9 ICAR-ICRISAT collaborative research projects

Contents

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1. Project title:

SG1: Breeding for trait-based sorghum hybrid parents for specific end-uses and their testing for use in the national program

2. Lead Scientists/ collaborators: ICAR: Prabhakar; ICRISAT: Belum VS Reddy

3. Objectives

1. Improve/develop *kharif* sorghum seed parents suitable for alternate industrial uses (*kharif* hybrids)
2. Improve/develop *rabi* sorghum seed parents suitable for indigenous food products making (*rabi* hybrids)
3. Develop techniques to screen for and unraveling the genetics of grain luster.
4. Develop forage sorghum hybrids
    a. Improve female lines of forage sorghum for high green fodder yield, brown mid-rib trait and sweet stalk with resistance to stem borer and foliar diseases – leaf rust, anthracnose and leaf blight (forage hybrids).
    b. Improve restorer lines/varieties for multicut ability with brown mid-rib trait and sweet stalk with resistance to stem borer and foliar diseases and Sudan grass lines with downy mildew resistance and sweet stalk.
    c. Improve tillering population for sweet stalk with brown mid-rib trait and resistance to stem borer, and foliar diseases.
    d. Characterize variability in populations of *Exserohilum turcicum*, the leaf blight (LB) pathogen from different agroecological zones (AEZs).
    e. Identify sources and genes/QTLs for resistance to LB
5. Test specific hypotheses and value of traits for adaptation to specific niches or end uses as per proposed target area through field testing and simulation modeling
6. Identify potential target regions for specific niche type (e.g, Sweet sorghum) and adaptation – salinity, acid soils etc. to extend the production regions and estimate sorghum production by variety/region
7. Verification of usefulness of all parental lines for specific traits based at ICRISAT (Seasonal adaptation. Sweet stalks, nutrient-dense varieties, etc.)

4. Status/ Progress report

In a work plan development meeting held at National Research Centre for Sorghum (NRCS) during 25 May 2007 and attended by Dr Belum VS Reddy, Dr CT Hash and Ms P Sanjana Reddy from ICRISAT and Scientists from NRCS, the following areas were decided to be concentrated through ICAR-ICRISAT research partnership in sorghum - (a) breeding for rainy season adaptation with resistance to grain mold, (b) breeding improved forage sorghum, (c) breeding for post rainy season adaptation and (d) breeding for abiotic stress (acidity and salinity) tolerant sorghums. In order to avoid similar parallel work, NRCS scientists were asked to develop full work plans. However, based on the meeting, the following outputs were achieved at ICRISAT, Patancheru under the aegis of ICAR-ICRISAT partnership project, "Project No. ICAR/ICRISAT SG 1. Breeding for trait-based sorghum hybrid parents for specific end-uses and their testing for use in the national program".

Objective 1: Improve/develop *kharif* sorghum seed parents suitable for alternate industrial uses (*kharif* hybrids)

Activity 1.1: Evaluation of available hybrid parents for high starch content (BVSR)
Rainy season sorghum cultivation can be promoted through its exploitation for alternative uses. Though the demand of rainy season sorghum for food use is declining, it is being increasingly used in poultry and animal feed rations and better prospects lie in its utilization in the making of potable alcohol. Grains with high starch content are preferred for this purpose. ICRISAT developed 689 high yielding and trait-specific A-/B-lines until 1998. A total of 51 A-/B-lines were selected based on grain size (ranging from 3.5 to 4.3 g 100^{-1} grains) and these were evaluated along with 14 new A-/B-lines (developed in 2006). Grain samples of these 65 A-/B-lines are being tested for starch content at ICRISAT, Patancheru. The starch content ranged from 60.2% to 72% in these lines. Seven B-lines (ICSB 73, ICSB 661, ICSB 474, ICSB 52, ICSB 745 and ICSB 625) had starch content above 70%.

Objective 2: Improve/develop *rabi* sorghum seed parents suitable for indigenous food products making (*rabi* hybrids)
Activity 2.1. Improvement of maintainer and restorer populations through recurrent mass selection (BVSR)

(a) Post rainy season B-population: Giddi Maldandi F_4 bulk was introgressed into post rainy B-population bulk (R1) during 2007 rainy season. From the population bulk, 196 dwarf steriles with moderate to bold grain size and from Giddi Maldandi F_4 bulk, 67 fertiles were harvested. These are planted along with M 35-1 derivatives bulk and dwarf B-lines × post rainy varieties bulk during 2007 post rainy season for the development of post rainy season adapted B-population.
(b) AICSP-shoot pest post rainy season population (restorer): The shoot pest population is being introgressed with SPV 1411, Moulee and M 35-1 (post rainy season varieties) for developing restorer population with postrainy season adaptation.

Objective 7: Verification of usefulness of all parental lines for specific traits based at ICRISAT (Seasonal adaptation. Sweet stalk, nutrient-dense varieties, etc.)
Activity 7.1 Conducting joint reviews, workshops, field days and monitoring nurseries

A. Training program: International learning program on "Sorghum hybrid parents and hybrids research and development" was conducted from 6 to 17 February, jointly by ICRISAT-Patancheru and National Research Center for Sorghum, Rajendranagar. There were 18 participants from both public and private sectors in India, Philippines (one) and Sudan (one).

B. Nurseries/ Trials: Seeds of sweet sorghum varieties (4), B-lines (3) and hybrids (3) were multiplied and sent to NRCS, Hyderabad, India, for testing at the All India Coordinated Sorghum Improvement Project (AICSIP) locations in the 2007 rainy season. Three hybrids (ICSSH 19, ICSSH 21 and ICSSH 24) and one variety (ICSV 93046) were tested along with 9 cultivars developed by NARS and 3 checks (SSV 84, CSV 19SS and CSH 22SS) at five AICSIP locations (Rahuri, Phaltan, Coimbatore, Perumal Palli, and NRCS) during 2007 rainy season. ICSSH 24 was the top yielder for ethanol (1390 l ha^{-1}), per day ethanol (11.79 l ha^{-1} day^{-1}), total sugar (2.61 t ha^{-1}) and second top yielder for grain (2.13 t ha^{-1}). ICSV 93046 ranked second for ethanol yield (1382 l ha^{-1}) and total sugar yield (2.6 t ha^{-1}). Apart from the sweet sorghum lines, Salinity tolerant lines (21), Acid soil tolerant lines (12), *Striga* tolerant lines (20) were sent to NRCS for trait-based screening and Sudan sorghum landraces (93) for downy mildew screening. The results are awaited.

