Improved Production Technologies for Rainy Season Sorghum in Andhra Pradesh

Citation: Belum Reddy VS, Ravinder Reddy Ch, Ashok S Alur, Varaprasad Reddy KM and Bhubeshkumar R. 2007. Improved production technologies for rainy season sorghum in Andhra Pradesh. Global Theme on Crop Improvement. International Crops Research Institute for the Semi-Arid Tropics, Patancheru 502 324, Andhra Pradesh, India: 20 pp.

This bulletin is published under the developmental project on "Enhanced utilization of sorghum and pearl millet grains in poultry feed industry to improve livelihoods of small-scale farmers in Asia" funded by CFC. (CFC/FIGG/32)

Global Theme on Crop Improvement

Improved Production Technologies for Rainy Season Sorghum in Andhra Pradesh

Belum VS Reddy, Ch Ravinder Reddy, Ashok S Alur, KM Varaprasad Reddy and R Bubesh Kumar

Project Executing Agency (PEA)
CFC-FAO-ICRISAT project
Global Theme on Crop Improvement
International Crops Research Institute for the Semi Arid Tropics
Patancheru 502 324, Andhra Pradesh, India

2007

About Authors

BVS Reddy Principal Scientist (Sorghum Breeding), Global Theme on Crop Improvement, ICRISAT Patancheru 502 324, Andhra Pradesh, India

Ch Ravinder Reddy Visiting Scientist, CFC-FAO-ICRISAT Project, Global Theme on Crop Imrovement, ICRISAT Patancheru 502 324, Andhra Pradesh, India

Ashok S Alur Project Coordinator,CFC-FAO-ICRISAT Project, Global Theme on Crop Imrovement, ICRISAT Patancheru 502 324, Andhra Pradesh, India

KM Varaprasad Reddy Agriculture Expert, Federation of Farmers Association, Hyderabad, AndhraPradesh, India

R Bhubeshkumar Agriculture Expert,Federation of Farmers Association, Hyderabad, AndhraPradesh, India

Acknowledgments

The contributions of the farmers (sharing experiences, constraints and present management practices) from Udityal and Palavai clusters, Mehaboobnagar district of Andhra Pradesh are thankfully acknowledged in this bulletin.

The authors acknowledge the valuable contributions, suggestions and insights provided by CLL Gowda, ST Borikar, RP Thakur, S Ramesh, HV Kalpandey and Sanjay N Biradar. The authors also gratefully acknowledge the contributions from scientists of Marathawada Agricultural University, ANG Ranga Agricultural University, Krishi Vignan Kendra (Beed), AP Federation of Farmers Association, for sharing their experiences. They are however, not responsible for the views expressed in this bulletin. The authors thank Ms AS Arpana for typing the manuscript.

Contents

About the project

Production of sorghum and pearl millet has been declining in the last two decades with an annual rate of 0.7 percent globally. Within Asia, India, China and Thailand are the major producers of sorghum and pearl millet (sorghum: 9.3 million ha area with a production of 7.3 million t in India, 8 million ha area with a production of 3.1 million t in China, and 0.1 million ha area with a production of 0.2 million t in Thailand; pearl millet: 9.5 million ha area with a production of 8.5 million t in India). In these countries, the market demand for food uses of sorghum and pearl millet grain has declined with the growth in the incomes and the subsequent changes in consumer preferences. Grain supply in market is affected by a relatively slower increase in productivity compared to competing crops as well as the policy-induced factors.

The demand for poultry feed is increasing due to fast growth (by 15–20%) of poultry sector, while the growth rate in maize, the usual energy source in the poultry feed, is limited to only 2–4 percent annually. Hence, some poultry feed manufacturers are using sorghum and pearl millet in poultry feed formulations to some extent whenever there is a shortage of maize supply. Therefore, it was felt that farmers will be benefited if the information on the recommended package of practices, supply of improved cultivar seeds, improved input supply, grain harvesting, processing, storage, bulking and market linkages between the grower/farmer and poultry feed manufacturer are facilitated through a project. The Common Fund for Commodities/Food and Agriculture Organization of United Nations (CFC/FAO) supports a project with the following objectives:

- Develop effective coalition of all stakeholders (small-scale sorghum and pearl millet farmers, poultry producers and feed manufacturers, private sector seed companies, NGOs, agricultural institutions/universities and farmers' associations) to augment the income of small-scale producers on a sustainable basis
- Identify constraints to sorghum and pearl millet production and to provide information on improved production packages and seeds of improved cultivars by involving private seed companies
- Strengthen input supply chain system (fertilizers, pesticides, seeds of improved cultivars, credit facility, etc) for sorghum and pearl millet production and supply chains to stimulate the use of these crops as raw material for commercial poultry feed production.

