of 50% flowering. Disease pressure in this location was severe (7.6) and all the entries were susceptible scoring more than 7.0 (Table 6.1).

In Pantnagar, Surat and Coimbatore score was recorded on individual disease such as Anthracnose, zonate and leaf blight, each of which are described below.

Anthracnose: Anthracnose was recorded in Pantnagar, Surat (Table 6.1). Disease pressure was severe at Pantnagar (5.5) and moderate at Surat (4.5). Disease reactions of the entries significantly differed at both the locations. The entries SPV 2317 and 2383 were resistant (<5.0), and rest were moderately resistant at Pantnagar. At Surat most of the entries behaved as moderately resistant (except SPV 2388, was susceptible). Based on pooled analysis SPV 2383 was resistant, SPV 2388 was susceptible and others were moderately resistant. Top four entries were SPV 2383, SPV 2317, SPV 2375 and SPV 2376 [3.8 to 4.5].

Zonate leaf spot: The disease was recorded in Pantnagar in moderate form (4.7) (Table 6.1). No other centre reported the disease this year. The entries did not differ significantly on resistance and variation was very less (4.5 to 4.8).

Leaf blight: The disease was recorded in forage sorghum at Surat in low-moderate form (3.5) and at Coimbatore in traces (1.8) (Table 6.1). No other centre reported the disease this year on forage. Because of low-moderate disease pressure the entries did not differ significantly at any of these locations. Based on pooled analysis top five entries (including checks) were CSH 13, SPV 2391, SPH 1797, SPH 1822 and SPV 2388 [1.8 to 2.3].

Time to flowering: Days to 50% flowering was recorded at Surat and Coimbatore. Location means were 79.4 (Surat) and 63.3 (Coimbatore) days with national mean 71.7 days (Table 6.1). Data was significant at 5% level at both the locations. Among the test entries SPV 2376 was the earliest (71 days) and SPV 2388 was the latest (80 days) to flower.

Plant height: Plant height was recorded at Coimbatore. Mean plant height was 125.6 cm (Table 6.2). **Variations** were not significantly different at 5% level. Among the test entries SPV 2376 was the shortest (111 cm) and SPV 2389 was the tallest (141 cm) in height.

Germination and seed weight: Not reported by the centres for AVHT-SC.

3. Initial Varietal and Hybrid Trial Single-cut (IVHT-SC)

Downy mildew: Incidence of downy mildew was recorded in percentage. Standard method of resistance grading [i.e. R = ≤5%; MR=6-10% S= 11-30%; HS= ≥30%] was followed. Downy mildew was reported from Coimbatore with mean incidence 19.5%. Incidence was highly sporadic and CV was high (even after transformation) and data were not considered (Table 7.2). Entries SPH 1856, SPH 2443 and SPV 2452 were moderately resistant and recorded less than 10% SDM. Entries (including checks) with less than 15% downy mildew were SPH 1856, SPH 2443, SPV 2452, SPH 1857, SPV 2446, SPV 2440, SPV 2451, and Local check (5 to 15%).

Foliar diseases: IVHT-SC entries were evaluated for foliar disease resistance under artificial/natural conditions in hot spots (Ludhiana, Pantnagar, Surat and Coimbatore) locations. The disease severity was scored on a 1-9 rating scale.

In Ludhiana the grey leaf spot started in August but later on anthracnose became predominant. The zonate leaf spot was in traces. All these diseases were recorded together on a 1-9 scale as 'foliar diseases' at the time of 50% flowering. Disease pressure in this location was severe (7.7) and all the entries were susceptible scoring more than 7.3 (Table 7.1). In Pantnagar, Surat and Coimbatore score was recorded on individual disease such as Anthracnose, zonate and leaf blight, each of which are described below.