C. Field days and meetings

1. Belum VS Reddy, CT Hash and P Sanjana Reddy attended a work plan development meeting held at NRCS during 25 May 2007 and identified the areas (a) breeding for rainy season adaptation with resistance to grain mold, (b) breeding improved forage sorghum, (c) breeding for post rainy season adaptation and (d) breeding for abiotic stress (acidity and salinity) tolerant sorghums – for full work plans development.
2. Belum VS Reddy and A Ashok Kumar attended the field day and seed sector researchers meeting at NRCS conducted on 29th September 2007 to visit the rainy season experiments and participate in the general discussion
3. Dr N Seetharama, Director, NRCS attended the ICRISAT-private sector consultation group meeting held on 31 October 2007 at ICRISAT Patancheru and contributed to the discussion.

Publications:

Journal Articles

1. Reddy BVS, **Ramesh S, Borikar ST** and **Hussain Sahib K** 2007. ICRISAT-Indian NARS partnership sorghum improvement research: strategies and impacts. Current Science, 92 (7): 909-915.
2. Ravinder Reddy Ch, **Tonapi Vilas A**, Ashok Alur A, Reddy BVS, Gowda CLL, Parthasarathy Rao P and Rai KN. 2007. Resurgence of sorghum foods in urban areas and alternate uses of sorghum grain. www.commodityindia.com, Comprehensive agri-commodity intelligence, 7(1): 28.
3. Reddy BVS, **Ramesh S**, Sanjana Reddy P and Ramaiah B. 2007. Combining ability and heterosis as influenced by male-sterility inducing cytoplasms in sorghum [Sorghum bicolor (L.) Moench]. Euphytica 154: 153-164.
4. Mula Rosana, **Ramesh S** and Reddy BVS. 2007. Harnessing public-private partnership for enhanced impacts of crop improvement research: The case of sorghum. Asian seed and planting material 14(4): 8-10.

Invited Seminars

1. Ashok Kumar A, Reddy BVS, Parthasarathy Rao P, Sahrawat KL, **Seetharama N** and **Longvah T.** 2007. Sorghum grain micronutrients and β-carotene – role in the diets and scope for their genetic enhancement, Indian biofortification program, 19-21 March 2007, New Delhi.

Manuals

1. Reddy BVS, **Ramesh S**, Ashok Kumar A and CLL Gowda (eds.). 2007. Sorghum Manual. Information Bulletin No. .Patancheru 502 324. Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

News Articles

1. Reddy BVS, Sharma HC, Thakur RP, **Ramesh S** and Ashok Kumar A. 2007. Characterization of ICRISAT-Bred Sorghum Hybrid Parents. Special Issue. International Sorghum and Millets Newsletter 48: 1-123.

Names of collaborating scientists:

ICAR/National institutes: Prabhakar , S Audilakshmi, B Venkatesh Bhat, SS Rao, HS Talwar, N Seetharama, R Madhusudhana, SK Ahmmed, R Velzhahan, TG 'Nageshwara Rao, VR Bhagwat, Vilas Tonapi, V Rajaram, Vijay Sai Reddy, Ashok Reddy, Shekarappa, Daware , PV Makar, Prem Kishore, Yogendra Singh, Kusum Mathur, M Khaiyum, K Mathur, YD Narayana, BD Biradar, Gowri Sajjanar, RB Solunke

ICRISAT: Belum VS Reddy, HC Sharma, RP Thakur, P Parthasarathy Rao

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Objective 4d. Characterize variability in populations of *Exserohilum turcicum*, the leaf blight pathogen from different agro-ecological zones.

Activity: Conduct Sorghum Leaf Blight Virulence Nursery at selected locations in India

Objectives-

=Characterize variability in populations of *E. turcicum*, and

= Identify sources of stable resistance to LB

Collaborators

Universities:

Dr. Kusum Mathur, Sorghum Pathologist, MPUAT, Udaipur

Dr. Y. D. Narayana, Sorghum Pathologist, UAS, Dharwad

ICRISAT

Dr. R. P. Thakur, Principal Scientist, ICRISAT, Patancheru

Brief report: The Sorghum Leaf blight Virulence Nursery comprising of 20 lines was conducted at three Locations - Udaipur, Patancheru (ICRISAT) and Dharma in Kharif 2007. The nursery comprised of 19 sorghum lines that had shown differential reactions to the populations of the pathogen in preliminary studies, and one susceptible line IS 18442 as check. Each entry was grown in two rows, 4m long in two replications. Standard cultural practices for crop management were followed according to the local recommendations. At Patancheru the entries were planted in September and overhead sprinklers were provided to maintain humidity above 90%, while at Udaipur and Dharwad, planting was done in July and during dry spells humidity was provided by irrigations. The entries were inoculated with actively growing culture of the local isolate of E. turcicum grown for 10 days on autoclaved sorghum grains, air-dried and 2-3 grains placed in whorls of 25-days- old plants. Ten plants in each entry in each replication were randomly tagged for recording observations. Observations for leaf blight severity were recorded at soft-dough stage of the plants, on the standard 1-5 scale Based on the per cent of the total leaf area infected, where 1= No symptoms seen on leaves; 2 = Traces to 10 per cent leaf area infected; 3 = 11 to 25 per cent leaf area infected, 4 = 26 to 50 per cent leaf area infected, and 5=Above 50 per cent of leaf area infected .The weather data during the crop were also collected. For

discerning disease reaction, disease scores of 1 ϕ 2 were considered as resistant (R) reaction, 2.1 to 3.0 as moderately resistant (MR), and 3.1 to 5 .0 as susceptible (S) reactions.