The project is being implemented in the following target areas in three countries:

1. Two clusters in Mahbubnagar district of Andhra Pradesh state in India
2. Three clusters in Beed and Parbhani districts of Maharastra state in India
3. One cluster in three counties – Beizen, Heishan, and Yi of Liaoning province in China
4. One cluster in Suphan Buri, Kanchan Buri, and Nakon Sawan provinces in Thailand

The CFC, The Netherlands, in partnership with FAO, is funding the project.

Introduction

Sorghum is one of the main staples of the world's poorest and most food-insecure people in the semi-arid tropics of the world. The crop is genetically suited to hot and dry agro-ecologies where it is difficult to grow other food grain crops. These areas are also subject to frequent droughts. In many of these regions, sorghum is an important dual-purpose crop, providing both grain and stover, which are highly valued products. In large parts of the developing world, stover represents up to 50 percent of the total value of the crop, especially in drought years.

Developing countries account for roughly 90 percent of the world's sorghum area and 70 percent of the total production. India contributes about 16 percent of the world's sorghum production. Sorghum is the third most important cereal staple after rice and wheat in India. Much of the crop is grown by small-scale farmers operating at subsistence farming levels. The area planted to sorghum has declined steeply from 18 m ha to 9.2 m ha in 2002–03.

Unlike in the rest of the world, sorghum in India is grown in two seasons: *kharif* (rainy season) and *rabi* (postrainy season). While much of *kharif* sorghum grain is used for animal/poultry feed and in the brewing industry, all of the *rabi* sorghum is consumed as food. Both *kharif* and *rabi* sorghum production is affected by an array of biotic (grain mold, shoot fly, stem borer, etc, in *kharif;* and shoot fly in *rabi*) and abiotic (terminal drought and low temperature in *rabi*) constraints.

The major challenge facing sorghum research systems in India is to provide technologies that help transform sorghum from a subsistence crop to a commercial crop. Adoption of improved production technologies could produce marketable surplus. The development of processing technologies enables farmers to increase marketing opportunities, which provide additional farm income and create off-farm employment in agriculture-related enterprises. Therefore, we need to develop strategies to resolve the constraints that inhibit the increased use of improved technologies in a cost-effective manner.

A CFC-FAO-ICRISAT project on enhanced utilization of sorghum and pearl millet grains in the poultry feed industry aims at improving the productivity of sorghum in the dry lands of Asia. The project also aims at linking small-scale sorghum-producing farmer groups with the poultry feed manufacturing industries to enhance the income levels and thus improve the livelihoods. The project is operating in India, China and Thailand.

Kharif sorghum production technology

1. Planting time

Sowing of sorghum has to be completed two weeks before the onset of the monsoon, ie, preferably before the second fortnight of June. Delay in sowing due to several reasons such as delay in the onset of the monsoons, non-availability of seeds, etc, results in substantial reduction in the yields and increased incidence of shoot fly. *Kharif* sorghum can also be sown even a week before the onset of the monsoon. In case of dry sowing, seed treatment with pesticide needs to be undertaken to safeguard the seedling against any damage by soil-borne insect pests.

- Recent experimental results clearly demonstrated that pre-monsoon dry sowing a week before the onset of the monsoon gives a yield advantage to an extent of 21 percent.

Recommended high yielding cultivars

State	Hybrids	Varieties	Area of adaptation
Andhra Pradesh	CSH 14, PSH 1	CSV 15	Low rainfall areas
	CSH 9	SPV 462 (PSV 1)	Normal rainfall
	CSH 13, PSH 1	CSV 10, CSV 11	Areas
	CSH 16, CSH18	CSV 13, CSV 15	Areas
		CSV 10, CSV 11	Late *kharif*
	CSH 13	Moti	

2. Row spacing, seed rate, plant population and sowing

The optimum plant population depends on different factors such as the available nutrients and moisture. The recommended optimum population is 1,80,000 plants per ha, which can be achieved by using 8 kg seed and planting in rows of 45 cm wide with a plant-to-plant distance of 12 cm (Figure 1). In case of dual-purpose cultivars (CSH 10, CSH 13, CSV 10, CSV 15), a plant population of 2.1 to 2.2 lakh/ha is recommended, which could be obtained by planting in rows of 45 cm wide with a plant-to-plant distance of 10 cm.

Figure 1. Sorghum crop showing row species.

3. Nutrient management (application of manures and fertilizers)

Sorghum grows best on soils with good tilth and relatively high and balanced fertility and a neutral pH. The crop can tolerate considerable variation in fertility and in the balance of various elements, but yield and plant growth efficiency is reduced by both low levels of fertility and fertility imbalance. Sorghum can tolerate low levels of salinity (up to 8 dsm^{-1}). The uptake of nutrients depends on soil and climatic factors. The uptake of nitrogen is very high during the period of rapid reproductive growth preceding the ear head emergence and also during grain development. Phosphorus accumulation is high during early vegetative growth and is highest during grain formation, whereas potassium uptake is highest during vegetative growth prior to ear head emergence. Split application of fertilizers is beneficial in case of light textured soils compared to heavy textured soils.