Anthracnose: Anthracnose was recorded in Pantnagar, Surat (Table 7.1). Disease pressure was moderate at both the locations Pantnagar (5.2) and Surat (5.0). Disease reactions of the entries significantly differed at both the locations. The entries SPH 1858, SPV 2448, SPV 2454 and SPV 2455 scored less than 5.0 and were promising at Pantnagar. At Surat seven entries (SPH 1856, SPH 1857, SPV 2445, SPV 2448, SPV 2452, SPV 2453 and SPV 2452) scored less than 5.0. Based on pooled analysis entries (including checks) with less than 5.0 score (moderately resistant) were SPH 1856, SPH 1857, SPH 1858, SPV 2445, SPV 2448, SPV 2452, SPV 2454 and CSH 13.

Zonate leaf spot: The disease was recorded in Pantnagar in moderate form (4.6) (Table 7.1). No other centre reported the disease this year. The entries did not differ significantly (range 4.5 to 4.8) on resistance (Susceptible check Kekri local 5.0; Resistant check Pant Chari 5 was 4.7).

Leaf blight: The disease was recorded in forage sorghum at Surat in low-moderate form (3.1) and at Coimbatore in traces (2.0) (Table 5.1). No other centre reported the disease this year on forage. Because of low-moderate disease pressure the entries did not differ significantly at any of these locations. Based on pooled analysis top five entries were SPH 1857, SPV 2444, SPV 2447, SPV 2447, SPV 2452 [1.8 to 2.3].

Time to flowering: Days to 50% flowering was recorded at Surat and Coimbatore. Location means were 75.4 (Surat) to 61.7 (Coimbatore) days with national mean 68.5 days (Table 7.1). Data was significant at 5% level at both the locations. Among the test entries SPV 2446 was the earliest (58 days) and SPH 1856 was the latest (81 days) to flower.

Plant height: Plant height was recorded at Coimbatore. Mean plant height was 132.9 cm (Table 7.2). Height differences were not significant at 5% level. Among the test entries SPV 2453 was the shortest (95 cm) and SPV 2451 was the tallest (171 cm) in height.

Germination and seed weight: Not reported by the centres for IVHT-SC.

IV. Evaluation of sweet sorghum experimental varieties/ hybrids/ parental lines for resistance to diseases

This season only one trial for sweet sorghum (Initial and Advanced Varietal and Hybrid Trial Sweet Sorghum) was allotted. Twenty-two genotypes including 15 test entries, 3 sweet sorghum checks and 4 pathology checks were evaluated at Parbhani, Akola and Surat for grain mold and at Pantnagar against foliar diseases. Entries were evaluated for resistance to grain mold and foliar diseases in hot spot locations under natural conditions in along with susceptible and resistant checks for different diseases.

1. Initial and Advanced Varietal and Hybrid Trial Sweet Sorghum (IAVHT-SS)

Grain mold: Grain mold was recorded at Parbhani, Akola, and Surat. Location severity index (LSI) for grain mold were 4.3 (Akola), 4.1 (Parbhani) and 3.9 (Surat).

Panicle grain mold score (PGS): PGS is important for assessing genetic resistance against grain mold in an entry. Trials were laid at four locations and disease pressure was low to moderate. PGS ranged from 1.0 to 6.7 (resistance to susceptible reaction) over locations. Location means were 3.6 (Akola), 2.1 (Parbhani) and 3.4 (Surat). Entries significantly differed in PGS scores in Parbhani and Akola (Table 8.1). At Parbhani PGS ranged from 1.0 to 5.7 with mean 2.1 indicating low disease pressure and all the test entries were moderately resistant. At Akola PGS range was 2.0 to 6.7 with mean 3.6. Mostly because of low-moderate disease favouring conditions six entries showed resistant and rest were moderately resistant at this location. At Surat disease pressure was moderate PGS ranged from 2.7 to 5.0 with mean 3.4. Pooled analysis of data showed that performance of test entries differed significantly from each other and they were moderately resistance to PGS. Best performing hybrid CSH 22SS scored 2.7 and all the test entries were at par with CSH 22SS. Top ranked five test entries were SPH1798, SPH 1825 and SPH1859, SPV 2458 and SPV 2457 (Table 8.1).