The disease pressure at Patancheu and Udaipur was good as the susceptible check IS 18442 developed mean disease scores of5.o and 4.6, respectively, showing susceptible reaction to leaf blight but at Dharwad, disease did not develop at all and hence the data from Dharwad have not been included in this report. Some entries showed differential reaction at Udaipur and Patancheru. IS 2834 showed R reaction at Patancheru but S (mean score 3.2) at Udaipur, while IS 3490 was S (mean score 4.1) at Patancheru but R (mean score 2.0) at Udaipur. Similarly, IS 25400 and IS 26866 showed S reaction (mean score 3.1 and 5.0, respectively) at Patancheru, but R (mean score 1.0 and 1.4, respectively) at Udaipur (Table 1). IS 26863 showed MR reaction (score 2.8) at Patancheru, but R reaction at Udaipur. IS 30403, IS 20944 and IS 22545 developed higher scores of LB (5.0, 5.0 and 4.9, respectively) at Patancheru as compared to 3.3, 3.6 (S reaction) and 2.6 (MR reaction), respectively, at Udaipur. IS 9303 showed R reaction at both the locations, while IS 12466, IS 13904, IS 18668 and IS 19163 showed MR reaction to leaf blight at both the locations. Pooled ANOVA (Table 2).for leaf blight severity across the two locations revealed significant (*P*= 0.001) effects of locations, genotypes and Location × Genoypes interactions

Table 1. Leaf blight severity of the 20-entry Sorghum Leaf Blight Virulence Nursery (SLBVN) during 2007 rainy season at two locations.

Ent No	Entry	Leaf blight severity (1-5 scale)[a]		
		Patancheru	Udaipur	Mean
1	IS 2683	2.4	2.3	2.3
2	IS 2834	1.3	3.2	2.3
3	IS 3490	4.1	2.0	3.0
4	IS 9303	2.0	1.0	1.5
5	IS 10284	4.5	3.3	3.9
6	IS 10775	3.9	3.2	3.5
7	IS 12466	2.6	2.7	2.6
8	IS 13057	2.7	3.1	2.9
9	IS 13904	2.2	2.1	2.1
10	IS 15745	3.6	3.8	3.7
11	IS 18668	2.3	2.0	2.1
12	IS 19163	2.3	1.8	2.0
13	IS 20944	5.0	3.6	4.3
14	IS 22545	4.9	2.6	3.7
15	IS 25069	2.3	3.0	2.6
16	IS 25400	3.2	1.4	2.3
17	IS 26863	2.8	1.0	1.9
18	IS 26866	3.1	1.6	2.3
19	IS 30403	5.0	3.3	4.1
20	IS 18442 (sus check)	5.0	4.8	4.9
	Mean	3.2	2.6	2.9
	SE (m)±	0.24	0.09	0.17
	LSD (*P*<0.05)	0.72	0.28	0.50
	CV (%)	10.6	5.1	7.9

[a]*Mean of 2 replications, 10 tagged plants/replication based on 1-5 scale, Where 1= no symptoms/chlorotic flecks; 2 = up to 10% leaf area covered With small restricted lesions; 3=11-25% leaf area covered with lesions; 4=26-50% leaf area covered with large coalescing lesions and 5=>50% leaf area covered with large coalescing lesions.*

Table 2. Pooled ANOVA for leaf blight severity across two locations (Patancheru and Udaipur)

Source of variation	df	SS	MS
Replication	1	0.28561	0.28561
Location (L)	1	8.45000	8.45000***
Genotypes (G)	19	67.08295	3.53068***
Location × genotype	19	21.80395	1.14758***
Residual	39	2.77130	0.07106
Total	79		

***Significant at P<0.001.

SG 2: Marker-assisted improvement of elite sorghum genotypes for shoot fly tolerance and the stay-green component of terminal drought tolerance

Objectives:

1. To improve sorghum cultivars for tolerance to terminal drought (staygreen) and resistance to shoot fly.
2. To evaluate stay-green trait and shoot fly resistance QTL introgression lines.

Sub-project 1: Marker-assisted backcrossing of stay-green QTL from B35 and E36-1 donors into the genetic back ground of M35-1 (Scientists involved: R Madhusudhana and CT Hash)

1. Marker-assisted introgression of staygreen QTL

Target regions for introgression of staygreen QTL: Quantitative trait loci and the corresponding flanking molecular markers for staygreen have been identified and validated across environments, years, and/or different genetic backgrounds in recent publications (Table 1). Using common markers and through comparison with other genetic linkage maps of sorghum [(Boivin et al. 1999; Peng et al. 1999; Subudhi and Nguyen 2000; Bhattramakki et al. 2000; Kong et al. 2000), Hausmann et al. (2003)], Subudhi *et al*. (2000) identified four consistent QTLs controlling staygreen (*stg1, stg2, stg3, stg4*) from B35 source of staygreen. Haussmann et al. (2003) identified three QTLs that could be potential candidates for marker-assisted transfer of staygreen from another staygreen genotype E36-1 (donor) into locally adapted materials.

Table 1: Summary of Quantitative Trait Loci Studies on staygreen in sorghum

Trait	Number of QTL	Phenotypic variation explained (%)	Effects of individual QTLs (Range, in %)	Number of linkage groups	Reference
Staygreen (Post-flowering stress tolerance)	6		2 Major	6	Tuinstra et al. (1997)
	7	63.0	3 major QTL- 42.0 4 minor QTL- 25.0	6	Crasta *et al.*(1999)
	2-3	-	10.3-15.3	3	Tao *et al.* (2000)
	4	30-46		3	Xu *et al.* (2000)
	4	30-54	9.1-29.2	3; Confirm Xu et al. (2000)	Subudhi et al. (2000)
	9	15.5-26.1	10.2-15.5	7; 3 QTL confirm earlier studies	Kebede et al.(2001)
	5-8	31-42	5-26	8; 3 QTL consistent across genotypes & years	Haussmann et al. (2003)

Based on the above information, we decided to target introgression of single QTL or more than one QTL among identified QTLs *stg1* (LG C), *stg2* (LG C), *stg3* (LG B) and *stg4* (LG J) from B35 source. As advised, for the time being, we are concentrating on the introgression of staygreen QTLs from B35 source only.