Application of 10 t/ha of farmyard manure (FYM) at the time of last ploughing and 40 kg N/ha fertilizer is advised. In the absence of FYM, 80 kg N and 40 kg P_2O_5 is to be applied at sowing and be placed 5 cm below the seed, while the remaining 40 kg N is to be applied 30–40 days after sowing. In case of light soils with low rainfall, the dosage is restricted to 60 kg N and 30 kg P_2O_5.

- Two micronutrients, viz, zinc and iron, are also found to be advantageous for improving the grain yields. Foliar application of zinc sulphate and ferrous sulphate @ 0.2% and 0.15% solution, respectively, twice each alternatively at weekly intervals during bootleaf initiation is recommended. This application has been found to give 12 percent additional grain yield.

4. Soil properties and status of fertility in the project area

The soils in the project area possess light texture ranging from sandy loam to sandy clay loams with a low to medium waterholding capacity. The soil reaction ranges from slightly acidic to neutral, however some of the soils are slightly alkaline in reaction. Majority of the soils are low in organic carbon content; medium to high in available phosporous and potash content. The sulphur content is low to medium. The available micronutrients (zinc, manganese, iron and copper) range from medium to high except boron which is low in these soils.

5. Intercultivation

Intercultivation with *guntaka* (blade harrow or Danti cultivator), 15–20 days after sowing is preferable. It helps to control weeds and conserve moisture in the soils.

6. Critical stages of water requirement

Sorghum grows well when adequate moisture is available throughout the developmental stages of the crop. The critical stages of the crop growth period, which require adequate moisture include (a) germination (b) seedling stage (c) flower primordial initiation stage (d) flowering and (e) dough stage of grain formation.

7. Weed management

There are different methods in weed management such as pre-planting cultivation practices to ensure weed-free seed bed, hoeing or inter row cultural operations, hand weeding, etc. As an alternative to hand weeding and inter-cultivation, spraying of Atrazine @ 0.5–1.0 kg ai/ha or stomp (pendimethalin) @ 1.5 kg ai/ha as pre-emergence weedicide application keeps the crop free from weeds for about 20–25 days. However, successful use of herbicides depends on proper calibration of sprayer, quantity of herbicide to be used, method and time of application, climatic conditions, type of weeds, etc. These herbicides can be applied before or after planting the crop.

- In case of dry sowing, the weedicide should be applied after one or two showers but before seed germination.

8. *Striga* and its management

The crop is parasitized by several species of *Striga*. Severe infestation of the weed results in leaf wilting and yellowing, and the infected plants are stunted and may die prior to setting seed.

The seeds of *Striga* are stimulated to germinate by root exudates of the young sorghum plants, which parasitize the seedling, by penetrating and colonizing. The weed emerges above the ground close to the infested plant 1–2 months after the crop is planted. The weed starts flowering in 3–4 weeks after emergence and the seed matures in a month (Figure 2).

Figure 2. Crop infestation with Striga (pink-flowering plants).

By adapting crop rotation with trap crops, viz, cotton, sunflower and groundnut, the losses due to *Striga* in the long-run are minimized. For immediate results, hand pulling when *Striga* population is sparse or spraying of 2,4-D @ 2 kg ai/ha helps to reduce adverse effects.

9. Harvesting

Kharif sorghum should be harvested at its physiological maturity to minimize grain mold damage. The grain quality deteriorates when it gets exposed to rains during the period between physiological maturity and normal harvesting. Therefore, harvesting the sorghum panicles at physiological maturity and drying in earhead drier (Figure 3) to reduce the grain moisture to 12.15% will reduce the grain deterioration.

- Sorghum is considered to be physiologically mature when a black layer forms at the hilar end of the grain (Figure 4). At this stage the plant has accumulated maximum total grain dry weight, and by harvesting at this stage there is no loss in the grain yield.

Figure 3. Sorghum earhead drier.

Figure 4. Educating farmer to identify physiological maturity; grain showing black discolorations at hilar end.

Sorghum based cropping systems

1. Intercropping

In low rainfall light soil areas, medium duration hybrids intercropped with pigeonpea in 2:1 (two rows of sorghum and one row of pigeonpea) row ratio is widely practised. In case of high rainfall and relatively heavy soils, 3:3 row ratios are recommended. Fertilizer application to intercropping system will be the same as that of sole sorghum crop.

- Another profitable intercropping system is sorghum and fodder cowpea in 2:2 row proportions. This system besides improving soil health and checking weed growth helps in providing green fodder.

2. Sequence cropping

In areas receiving rainfall above 700 mm with medium to deep black soils, a sequence crop in *rabi* season following sorghum could be successfully cultivated. Safflower and green gram/black gram are the most suitable and profitable crops under such situations. Under this system, sorghum is harvested at physiological maturity to facilitate early planting of the following *rabi* crop leading to increased profitability of the system.