Threshed grain mold score (TGS): TGS gives an indication of how much grain surface has been mold impacted and it is important to decide marketability of the grain. Trials were laid at four locations and TGS was reported from Akola and Parbhani. Surat did not report TGS. The disease pressure was moderate. TGS ranged from 1.0 to 7.7 (resistance to susceptible reaction) over locations. Location means were 4.0 (Akola), 3.7 (Parbhani). Entries significantly differed in TGS scores in both these locations (Table 8.1). At Parbhani TGS ranged from 1.0 to 7.7 with mean 3.7 and all the test entries were moderately resistant. At Akola TGS range was 2.3 to 5.7 with mean 4.0. As CV was high (25.7%) entries could not be judged by CD. Pooled analysis of data showed that performance of test entries differed from each other and they were moderately resistance to TGS. Best performing hybrid CSV 24SS scored 4.0 and all the entries were at par with CSV 24SS. Top ranked few test entries were SPH1798, SPH 1858, SPH 1859 and SPV 2324, SPV 2458 and SPV 2459 (Table 8.1).

Seed mycoflora: Studies of seed mycoflora of the harvested grain give an account of seed-borne microorganisms including grain mold fungi. These studies were carried out on harvested grains at Parbhani and Akola centres (Table 8.2). Frequency of infection of major grain mold fungi like *Fusarium* and *Curvularia* was estimated. Frequencies of *Fusarium* infection at different locations were 23.1% (Parbhani) and 23.0% (Akola) and that of *Curvularia* was 19.5% (Parbhani) and 18.8% (Akola). *Fusarium* and *Curvularia* infection significantly differed among the entries in both the locations. On national average *Fusarium* infection ranged from 11% (Pant

Chari 5) to 35% (Bulk Y) and *Curvularia* infection from 13% (B58586) to 35% (Bulk Y). Among the test entries *Fusarium* infection was less on SPH 1858 and SPH 1861 ($\leq 20\%$) and *Curvularia* on SPH 1798, SPH 1858, SPH 1859, SPH 1862, SPV 2324, SPV 2356, SPV 2357 and SPV 2462 ($\leq 17\%$). Data from two locations indicated that SPH 1858 and SPV 2456 were least affected by seed borne infection of mycoflora (each $< 20\%$).

Based on results of PGS, TGS and seed mycoflora studies SPH1798, SPH 1859 and SPV 2458 were found promising for grain mold resistance and had semi-compact (SPH 1798) and compact (SPH 1859 and SPV 2458) panicle structure (Table 8.1).

Foliar diseases: IAVHT sweet sorghum entries were evaluated for foliar disease resistance under artificial/natural conditions in hot spots (Akola, Parbhani, Pantnagar and Surat) locations. The disease severity was scored on a 1-9 rating scale. Anthracnose, zonate leaf spot and leaf blight were moderate in incidence. Minor and sporadic incidence of other leaf diseases including grey leaf spot and sooty stripe was noted in Parbhani and Akola (Table 8.3, 8.4).

Anthracnose: Anthracnose was reported from Pantnagar, Parbhani and Surat (Table 8.3). Disease pressure was severe at Pantnagar (5.3), moderate at Surat (4.9) and traces at Parbhani (1.1). Disease reactions of the entries significantly differed at all the locations. Parbhani centre was not included in analysis for low disease pressure. All entries showed moderately resistant reactions with respect to the resistant check (4.8). Five top ranked entries were SPH1798, SPH1825, SPH1859, SPH1862 and SPV2324 [4.3 to 4.7].

Zonate leaf spot: The disease was recorded at Pantnagar in moderate form (4.8) and in Parbhani (1.6) and Akola (1.2) in traces (Table 8.3). No other centre reported the disease this year. The entries differed significantly on resistance. Five top ranked entries were SPH 1859, SPH 1860, SPH 1861, SPH 1862 and SPV 2459 [2.2 to 2.4].

Leaf blight: Occurrence of moderate incidence of leaf blight was reported from Akola (4.2) and Surat (4.1) (Table 8.3). Entries were moderately resistant to leaf blight. Top five low scoring entries were SPV 2324, SPV 2462, SPH 1859 and SPH 1862 [2.5 to 3.7].

Pokkah boeng: Minor incidence of pokkah boeng (4.0 to 12%) was recorded in few entries at Parbhani (Table 8.4).