Progress during 2007-08: Production of BC_2F_1s: Under this programme, improvement of popular rabi cultivar, M35-1 for staygreen trait is targeted through marker-assisted backcrossing using staygreen trait donor parent B35. The elite rabi sorghum varieties, M35-1 were crossed with B35 during summer 2006. The $F_{1:0}$ seeds of M35-1 x B35 have been harvested along with parents for further backcrossing. The F_1 between M35-1 x B35 was planted during rabi 2006 for the development of BC_1F_1 of (M35-1 x B35) x B35. The BC1F1 progeny were planted during Kharif 2007 along with recurrent parent M35-1, and 23 BC_2F_1s (((M35-1 x B35) x M35-1) x M35-1) were developed. The material will be advanced to BC_3F_1s and BC_2F_2s involving foreground and background selections.

Development of sorghum drought EST-SSRs: At NRCS, a total of 109 EST-SSRs have been synthesized for use in mapping. These EST sequences contain high-quality SSRs which may be useful for mapping drought related genes, diversity analysis and also genetic purity test. Out of the 109 SSRs, 42% were polymorphic between the parents, M35-1 x B35.

Development of Staygreen linked SSRs: Most of the earlier reported staygreen linked markers are RFLPs and therefore, their routine use in marker-assisted sorghum breeding is too cumbersome and not easily applicable. At NRCS, to increase the marker density around the staygreen QTL with genic-microsatellites, we studied the synteny between reported four major staygreen QTL regions with that in the rice genome, and developed 50 genic-microsatellites specific to 4 QTLs (18, 12, 15, and 5, for Stg1, Stg2, Stg3, and Stg4 QTL, respectively). we could establish synteny of the sorghum QTL regions Stg1, Stg2, Stg3, and Stg4 with that of the rice genome by mapping ten polymorphic genic-microsatellite markers (20%) to the positions of the staygreen QTL (Fig. 1) using 296B x IS 18551 population. Moreover, the synteny of the QTL with rice genome enabled us to identify some possible candidate genes related to leaf senescence. The markers so developed provide an easy option for MAS of the staygreen trait in sorghum.

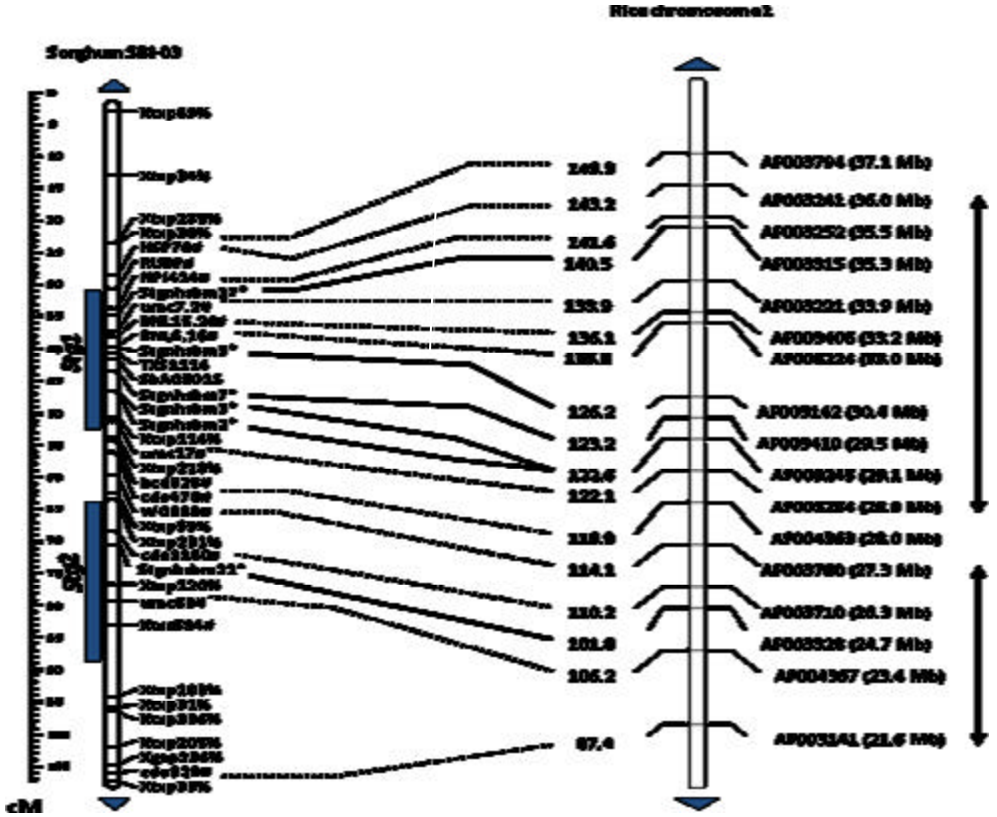

Fig.1. Synteny of the sorghum QTL regions Stg1, Stg2 with that of the rice genome

Sub-project 2: Pyramiding of shoot fly tolerance QTL in the genetic background of 296B and BTx623 (Scientists involved: CT Hash and PG Padmaja)

NRCS:

1. **Evaluation of BTx623 lines for shoot fly tolerance:** A total of 32 shoot fly introgression lines in BTx623 background from ICARISAT were evaluated along with the recurrent parent (BTx623) and the donor (IS18551) in 3 replications during both Kharif 2007 and rabi 2007-08 seasons at NRCS, Hyderabad using the standard fish-meal technique.