Major pests and their management

1. Shoot fly

Shoot fly is one of the serious pests of sorghum. It affects the crop during the first fortnight. The shoot fly damages are less when the crop is planted before the second fortnight of June.

a. Biology

The adult is a small, grey fly which deposits small, white cigar shaped eggs, singly on the undersurface of the seedling leaves. After hatching in 2–3 days, the maggot enters the seedling through the whorl and destroys the growing point. The larval period lasts for 8–10 days. A mature larva is yellow and about 6 mm in length. Pupation takes place either at the plant base or in the soil and lasts for 8–10 days. The fly population exhibits considerable variation and is normally very low in April to June. It tends to increase in July and reaches the peak in August. From September onwards, the population gradually declines and remains at a moderate level until March.

- Activity of shoot fly increases due to high or low temperatures and also by continuous rains.

Figure 5. Seedlings showing drying of growing tips (dead hearts).

b. Damage symptoms

It is a seedling pest and normally occurs in 1–4 weeks after germination. Maggots feed on the growing tip causing wilting of leaf and later drying of central leaf giving a typical appearance of 'dead heart' symptoms (Figure 5). If the infestation occurs a little later, damaged plants produce side tillers, which again are infested increasing the population build up. To schedule the chemical control, the shoot fly infestation can be monitored by checking the egg laying on the lower surface of the seedling leaves before the formation of dead heart.

c. Cultural management methods

Shoot fly damage can be minimized by suitable adjustment of the planting time so that the vulnerable stage of the crop does not coincide with its active period. During *kharif*, if plantings are done within 7–10 days of the onset of the monsoon before 15 July, the crop can escape the shoot fly damage.

d. Chemical management methods

When planted late, the pest can effectively be controlled by seed treatment with Furadan 50 SP @ 100 g/kg seed. Under moderate levels of infestation, a mixture of 60 percent treated and 40 percent untreated seed could be used. Besides, any of the granular formulations of Furadan 3G or Phorate 10G at the time of sowing as soil application in the seed furrows @ 20 kg/ha can also effectively check the pest incidence. In case soil granular application is not done, damage can be contained by spraying the seedling at 7 and 14 days stages with endosulfan @ 2 mL/L of water.

2. Stem borer

a. Biology

The moth is medium-sized and straw colored. The female lays nearly 500 eggs in masses of 10–80 on the undersurface of the leaf often near the midrib. The eggs hatch in 4–5 days. The larval period lasts from 19 to 27 days. Pupation takes place inside the stem and the adult emerges in 7–10 days. During the dry season, the larva enters into diapause and survives in harvested stalks/stems as well as stubbles left in the field. As the rainy season starts, the diapause is broken and pupation takes place.

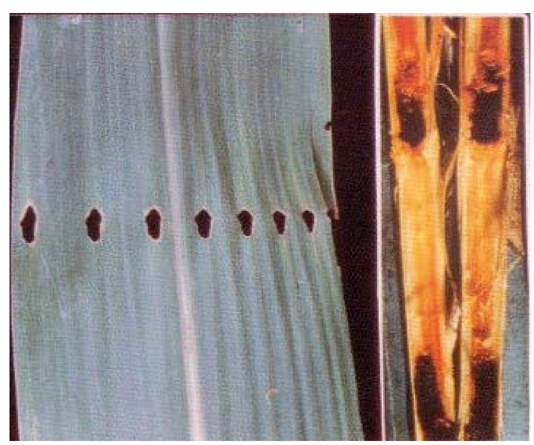

Figure 6. Upper leaf showing oval shaped holes and stem tunnelling.

b. Damage symptoms

It infests the crop from second week until maturity. Initially, the larvae feed on the upper surface of whorl leaves leaving the lower surface intact as transparent window. As the severity of the feeding increases, a blend of punctures (Figure 6) and scratches of epidermal feeding appears prominently. Sometimes, 'dead heart' symptoms also develop in younger plants due to early attack. Subsequently, the larvae bore into the stem resulting in extensive stem tunneling. Peduncle tunneling results in either breakage or complete or partial chaffy panicles.

- Another important practice is to increase the seed rate and destroy the 'dead heart' seedlings after removal, to maintain the optimum plant stand.

c. Cultural management methods

The carry over of the pest from one season to another is through stubbles left in the field as well as the stems/stalks kept for use as fodder after harvest. Uprooting and burning of stubbles and chopping of stems prevent its carry over.

d. Chemical management methods

Effective control of the borer can be achieved by application of any of the following insecticides into the whorl, ie, Endosulfan 4G/4D, Carbaryl 3G, Malathion 10D or Furadan 3G @ 8-12 kg/ha at 20 and 35 days after emergence.

- The treatment should only be given after ascertaining the infestation levels as evidenced by leaf injury symptoms.