Time to flowering: Days to 50% flowering was recorded at Parbhani, Akola and Surat. Location means varied from 78.3 (Parbhani) to 83.2 (Akola) days with national mean 80.7 days (Table 8.1). Data was significant at 5% level across locations. Among the test entries SPV 2462 was the earliest (75 days) and SPH 1798 was the latest (49 days) to flower.

Germination and seed weight: Germination ability of seed was tested in Parbhani and Akola centres (Table 8.2). Germination ranged from 53.7% (Parbhani) to 75.1% (Akola) with national mean 64.6%. Data was significant at 5% level across locations. Among the test entries germination was highest in SPH 1859 (81%) and lowest in SPV 2461 (44%). Seed weight (g/100) was recorded at Parbhani (2.23) and Akola (2.87) and entries did not differ significantly in these locations (range 2.2 to 3.2). All the test entries were at par with the checks.

V. National grain mold nursery

Objective of this study was to monitor stability of grain mold resistance in newly identified and known sources and study pathogen population across locations. Thirty entries (including 3 checks B58586, Bulk Y and 296B) tested during this season included 4 entries promoted during 2014 and 2015 (GMN14-3, GMN14-6, GMN14-7 and GMN14-9), 7 entries promoted during 2015 (GMN15-1, RMP42, AKGMR111, IS20956, IS21425, IS21645 and IS29314) plus 16 new entries contributed by various centres during 2016. Entries were evaluated at grain mold hot spots like Parbhani, Akola, Surat and Hyderabad. Field experiment was conducted in RBD with 3 replications. Each test entry was sown in two rows of 4 m long and 45 cm apart. Grain mold was scored following 1 to 9 rating scale on grains on panicle and on threshed grains. Other grain mold related characters like days to flowering, plant height, panicle compactness, fungal load etc were recorded. Due to heavy rain, meaningful data could be generated for NGN trial at Hyderabad. Results are presented in Tables 9.1, 9.2 & 9.3. All the new entries scored PGS ≤ 4.0 (except GMN16 -6). These entries will be tested for one more year for drawing conclusion.

Eleven entries (GMN14-3, GMN14-6, GMN14-7, GMN14-9, GMN15-1, RMP42, AKGMR111, IS20956, IS21425, IS21645 and IS29314) that were evaluated during 2015 (at Akola, Surat, Hyderabad) and 2016 (at Akola, Surat) along with hybrid, varieties and resistant and susceptible checks were subjected to pooled analysis (Table S4). The entry GMN 14-6 (2.7) and RMP 42 (3.1) performed superior to other entries and were at par with the resistant check B58586 (2.6) for panicle grain mold resistance. Few other improved sorghum lines namely AKGMR111, GMN14-9 and GMN15-1 and germplasm lines IS20956, IS21425 and IS21645 also had improved grain mold resistance that were at par with the variety CSV 27 (3.8) and CSH 25 (3.9). AKGMR111 had grain mold resistance (4.0) combine with bold grain (2.9 g /100) and might be important as mold resistant variety. All these test entries were medium in duration (range 69 to 75 days) (except IS20956, which was late type 80 days).

VI. National anthracnose nursery

Earlier studies on characterization of the virulence spectrum of the anthracnose pathogen in hot spot locations revealed high degree of variability among the isolates in Pantnagar and Udaipur regions where forage sorghum is important. Study revealed that susceptibility of few sorghum lines had changed over the years. CSV21F and IRTA204 lines which were resistant or moderately resistant to CgA, CgB, CgD and CgL isolates during 2012, showing susceptible reactions during 2014. It was decided to identify new sources of anthracnose resistant that could be used for a resistant breeding programme.

Nineteen entries along with resistant (Pant Chari 5) and Susceptible (Kekri Local and R Local) were evaluated for anthracnose resistance at Pantnagar for identification of new sources of resistance. Disease pressure was moderate to severe and none of the test entries were resistant. Sixteen entries (AKSV380, AKSV382, AKSV386, RSSH18, RSSH50, RSSV397, IS10302, IS20956, IS23521, IS23586, IS473I, CSB12012, ICSB12019, ICSB12021, ICSB467 and ICSB474) were moderately resistant and three (AKSV388, AKSV394 and ICSB654) were susceptible to the disease (Table S5).