Kharif 07: The introgressed lines differed significantly for their shoot fly response expressed as deadhearts (DH %). The recurrent parent, BTx 623 recorded 82% of deadhearts while the donor, IS18551 showed 32% DH. Of the 32 lines tested, 19 were significantly better than the recurrent parent in their DH. However, none were significantly better than the donor IS18551. The line J2650 was the best among the introgressed lines with 38% of DH followed by J2680, J2752 and J2777 (all <42 DH %).

Rabi 07-08: The introgressed lines differed significantly for their shoot fly response expressed as deadhearts (DH %). The recurrent parent, BTx 623 recorded 63% of deadhearts while the donor, IS18551 showed 18% DH. Of the 32 lines tested, 29 were significantly better than the recurrent parent in their DH. However, none were significantly better than the donor IS18551. The line J27520 was the best among the introgressed lines with 25% of DH followed by J2662, J2785 and J2833 (all < 29 DH %). Across the two seasons, J2752 performed significantly better than its recurrent parent BTx623. The combined analysis over both the seasons identified 4 introgressed lines viz., J2752 (33%), J2662 (36%), J2650 and J2833 (37%) as better than the recurrent parent BTx 623(72%) while the donor IS18551 recorded 25% deadhearts.

2. **Evaluation of 296B lines for shoot fly tolerance:** A total of 72 shoot fly introgression lines in 296B background from ICRISAT were evaluated along with the recurrent parent (296B), the donor (IS18551) and the standard line BTx623 in 2 replications during both Kharif 2007 and rabi 2007-08 seasons at NRCS, Hyderabad using the standard fish-meal technique. However, during Kharif 2007 season, there was no/very poor germination of the lines. Hence the trial was vitiated.

In the rabi season of 2007/08, out of the 72 lines evaluated, data from 39 lines was recorded due to poor germination in the other 33 lines. Hence the data from 39 lines along with the 3 checks was used for analysis. The introgressed lines differed significantly for their shoot fly response expressed as deadhearts (DH %). The recurrent parent, 296B recorded 75% of deadhearts while the donor, IS18551 showed 18% DH. Of the 39 lines tested, 29 were significantly better than the recurrent parent in their DH. However, none were significantly better than the donor IS18551. The line J3315 was the best among the introgressed lines with 27% of DH followed by J3059(28%), J3121(29%) and J3119 (31%).

MAS to improve 296B: At NRCS, to intogress shoot fly tolerance traits into 296B from the donor, IS18551, Six BC_2F_1s of ((296B x IS18551) x 296B) were developed using 296B as recurrent parent. The material will be advanced to BC_3F_1s and BC_2F_2s and foreground and background selection will be done to identify the backcross progenies similar to the recurrent parents with introgressed genomic segments for shoot fly resistance from the donor parents.

ICRISAT:

MAS to improve BTx623: Selected BTx623-background QTL introgression lines [for QTLs on LG G (trichomes and glossiness) and LG J (glossiness)] were crossed at ICRISAT to initiate resistance QTL pyramiding and conversion to A-lines during kharif 2007. During rabi 2007-08, replicated SF nursery evaluation of BTx623-background introgression lines were conducted at ICRISAT. Additional seed of 296B- and BTx623-background shoot fly resistance QTL introgression lines, parents and checks were multiplied for furhter experiments.

Sub-project 3: Marker-assisted backcross introgression of shoot fly and stay-green QTL in the genetic background of rabi B and R parental lines; (Scientists involved: CT Hash and Gowri Sajjanar and SP Mehtre)

Parbhani: In the new marker-assisted backcross program for shoot fly resistance, during 2006-07, 20 BC_1F_1 were developed using four recurrent parent i.e. 116B, 104B, 107B, SPV 492 (rabi adopted maintainer line) and nine shoot fly resistance donor parents i.e. IS 18551, RIL 153, 166, 189, 252 (derived from BTx 623 X IS 18551) and RIL 97, 168, 174, 222 (derived from 296B X IS 18551) shoot fly resistance mapping populations.

During 2007-08, fifteen plants of each of thirteen BC_1F_1 populations were genotyped with six SSR marker loci linked to three targeted shoot fly resistance QTLs. Heterozygous plants with one or more than one QTL introgression were identified and crossed with respective recurrent parent and developed seed of 13 BC_2F_1. During summer 2008, thirty plants of each of thirteen BC_2F_1 populations will be genotyped with six SSR marker loci linked to three targeted shoot fly resistance QTLs. Heterozygous plants have one or more than one QTL introgression will be identified and crossed with respective recurrent parent and developed seed of 13 BC_3F_1.

In advance Marker Assisted backcross breeding program, during 2006-07, generated BC_2F_4 material using two recurrent parent backgrounds (20B, KR192 developed at MAU, Parbhani) for shoot fly resistance. 23 BC_2F_4 MAS generated progenies were screened along with 3 resistant checks, 1 susceptible check, 1 local check, 2 RILs and 2 susceptible recurrent parents in three locations (NRCS-Hyderabad, UAS-Dharwad, MAU-Parbhani) during late Kharif 2007. The entries were evaluated in two-row plots with three replications against shoot fly using fish meal technique. The observations were recorded on number of shoot fly eggs per 5 plants at Dharwad, Hyderabad, Parbhani; no. of

plants with eggs (%) at Parbhani; and deadhearts (%) at Dharwad, Parbhani and Hyderabad at 14- , 21-, and 28- days after emergence (DAE).