3. Aphids

a. Biology

The corn leaf aphids are dark bluish-green. Female gives birth to young ones and a generation takes 7 days. The colonies are typically found deep inside the plant whorl of the middle leaf on the ventral surface of the leaves and panicle (Figure 7).

Figure 7. Ventral surface of leaf showing aphid colonies.

b. Damage symptoms

Occasionally, they cause damage to seedling sorghums. Attack during boot stage may result in poor panicle exertion. However, after panicle emergence, their population rapidly declines. Bigger plants in boot and later stages generally tolerate larger populations without any significant damage. Both the adults and nymphs suck the sap and heavily infested leaves show yellowish blotches. Necrosis may occur on leaf edges. They produce abundant honeydew, which predispose the plant to sooty and other sporadic fungal pathogens. The honeydew excretion hinders the harvesting process and results in poor quality grain. Severe damage is possible under moisture stress conditions resulting in drying of leaves as well as plant death. Unlike the corn leaf aphid, sugarcane aphid predominantly is a serious pest in *rabi* and prefers to feed on older leaves and also infest younger leaves including panicle at flowering stage. Adults are yellow to buff colored. Both adults and nymphs suck the plant sap and cause stunted growth.

c. Chemical management methods

Spraying of Metasystox 35 EC @ 1 L/ha in 500 L water effectively controls aphids.

Major diseases and their management

- The toxins produced are harmful to animals and human beings.

Grain mold, downy mildew, ergot, leaf spot, anthracnose and rust are major diseases that affect sorghum production.

1. Grain molds (A complex of several fungal species)

a. Symptoms

Grain infected with *Fusarium moniliforme* develops a fluffy white or pinkish coloration and those infected by *Curvularia lunata* turns black.

b. Damage

Grain molds occur if rains prevail during the flowering and grain filling stage. Thus molds are severe during the years of prolonged rainfall at the time of grain maturity. It results in the discoloration of grain (fluffy white or pinkish coloration), but the severity of infection results in black grains (Figure 8), which also reduces grain weight and size leading to considerable loss of yields even up to 100 percent. The grain mold infection reduces germination and acceptability of the harvested grain, nutritive value and market price.

Figure 8. Grain mold affected earheads, seeds covered with black or white or pink fungal growth.

c. Grain mold management

Because the host-pathogen-environment interaction is highly complex and variable in sorghum grain mold, no single control method has been found effective. Adjusting sowing dates to avoid warm and humid conditions during flowering to grain maturity does reduce grain mold severity, but it is not realistic in most environments due to the constraint of limited growing season. Several other methods, such as application of chemical fungicides and biocontrol agents have been shown to provide some degree of protection under experimental conditions, but their effectiveness and economic feasibility in on-farm situations have not been demonstrated. Host-plant resistance, therefore, forms the major component of grain mold management (Thakur et al. 2006).

d. Integrated disease management methods

Integrated management of grain molds in sorghum involves growing mold resistant/tolerant cultivars; harvesting the crop at physiological maturity and quick drying to bring down the grain moisture content to around 10 percent; storing grains under proper storage conditions; adjusting sowing time, if feasible, to avoid flowering and maturity in heavy rains; and need-based sprays with tilt (chemical) and bio-control agents where feasible (Thakur et al. 2006).

2. Rust (*Puccinia purpurea)*

a. Symptoms

Small flecks in purple, tan or red on the lower leaves appear depending on cultivar. The rust pustules are elliptical and lie between and parallel with the leaf veins. The rust postules may occur on sheaths and inflorescence stalks. In case of highly susceptible cultivars rust pustules develop on lower surface of the leaf and can destroy the entire leaf.

b. Damage

In susceptible cultivars, the pustules occur so densely that almost the entire leaf tissue is destroyed.

c. Cultural management methods

Using clean seed, crop rotation, destroying residues of previous susceptible crops and use of cultivars with tan pigment are the useful practices in reducing the disease incidence. All the popular and recently released *kharif* cultivars are tolerant to rust.

d. Chemical management methods

Spraying with Dithane M-45 @ 0.2% thrice at 10 days interval commencing from a month after sowing is recommended. Application of chemical fungicides appears to provide limited protection (especially limited to research stations and useful to germplasm). This is not economical at farmer field level.

3. Ergot (*Sphacelia sorghi*)

a. Symptoms

It is commonly known as sugary disease and its first symptom is the secretion of a creamy sticky liquid (honeydew) from the infected florets (Figure 9). When this honeydew is plenty, it results in blackening of ear head. If further favorable conditions prevail, long, straight or curved, cream to light brown colored sclerotia would develop.

Figure 9. Creamy sticky liquid effected florets showing.

b. Damage

The male sterile lines if not pollinated become almost 100 percent infected. Seed setting is severely affected.

c. Cultural management methods

Collateral host plants *Ischaemum pilosum* (a perennial grass) on the field bunds must be destroyed. Soaking seed in salt water (5%) and mechanical removal of floating sclerotia before sowing is recommended. In seed production plots, ensuring synchrony of flowering avoids the occurrence of ergot.

d. Chemical management methods

Spraying with Bentlate (0.1%) or Thiram (0.2%) two times starting at 50 percent flowering and subsequent spray after a fortnight is most effective. Chemical control measures are not economical at farmer field level.