Table S4. National Grain mold Nursery- combined analysis kharif 2015 & 2016

Entry	Grain mold field grade (1to9)						Seed weight (g/100)			Days to flower (day)		
	2015			2016			2015	2016	Mean	2015	2016	Mean
Year	AKO	SUR	HYD	AKO	SUR	IND	IND	IND	IND	IND	IND	IND
AKGMR111	2.3	4.7	4.7	4.3	4.0	4.0	3.1	2.7	2.9	74	75	74
GMN14-3	2.7	5.0	4.7	4.3	4.7	4.3	2.4	2.0	2.2	70	69	70
GMN14-6	2.0	3.7	2.7	2.0	3.0	2.7	1.9	1.8	1.8	75	71	74
GMN14-7	4.3	5.3	6.3	4.7	3.3	4.8	2.3	1.8	2.0	66	71	68
GMN14-9	2.7	4.7	4.0	3.7	3.7	3.7	2.1	1.6	1.9	70	65	68
GMN15-1	2.7	3.0	5.3	3.0	3.3	3.5	1.9	2.0	2.0	72	72	72
IS20956	2.0	4.7	5.3	2.7	2.7	3.5	2.4	2.1	2.2	79	83	80
IS21425	2.3	4.3	3.3	2.3	5.0	3.5	1.7	1.9	1.8	75	74	75
IS21645	2.3	3.7	4.0	4.0	3.7	3.5	1.7	2.1	1.9	75	77	75
IS29314	3.7	3.7	5.0	5.0	4.7	4.4	1.9	1.8	1.9	69	73	70
RMP42	2.0	4.3	3.0	2.3	4.0	3.1	2.0	1.8	1.9	70	67	69
CSH25	4.3	4.3	-	3.7	3.3	3.9	3.3	2.3	2.6	73	73	73
CSH30	3.7	4.3	-	4.7	5.0	4.4	2.4	2.0	2.1	65	73	68
CSV23	2.3	6.0	-	4.0	4.7	4.3	2.8	2.4	2.5	73	77	75
CSV27	2.7	5.7	-	3.0	4.0	3.8	2.6	2.8	2.7	75	77	76
B58586	2.0	4.3	2.3	2.0	2.3	2.6	2.2	1.8	2.0	73	70	72
296B	4.7	7.0	8.7	6.3	4.7	6.3	2.4	2.0	2.2	75	77	75
Bulk Y	5.3	7.0	9.0	7.7	4.3	6.7	3.1	1.7	2.4	62	71	65
Loc. Mean	3.0	4.8	4.9	3.9	3.9	4.0	2.4	2.0	2.2	71.6	73.0	72.1
C.D. (5%)	1.2	NS	1.4	1.3	1.3	-	-	-	-	-	-	-
C.V. (%)	23	29	15	20	20	-	-	-	-	-	-	-

Table S5. National Anthracnose Nursery

Sl.	Entry	Anthracnose (1-9)			Sl.	Entry	Anthracnose (1-9)		
		Boot leaf	Flowering	Overall			Boot leaf	Flowering	Overall
1	AKSV380	4.0	6.0	5.0	14	ICSB12012	4.3	6.3	5.3
2	AKSV382	4.3	6.0	5.2	15	ICSB12019	4.7	6.0	5.3
3	AKSV386	4.3	6.0	5.2	16	ICSB12021	4.0	5.7	4.8
4	AKSV388	4.3	6.7	5.5	17	ICSB467	4.3	6.0	5.2
5	AKSV394	5.0	6.3	5.7	18	ICSB474	4.0	6.0	5.0