There are no significant differences in eggs infested plants at 1% level, the least eggs infested plants were noticed in MAS 1076-1 (73.8%). The no. of eggs per 5 plants ranged from 1.6 to 5.9 across locations. The resistant check (ICSV 705, IS 2312 and IS 18551 recorded 45% deadhearts, while susceptible check (DJ 6514) showed 79.9 % deadhearts. The recurrent parents 20B and KR 192 were highly susceptible with more than 85% deadhearts. Among the MAS progeny, for deadhearts at 28 DAE, progenies MAS 1061-1, MAS 1062-1, MAS 1062-3, MAS 1062-7, MAS 1076-1, MAS 1261-3 at Parbhani; MAS 1062-3, MAS 1261-3 at Hyderabad were found to be at par with resistant checks at 5% level, while at Dharwad location no entry was recorded lower deadhearts% than resistant checks. Across locations, the MAS progenies of 20B *viz.,* MAS 1062-3 (single QTL on G), MAS 1076-1(three QTLs on A+G+J), and MAS 1261-3 (QTL on G) recorded lower infestation and were at par with resistant check IS18551 at 5%.

Similarly, 34 BC_2F_4 MAS generated progenies along with its parents and check were screened for shoot fly resistance across three locations (NRCS-Hyderabad, RRS-Bijapur and MAU-Parbhani) in rabi 2007-08. The performance of MAS entries will be presented in the next rabi sorghum meeting to be held during July 2008

Bijapur: Selected BC_3F_1 generation breeding material is being advanced to BC_4F_1/BC_1F_4 at Bijapur

Sub-project 4: Field evaluation of staygreen QTL introgression lines in the genetic background of R16 (Scientists involved: CT Hash, Gowri Sajjanar, HS Talwar and SP Mehtre)

During rabi 2007-08, Replicated trials are being conducted to evaluate R16- and S35-background stay-green QTL introgression lines in replicated field trials at ICRISAT (irrigated control and rainfed); RRS-Bijapur (rainfed); MAU-Parbhani (rainfed) and NRCS (rainfed). At NRCS, trials are being conducted under "plus" and "minus" irrigations treatments to be imposed during terminal growth period. The germination was poor in about 45 entries in R16 background. The required sets of observations (phenology, pant stand, SPAD score, estimation of green leaf area etc) in both the trials are being recorded at present. The progress of the experiments will be presented in the next rabi sorghum meeting to be held during July 2008

Others:
Evaluation of RIL populations: F_8 generation recombinant inbred lines of two staygreen populations viz., N13 x E36-1(221 RILs) and IS9830 x E36-1 (223 RILs) are being evaluated in three replications for various agronomic, staygreen and charcoal rot traits at Bijapur, Rahuri, and Parbhani centers.

1. Project no and Title:

SG 3: Insect-host plant-environment interactions on aphids, shoot fly and shoot bug in rabi sorghum

2. Lead scientists: VR Bhagwat / HC Sharma
3. Objectives:

1. Identification of stable sources / improved lines for resistance to insect pests.
2. Insect-host plant-environment interactions for shoot bug and sugarcane aphid.
3. Role of HPR in IPM of sorghum pests (with special reference to sucking pests)
4. Effect of damage by sucking pests on grain and fodder quality

4. Status/Progress report:

Objective 1: Identification of stable sources / improved lines for resistance to insect pests.

Activity and time frame: Evaluation of germplasm/improved lines for resistance to insect pests across locations (2006-2008)

Identification of sources of resistance to sugarcane aphid, *Melanaphis sacchari*: Thirty-five sorghum lines comprising of improved breeding lines and germplasm accessions were screened for resistance to sugarcane aphid, *M. sacchari* during the 2006/07 postrainy season. There were three replications in a RCBD, and observations were recorded at physiological maturity on aphid damage (1 = <10% leaf area damaged, and 9 = >80% leaf area with aphid damage). Aphid damage scores ranged from 2.0 to 8.3, and the lines 61523, 61581, 61582, 61588, 61592, 61602, IS 40615, and IS 40616 suffered an aphid damage rating of <3.0 compared to 2.7 in the resistant check, TAM 428, and 8.3 in the susceptible check, Swarna.

In the cooperative trial with the All India Coordinated Sorghum Improvement Project, 48 genotypes were screened for resistance to sugarcane aphid, *M. sacchari* under natural field conditions. The material was evaluated for aphid damage at physiological maturity. The genotypes SLR 8, SLR 27, SLR 31, SLR 35, SLR 39, SLR 41, SLV 25, IS 3420, and PU 10-1 suffered an aphid damage rating of <4.0 compared to 3.3 in the resistant check, TAM 428, and 9.0 in the susceptible check, Swarna.

Twenty-eight sorghum lines comprising of improved breeding lines and germplasm accessions were screened for resistance to sugarcane aphid, *M. sacchari* during the 2007 rainy season. There were three replications in a RCBD, and observations were recorded at physiological maturity on aphid damage on a 1 – 9 scale as described above. Aphid damage scores ranged from 3.0 to 8.0, and the lines 61581, 61588, 61592, and DJ 6514 showed an aphid damage rating of <4.0 compared to 5.5 of the resistant check, TAM 428, and 8.0 in the susceptible check, Swarna.

Evaluation of segregating material for resistance to shoot fly, *Atherigona soccata* during the postrainy season: During the post rainy season 2006/07, 205 F_5 lines along with the resistant, IS 18551 and susceptible, Swarna checks, were evaluated for shoot fly resistance in a randomized complete block design with three replications. Deadheart incidence ranged from 5.7 to 83.6%, and 76 lines suffered <30% deadheart incidence compared to 19.7% in the resistant check, IS 18551, and 83.6% in Swarna. In another trial, 166 F_6 lines were evaluated for shoot fly resistance along with IS 18551 and Swarna. Deadheart incidence varied from 17.9 to 91.6% in the test material. Nine lines suffered <25% deadhearts compared to 28.3% in the resistant check, IS 18551, and 83.8% in Swarna.

In the F_7 trial, 19 lines were evaluated for shoot fly resistance along with IS 18551 – resistant check, and Swarna susceptible check. Deadheart incidence in the test material varied from 14.4 to 88.1%, and the lines 105-2, 104, 102, 107-3, 31`83-1, 114-1, and 103 suffered <40% deadhearts compared to 37.2% in the resistant check, IS 18551, and 86.0% in Swarna.