4. Smuts

There are four types of smut: (a) covered kernel smut (Figure 10) – individual grains are replaced by smut; (b) loose kernel smut (Figure 11) – the infected plants flower prematurely and show increased tillering with loose ear head and infected florets; (c) long smut (Figure 12) – this is restricted to the florets that are located on a head and it mainly spreads through the wind. The infected sori are longer and wider than that of covered kernel smut; (d) head smut (Figure 13) – the head is either completely or partially replaced by large whitish gall. Smuts infect the ovules in ear head and replace the seed with smut sorus, a sac enclosing dark brown to black powdery mass. All the four smut diseases are seed-borne.

Since the disease is seed borne, seed treatment with carboxin (vitavax) @ 2.5 g/kg or elemental sulphur at about 5 g/kg helps to eradicate the seed-borne inoculums.

Figure 10. Covered kernel smut.

Figure 11. Loose kernel smut.

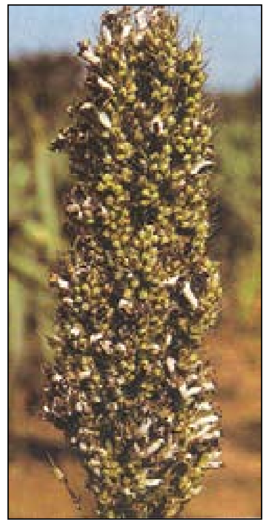

Figure 12. Long smut.

Figure 13. Head smut.

5. Sorghum downy mildew

a. Symptoms

The most conspicuous symptom is appearance of vivid green and white stripes on the leaves and providing growth on ventral side of the leaf (Figure 14). At advanced stage, it results in shredding of leaves and stunting of plant growth (Figure 15).

Figure 14. White stripes on the leaf and downy white growth on the lower surface.

Figure 15. Leaf shredding symplom.

b. Damage

Infested plants usually fail to head. Even if heads are exerted, they are small, compact or club shaped and have little or no seed.

c. Cultural management methods

It can be controlled by growing resistant varieties and hybrids. All the popular *kharif* hybrids and varieties are resistant to this disease.

d. Chemical management methods

Metalaxyl, ie, Ridomil 25 as seed dressing @ 1 g ai/kg or Apron 35SD @ 1 g ai/kg will control downy mildew. Satisfactory control can be achieved with 4 sprays of Dithane M45 (0.3%) at 7 day intervals beginning from germination.

Risk aversion through contingency planning

1. Early onset of monsoon

It is welcome for *kharif* sorghum. Sowing with the onset of monsoon is recommended for assured high yields.

2. Early onset of monsoon followed by a long gap

Repeated inter-cultivation operations such as hoeing, weeding and mulching for some moisture conservation are suggested. Under severe moisture stress, reduce the plant population by two-thirds through thinning. Limited plant population assures normal growth of the crop. Secondly, sporadic break of armyworm is expected under such situation. A poisonous mixture of Metasystax (250 mL) and 4 kg of rice bran with 8L of water is recommended to be broadcasted in the field as bait. This will effectively control both the moths and the larvae. This practice is widely used in Karnataka.

3. Delayed onset of monsoon

Normal recommendation can be followed. In case there is a delay in monsoon by 2–3 weeks, short duration cultivars such as CSH 6 and CSH 14 can be preferred. In case of staggered planting where some farmers have already sown and others did not, increase the seed rate to an extent of 1.5 times of the recommended rate and apply 20 kg of carbofuran or phorate (3 g) granules in the seed rows before sowing to safeguard against the anticipated shoot fly attack. Other shoot fly control measures (spraying of endosulfan 2 mL/L of water after sowing) can also be followed if soil application is not adopted.

4. Prolonged monsoon and excessive rainfall at maturity

These situations at the seed development stage are likely to cause heavy grain mold infestation. Harvesting of the crop at its physiological maturity to avoid damage by grain mold and alternatively spraying fungicidal mixture containing 0.3% Dithane M-45 three times at 10 days interval starting from 50 percent flowering onwards are recommended.

5. Failure of monsoon

If the monsoon fails after sowing the crop, the plant population should be reduced proportionately to half by either uprooting alternate plants or alternate rows. However, in case of partial failure and extremely delayed monsoon, alternative crops such as castor, bajra and horse gram are suggested for light soils.

Grain and fodder quality of sorghum

The grain and fodder quality of sorghum is affected by the agronomic practices to a greater extent. The quality of grain and fodder can be modified by different agronomic practices such as (1) date of planting; (2) method of planting; (3) crop sanitation; (4) plant population; (5) time, method and quantity of fertilizer application; (6) availability of water; and (7) inter/mixed cropping methods.