Sl.	Entry	Anthracnose (1-9)			Sl.	Entry	Anthracnose (1-9)		
		Boot leaf	Flowering	Overall			Boot leaf	Flowering	Overall
6	RSSH18	4.0	6.0	5.0	19	ICSB654	5.0	6.0	5.5
7	RSSH50	4.7	6.0	5.3	20	Kekri local	5.0	6.0	5.5
8	RSSV397	4.3	6.3	5.3	21	Pant Chari 5	2.0	4.0	3.0
9	IS10302	4.0	6.0	5.0	22	R local	5.0	7.0	6.0
10	IS20956	4.0	6.0	5.0		Loc. Mean	4.3	6.1	5.2
11	IS23521	4.3	6.0	5.2		CD at 5%	0.3	0.3	0.2
12	IS23586	5.0	6.3	5.7		CV (%)	8.8	5.1	5.0
13	IS473	4.0	6.0	5.0		Probability	0.00	0.00	0.00

VII. Publications and recognitions

The group was involved in publishing 22 different publications including 9 journal papers, 1 book, 4 book chapter 4 popular article 1 information bulletin and two conference papers during 2016-17. Scientists from different centres participated in regional and national symposia. Dr. SN Chattannavar received best poster award in IPS zonal meet and acted as examiner for Ph D Thesis. The details of the publications are given below.

Journal article

- Bhanderi G. R., Prashant B. Sandipan, Radadiya N. V. and Davda B. K. (2016). To Study the Bioefficacy of Different Fungicides Against the Ergot Disease of Sorghum Caused by *Claviceps* sp. Under South Gujarat Condition of Gujarat. *Multilogic in Science*, 6: 28-31.
- Das IK, Govardhan C, Gahukar HS, Narayana YD, Bhanderi GR, Kannababau N, Sunil Kumar and Tonapi AV. (2017). Milk stage kernel infection frequency in kharif sorghum at grain mold prone locations in India. *Indian Phytopathology* (In communication).
- Kharayat, B.S. and Y.Singh (2016). Studies on interactions among bioagents colonized vermicompost, rhizospheric earthworms and stalk rot disease of sorghum caused by *Erwinia chrysanthemi*. *American J.Agric.Res.* 1(5): 15-29.
- Rana, M, Y. Singh and K.S.Bisht, (2016). *In vitro* evaluation of essential oils, bio-control agents and fungicides against *Colletotrichum graminicola* causing anthracnose of sorghum. *J. Env. Bio-sci.*30 (2): 299-302.
- Rashmi, U. S. and Chattannavar, S. N., 2016. Cultural and Morphological diversity among the isolates of *Fusarium udum*. *Karnataka. J. Farm. Sci.*29 (3) : 299-306
- Rashmi, U. S. and Chattannavar, S. N., 2016. Prevalance of *Fusarium* wilt of pigeon pea caused by *Fusarium udum* Butler. *Karnataka. J. Farm. Sci.*29 (4) : 521-523
- Rekha and Y. Singh (2016). *In vitro* efficacy of bio-agents and organic amended soil extracts against *Colletotrichum graminicola* causing anthracnose of sorghum. *J. Env. Bio-sci.*30 (2): 271-273.
- Rekha and Y. Singh (2016). Effect of soil solarization along with bio control- agents against anthracnose of sorghum caused by *Colletotrichum graminicola*. *J. Env. Bio-sci.*30 (2): 317-319.
- Singh,P and Y.Singh (2016). Evaluation of inoculation methods and standardization of *Erwinia chrysanthemi* inoculum concentration for germplasm screening against stalk rot in sorghum. *J Pure Appl Microbio.* 10 (4): 2747-2752.

Books

- Das, I.K. and Padmaja, P.G., 2016. Biotic stress resistance in sorghum. Academic Press, USA, 246p.

Book chapter

- Das, I.K. and Rakshit, S., 2016. Millets their importance and production constraints. In: Das, I.K., Padmaja, P.G., (Eds.), biotic stress resistance in sorghum. Academic Press, USA, pp.1-22.
- Das, I.K. and Rajendrakumar, P., 2016. Disease resistance in sorghum. In: Das, I.K., Padmaja, P.G., (Eds.), biotic stress resistance in sorghum. Academic Press, USA, pp.23-68.
- Das, I.K., 2016. Diseases of Sorghum. In: Dubey, H.C., Rashmi Aggarwal, Patro, T.S.S.K., Pratibha Sharma, (Eds.). Diseases of field crops and their management. Today & Tomorrow's Printers & Publishers, New Delhi, pp.131-179.
- Nagaraja, A., and Das, I.K., 2016. Disease resistance in pearl millet and small millets. In: Das, I.K., Padmaja, P.G., (Eds.), biotic stress resistance in sorghum. Academic Press, USA, pp.69-104.