Activity and time frame: Develop greenhouse/lab techniques to screen for resistance to sucking pests.

Technique to screen for resistance to sugarcane aphid, *Melanaphis sacchari*: Nine genotypes along with the susceptible check, Swarna were evaluated for resistance to *M. sacchari* under greenhouse conditions using artificial infestation, and under laboratory conditions using detached leaf assay. Under greenhouse conditions, artificial infestation of the test material with aphid infested leaves from the field resulted in very high infestation by the sugarcane aphid. However, the trial entries could not be evaluated for aphid damage because of heavy shoot bug, *Peregrinus maidis* infestation. Under laboratory conditions, the test material was evaluated using detached leaf assay. Fifteen cm leaf discs from the middle portion of 5th leaf were inserted in 3% agar-agar in a 1 L plastic jar. Each leaf was infested with 10 gravid females. Numbers of aphids were counted 7 days after infestation. Aphid numbers varied from 19.8 on CK 60B to 168 aphids on Swarna. Aphid multiplication was lower on CK 60B, IS 21870, IS 40615, IS 40616, and IS 40618 (<90 aphids) compared to that on Swarna (168 aphids). These experiments will be repeated in the coming seasons to refine the screening technique.

Objective 2: Insect-host plant-environment interactions for shoot bug and sugarcane aphid.
Activity and time frame: Incidence/losses due to sucking pests in a diverse array of sorghum lines across sowing dates (2006-2008).

A trial on aphid/shoot bug was carried out at Rahuri, Solapur and Bijapur. The incidence of shoot bug was moderate (5-7 in 1-9 scale) at Bijapur. No incidence of aphid was occurred. The early incidence during seed ling was also observed but was very meager. (The results of rabi 2007-08 are awaited).

Objective 3: Role of HPR in IPM of sorghum pests (with special reference to sucking pests)

Activity and time frame: Evaluate HPR, agronomic practices, seed treatment, and chemicals for IPM of sorghum pests (2006-2008).

In Rabi 2006, a validation of IPM program has been conducted during Rabi 2006 at Kovilpatti, Solapur, Parbhani and Bijapur. The treatment of soil application of carbofuran 3G @ 20 kg/ha + whorl application of carbofuran 3G @ 8 kg/ha at 30 DAE + Pongemia pinnata leaf extract @ 5% spray at 60 DAE recorded lowest shoot fly dead hearts (4.3 %) and lowest aphid index (10.2%) on M 35-1 at Bijapur. Other centre also indicated that seed treatment either with Imidacloprid @ 5g/kg of seed or Thiomethoxam 70 WS @ 3 g/kg seed followed by application of endosulfan 0.07 % at 45 DAE or + spray of endosulfan @ 0.07% at 45 DAE gave highest grain and fodder yield. Intercropping with chickpea was proved economical, when seed treated with Thiomethoxam 70 WS @ 3 g/kg at Bijapur. (The results of Rabi 2007-08 are awaited)

Objective 4: Effect of damage by sucking pests on grain and fodder quality
Activity and time frame: Assess losses due to shoot fly and sucking pests.

Results of Rabi 2006-07:
Karnataka: In Dharwad region, there was heavy attack of shoot bug in Rabi sorghum and as a result severe incidence of stripe virus was observed. The intensity of shoot bug population and plant damage is increasing every year.

Maharashtra: In Marathwada region, the infestation of corn plant hopper (5-7%) was low and sugarcane aphid was moderate. In western Maharashtra, the appearance of sugarcane aphid was moderate, whereas shoot bug incidence was low (> 10%).

5. Summary and conclusion: Greenhouse and leaf disc assay are under evaluation to screen for resistance to sugarcane aphid, *M. sacchari*. Considerable progress has been made in identification of sources of resistance to shoot fly, sugarcane aphid, and shoot bug. Experiments are underway to assess the losses due to sucking pests during the postrainy season.

6. Names of collaborating scientists

ICRISAT:	HC Sharma	**ICAR**: 1.	VR Bhagwat
	BVS Reddy	2.	C Aruna
	Ashok Kumar	3.	G Shyam Prasad
	(ii) AICSIP centers-UAS, Dharwad	4.	Shekrappa

7. Project Status: Continuing.

Project No. and Title:

SG.4. Bio-intensive approaches for disease and nutrient management in sorghum

2. Lead Scientists/collaborators: ***ICAR***: IK Das; ***ICRISAT***: RP Thakur

3. Objectives
3.1 Explore induced systemic resistance as a mechanism for grain mold, stalk rot, stem borer and shoot fly management using microbial agents or their products.
3.2 Identify bacterial isolates imparting growth promotion and phosphate solubilization in sorghum.

4. Status/Progress report
Objective 3.1: Explore induced systemic resistance as a mechanism for grain mold, stalk rot, stem borer and shoot fly management using microbial agents or their products.

3.1.1 Evaluate bacterial and their products that reduce the incidence of grain mold and stalk rot; shoot fly and stem borer in glasshouse and field experiments (2006-2007).

Living cells of bacteria and bacterial protein (harpin$_{Ps}$) were evaluated for biocontrol efficacy against major sorghum diseases and pests. Some treatments gave promising results for management of grain mold and charcoal rot. At ICRISAT, Patancheru foliar application of harpin$_{Ps}$ (@20 µg/ ml) and bacterial bioagent (B4) (1x10^6 cfu/ ml) effectively reduced mold severity (panicle grain mold rating 8% and 11% at physiological maturity) in susceptible 296B compared to control (40%). However, these treatments were not effective on the susceptible Bulk Y (>80% incidence) and also in reducing post harvest grain colonization by mold fungi. For management of charcoal rot the Pseudomonas strains B2 & B4 were promising at NRCS, Hyderabad. Seed treatment with B2 and B4 reduced charcoal rot incidence (40% over control) in susceptible cv. CSV8R.