Early sowing can result in a healthier crop and larger and healthier grains with higher protein content than the late sown crop. Unlike late sown crop, early sown crop is not affected by foliar diseases.

Thus the quality of the fodder can be very high. When proper dosage of nutrients is applied, the quality of grain and fodder can be high. Phosphorous dressing reduces the HCN content in the fodder. When the plant population increases beyond the optimum level, the quality of the fodder also gets reduced.

Production constraints

The production of sorghum is associated with several biotic and abiotic constraints. Rising labor costs have also affected most farm operations – from land preparation, weeding and bird scaring to harvesting and grain processing. Another factor, important throughout Asia is changing food preferences. As incomes rise, consumers tend to purchase wheat, rice and in some cases maize, rather than traditional coarse grains.

Grain molds cause significant losses in both grain yield and quality, particularly in areas where improved cultivars have been adopted. Other important diseases include anthracnose, charcoal rot, downy mildew, ergot and leaf blight. Insect pests constrain production in many areas. Shoot fly and stem borers are endemic in many areas; aphids, head bugs and midge are sporadic, sometimes high incidence is observed during conducive climatic conditions; and shoot fly causes substantial losses in late and off-season sowings in Asia.

Another major problem is that variable rainfall leads to large fluctuations in the production. Prices fall abruptly in good years, leaving traders reluctant to enter the market, especially since stockholding infrastructure is usually inadequate. This increases the price risk that sorghum producers face, and their unwillingness to invest in commercial sorghum production.

Utilization

Worldwide, total utilization of sorghum fell slightly from 65.4 million tons in 1979–81 to 63.5 million tons in 1992–94. In the early 1980s, an estimated 39 percent of global production was used as food and 54 percent as feed. By 1992–94, 42 percent of total utilization was for food and 48 percent for animal feed.

Food use

Worldwide, approximately 27 million tons of sorghum was consumed as food each year during 1992–94. It is a key staple in many parts of the developing world, especially in the drier and more marginal areas of the semi-arid tropics. Per capita consumption of sorghum-based food in rural producing areas is more stable, and usually considerably higher, than in urban centers. And within these rural areas, consumption tends to be highest in the most food-insecure regions.

Sorghum is eaten in a variety of forms that vary from region to region. In general, it is consumed as whole grain or processed into flour, from which traditional meals are prepared. There are four main sorghum-based foods:

- Flat bread mostly unleavened and prepared from fermented or unfermented dough in Asia and parts of Africa
- Thin or thick fermented or unfermented porridge, mainly consumed in Africa
- Boiled products similar to those prepared from maize grits or rice
- Preparations deep-fried in oil.

Alternate uses of sorghum

Sorghum has got several alternate uses. Research on development and strengthening alternate uses of *kharif* grain was started recently. The major objectives of these researches are to create demand for *kharif* grain from non-food sector, particularly from feed, starch production and beverage manufacture sectors and to provide value addition to *kharif* grain and stalk.

Demand for grain from the poultry and animal feed industry is rising (Table 1). While maize is the preferred coarse grain by this industry, sorghum has potential to emerge as a major feed grain with favourable pricing and with demonstration that it could largely serve the role of maize in feed. Hence, studies were conducted to assess the feed value of sorghum as a sole grain source and in equal combination with maize. Most of these studies on poultry tend to suggest that despite the relatively lower energy value of sorghum grain, the feed value of sole grain sorghum-based diets on layer and broiler birds was on par with that based on maize, except that the yolk of egg and shank color of broiler birds were less yellowish in the sole sorghum based diet. These disadvantages were absent in feeds formulated from equal parts of sorghum and maize. In the case of cattle, sorghum-based feed is found satisfactory. Molded *kharif* grain is found as an acceptable grain component in the feed of goat and swine.

Molded *kharif* grain, which fetches lower market value, is a cheap raw material for production of potable or industrial alcohol. Much often this grain is available at prices lower than the minimum support price. It is found to produce good quality potable alcohol, which could be exported for blending purpose.

Regular export of grain is another approach to enhance the demand. Sorghum grain is internationally marketed as a feed and its current market is for about 12–13 million t/year.

Table 1. Summary of industrial demand for sorghum in India (in '000 tonnes).