(C) Popular article

- Das IK, Nageswara Rao TG and Nagaraja A. 2016. Diseases of millets and their management. *Indian Farming* 65(12): 41-45.
- Sharma, D. and Singh Y. 2016. Major diseases of sorghum in Tarai region of Uttarakhand and their management. *Indian Farmers' Digest* 49 (2): 16-17.

- V.M.Gholve, H.V.Kalpande and Mohd.Ilyas. (2016). *Kharif Jowarivaril dani bhurashi chi lakshane, nuksan ani vaivsthapan*. Vasantrya Naik Marathwada Agricultural University, Parbhani. *Shetbhati*.
- V.M.Gholve, H.V.Kalpande and Mohd.Ilyas. (2016). *Rabi Jowarivaril rogachi lakshane, nuksan ani vaivsthapan*. Vasantrya Naik Marathwada Agricultural University, Parbhani. *Shetbhati*.

Information bulletin

- Das IK, Nagaraja A and Tonapi VA. 2016. Diseases of millets- a ready reckoner. Indian Institute of Millets Research, Rajendranagar, Hyderabad 500030, Telangana. 67p. ISBN: 81-89-335-59-6.

Conference paper / poster

- Rashmi, U. S. and Chattannavar, S. N., 2016. *Rhizobacteria* for the management of *Fusarium* wilt in pigeon pea. Indian Phytopathological Society, South Zone Meet held at UAS Dharwad, 15-16 December, 2016.
- Das, I.K., Sharma, S.K., Govardhan, C., and Vilas A Tonapi 2016. Management of millet diseases- challenges and way forward. Lead lecture presentation in national symposium on "Challenges towards Plants health under Changing Climate Scenario for Sustainable Agriculture" organized by Indian Society of Mycology & Plant Pathology and Bidhan Chandra Krishi Viswavidyalaya, Kalyani from 24-26, November 2016.

Annexure I: Performance of the Centres

Trial No.	1	2	3	4	5	6	7	9	10	11	
Sr.	Trail/ Location	AHT- GS	AVT- GS	IHT- GS	IVT- GS	IAVHT- MC	AVHT- SC	IVHT- SC	IAVHT- SS	NGN- I&II	AVN
1	Parbhani	Y	Y	Y	Y	-	-	-	Y	Y	-
2	Akola	Y	Y	Y	Y	-	-	-	Y	Y	-
3	Dharwad	-	-	-	-	-	-	-	-	-	-
4	Coimbatore	Y	Y	Y	Y	Y	Y	Y	-	-	-
5	Surat	Y	Y	Y	Y	Y	Y	Y	Y	Y	-
6	Pantnagar	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
7	Ludhiana	-	-	-	-	Y	Y	Y	-	-	-
8	Hyderabad	-	-	-	-	-	-	-	-	Y	-

Y= data received in time; '-'= Trial not allotted

Annexure II: Details of collaborator

Centre	Collaborator, Address
Akola	Prof. HS Gahukar, Sorghum Pathologist, Sorghum Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth Akola-444104, Maharashtra
Parbhani	Dr. VM Gholve, Pathologist, AICSIP, Vasantrya Naik Marathwada Agricultural University, Parbhani-413722, Maharashtra.
Surat	Mr Nirav Radadiya, Research Scientist, Main Sorghum Research Station, Gujarat Agricultural University, Surat-397007, Gujarat
Pantnagar	Dr. Yogendra Singh, Senior Research Officer, CAS in Plant Pathology, College of Agricultural GB Pant University of Agriculture & Technology, Pantnagar-263145, Uttarakhand
Ludhiana	Dr. Upasana Rani, Plant pathologist, Pulses section, PBG, Punjab Agriculture University Ludhiana, Punjab
Coimbatore	Dr. B Selvi, In charge AICSIP, Tamil Nadu Agricultural University, Coimbatore-641003, Tamil Nadu