The effect of harpin$_{Ps}$ in reducing damage by shoot fly and stem borer was studied on the genotypes IS2312 (Shoot fly resistant), IS 2205 (stem borer resistant), DJ 6514 (susceptible check) and CSV 15 (local check) at NRCS. Application of harpin$_{Ps}$ (@10 µg/ ml) showed no significant difference in stem borer leaf damage percentage and shoot fly dead hearts percentage when compared within the same sorghum line. Irrespective of the genotypes, harpin$_{Ps}$ application had no significant effect on shoot fly oviposition at 21, 28 DAE. However, there was significant interaction effect between treatment and genotype.

3.1.2 Evaluate the selected potential bacterial agents for the mechanism of induced systemic resistance to grain mold and stalk rot complex (2006-2008).

Application of harpin$_{Ps}$ (@20 µg/ ml) at boot leaf stage effectively reduced mold severity in Curvularia lunata inoculated susceptible 296B compared to control (40% infection) at ICRISAT. However, induction of resistance was not sufficient to reduce mold infection and post-harvest grain colonization in highly susceptible line (Bulk Y; >80% mold infection). Therefore, efficacy of harpin$_{Ps}$ to induce systemic resistance in sorghum lines against grain mold should be confirmed using sorghum lines with varying levels of resistance.

Effect of foliar application of harpin$_{Ps}$ was negligible in reducing severity of leaf anthracnose in susceptible sorghum cultivar. At ICRISAT, anthracnose severity varied progressively from low to moderate to high at 10, 20 and 30 DAI. At 10 DAI, harpin$_{Ps}$ reduced anthracnose severity compared to control. However, at 20 and 30 DAI these treatments were not effective in influencing anthracnose severity on any of the sorghum lines.

At NRCS, three selected bacterial bioagents, Pseudomonas strain B2 and Bacillus strain B1 & B10 and salicylic acid were tested for their efficacy to impart induced resistance against stalk rot pathogen under pot experiments. Bioagent treatments reduced the length of stalk infection compared to control in charcoal rot susceptible cultivar. The Pseudomonas strain B2 restricted the intensity of tissue colonization in susceptible cultivar. Amount of stalk rotting by M. phaseolina in sorghum is highly influenced by physiological conditions of the plants and environmental stresses (moisture and temperature stress). As these variations were minimized in present experiment, ISR might have played some role in lesion inhibition.

Objective 3.2: Identify bacterial isolates imparting growth promotion and phosphate solubilization in sorghum

3.2.1 Evaluate bacterial isolates for their early stage growth promotional properties in sorghum (2006-2007).

There were significant variations among the bacterial strains in terms of response to growth of sorghum seedling at NRCS. Out of 15, two strains (Rb202 and Rb204) significantly improved seedling vigor (up to 30%) while three strains (Rb206, Rb207 and Rb208) reduced the vigor. One strain (Rb202) increased shoot biomass while others were neutral with no deleterious effect on biomass. Most of the strains had no negative effect on germination. The strain Rb202, which increased biomass and vigor and had no inhibitory effect on seed germination, is the most promising strain. This strain can be further tested for multiplication ability on sorghum root and rhizosphere compatibility.

3.2.2 **Evaluate bacterial isolates for their efficacy to improve phosphorus availability in sorghum growing soils (2007-2008)**

Useful bacteria for P-solubilization, siderophore production and antagonists for *M phaseolina* (*Mp*) were isolated from soil samples collected from farmers' fields in Andhra Pradesh, Maharashtra and Karnataka at ICRISAT and NRCS. One hundred and fifty four cultures promising for the traits listed above were obtained from the microbial collection at ICRISAT and subjected to confirmation studies. Based on *in vitro* study, one consortium of PSB has been identified. Testing of the PSB consortia along with consortia of *Mp* antagonists and TK ferment is in progress under field trial at Solapur. Analysis of soil of the experimental field for available P, total P, Kjhel N, exchangeable K and organic carbon have been completed. Recording of all required observations on the trial are in progress. Results are expected by end of February 2008.

5. Summary and/conclusions: Selected strains of bacteria can be useful for management of the soil-borne disease, such as charcoal rot but may not be as effective for foliar (anthracnose) and panicle (grain mold) diseases in sorghum. Bacterial protein, harpin$_{Ps}$ (from Pseudomonas syringae) induced limited resistance against grain mold but induction was not sufficient for effective disease control. Against shoot fly and stem borer no significant reduction was noticed with harpin$_{Ps}$ application. However, interactions between genotypes and harpin$_{Ps}$ treatments showed significant effect. Therefore, efficacy of harpin$_{Ps}$ to ISR in sorghum lines should be confirmed using sorghum lines with varying levels of resistance. Sorghum rhizosphere contained many useful bacteria and few strains improved plant growth in sorghum and this needs further investigation.

6. Names of collaborating scientists:

ICAR/National institutes:	IK Das, VR Bhagwat, N Seetharama, S Desai and AR Podile
ICRISAT:	*RP Thakur and OP Rupela*

7. Project Status: The objective No. 2, "To develop grain mold prediction model from the available weather data for the effective risk management by farmer" has been deleted as per decision taken in the group meeting held at NRCS on 23rd June 2006. The first phase of the project will be over soon, may initiate second phase if funding is available.

Linked project:

NRCS- JOWAR B&CU 6- Use of sorghum associated microorganisms for the improvement of stalk rot resistance.

I**CRISAT-Project 5**- Producing more and better food at lower cost of staple cereal and legume hybrids in the Asian SAT (sorghum, pearl millet and pigeon pea) through genetic improvement.

ICRISAT- Harnessing agriculturally beneficial microorganisms for production and protection of sorghum and rice – an activity of a project from ICAR and titled application of microorganisms in agriculture and allied sectors (AMAAS). It is coordinated/managed by the Director, National Bureau of Agriculturally Important Microorganisms (NBAIM), Mau.