Annexure III: Disease resistant and susceptible checks

Checks	Grain Mold	SDM	Rust	Anthracnose	Zonate LS	Leaf blight
IS 14332	R	R	R	R	MR	R
B58586	R		R	R	MR	R
Bulk Y	S		S		S	
296B	S	R	R	R	MR	R
QL 3		R	S		S	
DMS 652		S	S		S	
H 112	S	S	S	S	MR	S
IS 2312			R	MR	S	R
Kekri Local	R	S	S	S	S	S
Rampur Local	R			S	S	
Pant Chari 5				R	R	
SSG 59-3			R	MR	S	MR

R= resistance, S= susceptible, MR= moderately resistance

Appendix 1.1: Diseases and causal organisms

Grade	Disease	Causal organism
1	Grain mold	<i>Fusarium moniliforme</i> , J. Sheld; <i>Curvularia lunata</i> , <i>Phoma sorghina</i> & other
2	Downy mildew	<i>Peronosclerospora sorghi</i> (W. Weston & Uppal) C. G. Shaw
3	Ergot/Sugar diseases	<i>Sphacelia sorghi</i> Mc Rae
4	Charcoal rot	<i>Macrophomina phaseolina</i> Tassi. Goid
5	Rust	<i>Puccinia sorghi</i> Cooke
6	Anthraxnose	<i>Colletotrichum graminicola</i> (Ces G.W. Wils)
7	Leaf blight	<i>Exserohilum turcicum</i>
8	Zonate leaf spot	<i>Gloeocercospora sorghi</i> Bain & Edgertom ex Deighton
9	Rough leaf spot	<i>Aschochyta sorghi</i> Sacc
10	Gray leaf spot	<i>Cercospora sorghi</i> Ellis & Everh
11	Sooty stripe	<i>Ramulispora sorghi</i> (Ellis & Everh) Olive & Lefebvre in Olive et.al.
12	Target leaf spot	<i>Bipolaris sorghi</i> (Sacc) Shoemaker.

Appendix 1.2: Grades for estimation of diseases

Grain mold: Field grade/Panicle grain mold rating (PGS), Threshed grade/threshed grain mold rating (TGS)

Severity Grade	Description (% grains molded on panicle)	Disease Reaction
1	0 to <1	Highly Resistant
2	1-5	Resistant
3	6-10	Resistant
4	11-20	Moderately resistant
5	21-30	Moderately resistant
6	31-40	Susceptible
7	41-50	Susceptible
8	51-75	Highly Susceptible
9	>75	Highly Susceptible

Ergot (incidence)

Grade	Description (% panicle infected)	Disease Reaction
1	0 to <1	Highly Resistant
2	1-5	Resistant
3	6-10	Resistant
4	11-20	Moderately resistant
5	21-30	Moderately resistant
6	31-40	Susceptible
7	41-50	Susceptible
8	51-75	Highly Susceptible
9	>75	Highly Susceptible

Downy mildew: Calculate in per cent term for systemically infected plants. Grade disease reactions as follows; Resistant =≤5%; Moderately Resistant =6-10% Susceptible =11-30%; Highly Susceptible =≥30%.

Foliar Diseases: (anthracnose, zonate leaf spot, leaf blight, rust, sooty stripe, grey leaf spot, target leaf spot)

Grade	Description	Disease Reaction
1	No symptoms seen on the leaf and perfectly healthy	Highly Resistant
2	1-5% of the leaf area is affected by spot	Resistant
3	6-10% of the leaf area is affected by spot	Resistant
4	11-20% of the leaf area is affected by spot	Moderately resistant
5	21-30% of the leaf area is affected by spot	Moderately resistant
6	31-40% of the leaf area is affected by spot	Susceptible
7	41-50% of the leaf area is affected by spot	Susceptible
8	51-75% of the leaf area is affected by spot	Highly Susceptible
9	>75% of the leaf area is affected by spot	Highly Susceptible