			Revised estimates	
Industry	1998	2010	2001-2002	2010
Poultry feed (Total)	418–627	1826–3214	1078–1270	2668–3085
Broilers	86–129	570–1150	240	840
Layers	312–468	1100–1830	768–960	1668–2085
Others (grower & Parent stock)	20–30	156–234	70	160
Diary feed	160–240	290–570	440–450	600
Alcohol	90–100	200–500	92	216
Starch	50	30-80	-	-
Exports	-	-	11	-
Total	**718–1017**	**2346–4364**	**1621–1823**	**3484–3901**

Recommendations

- In general, the food security objectives can best be met by stimulating growth in market-oriented production systems which should generate additional cash resources for small-scale farmers and increase off-farm employment for rural and urban poor. This strategy highlights the fact that it represents a major change from traditional approaches to conducting research. As a result, initially there will be a greater emphasis in market analysis and management themes. It will also require a certain period of institutional learning and restructuring, while studying further the apparent gaps in productivities/factors and the process itself, specifically with the objective of harmonizing them with the changing economic situation as well as sorghum development priorities in India. In addition, we need to implement the priorities identified to develop capacity to respond to emergency situations such as major outbreaks of diseases, droughts and floods.
- The positive trend of addressing issues of postharvest, food technology, and socio-economics, needs to be encouraged and reinforced by widening participation in the networks to include relevant private sector institutions and non-governmental organizations, and to stimulate the NARS to give high priority to these issues as well.
- In implementing the current research priorities, subject to availability of resources, due consideration should be given to development of technology options which have high potential pay-off in a wide range of agro-ecological systems including arid and semi-arid lands, irrigated agriculture and peri-urban farming. Gender, regional and other equity issues should also be addressed, and local needs will be served efficiently through networking with local entities.

- Crop production changes in the plant type of new High Yielding Varieties (HYV). The input response for higher yield and decreased biotic stress resistance level over traditional varieties necessitated development of suitable production technologies. Sowing at the onset of monsoon during *kharif* is the most effective for production response and avoidance of losses due to shoot fly and other pests. A plant population of 180,000/ha with a crop geometry of 45 cm x 12 cm is optimum. A population of 110,000 plants/ha at harvest as the lowest threshold unit influences the yield. A fertilizer dose of 80 kg N: 40 kg P_2O_5: 40 kg K per ha was found remunerative in assured rainfall areas so as to realize the full potential of hybrids, and 60:30:30 dose of NPK dose was remunerative in low rainfall areas. Superiority of hybrids over locals even at native soil fertility was well demonstrated. Basic information was also generated on split application of nutrient and its responses in important high yielding genotypes. The principles of contrasting growth rhythms and crop geometry of these crops in conjunction with specific attributes of cultivars were used to design and develop transgressively productive intercropping systems with enhanced land equivalent ratio. Multi-location testing concluded that sorghum and pigeonpea in 2:1, 3:3 ratios were found suitable in intercrops using early and medium maturing sorghum hybrids, respectively. Studies on crop sequences showed the mung bean–sorghum, sorghum-chickpea and sorghum-safflower systems as the most rewarding. Fertilizer recommendations of these sequences were also worked out.

Bibliography

Audilakshmi S, Aruna C, Solunke RB, Soni SB, Kamtar MY, Kandelkar HG, Gaikwad P, Ganesamurthy K, Jayaraj K, Ratnavathi CV, Dayakar Rao B, Kannababu N, Indira S and **Seetharama N.** 2004. Technologies to improve grain quality of kharif sorghum. Rajendernagar, Hyderabad, 500 030, AP, India: National Research Center for Sorghum. 28 pp.

FAO and **ICRISAT.** 1996. The world sorghum and millet economies – Facts, trends and outlook.

Rana BS, Rao MH, Jndira S, Singh BU, Chari Appaji and **Vilas Tonapi.** 1999. Technology for increasing sorghum production and value addition. Rajendranagar, Hyderabad – 500 030, AP, India: National Research Center for Sorghum.

Thakur RP, Reddy BVS, India S, Rao VP, Vavi SS, Yong XB and **Ramesh S.** 2006. Sorghum Grain Mold. Information Bulletion No. 72 International Crops Research Institute for the Semi-Arid Tropics. 32 pp. ISBN 92-9066-488-6.

Wall JS and **William M Ross.** 1970. Sorghum Production and Utilization: Major feed and food crops in agriculture and food series. Westport Connecticut, USA: The AVI Publishing Company Inc.

Williams RJ, Frederiksen RA and **Girard JC.** 1978. Sorghum and Pearl Millet Disease Identification Handbook. Information Bulletin No.2. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

About CFC

The Common Fund for Commodities (CFC) is an autonomous intergovernmental financial institution established within the framework of the United Nations. The Agreement Establishing the Common Fund for Commodities was negotiated in the United Nations Conference on Trade and Development (UNCT AD) from 1976 to 1980 and became effective in 1989. The first project was approved in 1991.

The CFC forms a partnership of 106 Member States plus the European Community (EC), the African Union (AU) and the Common Market for Eastern and Southern Africa (COMES A) as institutional members. Membership is open to all Member States of the United Nations or any of its specialized agencies, or of the International Atomic Energy Agency, and intergovernmental organizations of regional economic integration, which exercise competence in the fields of activity of the Fund.

CFC's mandate is to enhance the socio-economic development of commodity producers and contribute to the development of society as a whole. In line with its market-oriented approach, the Fund concentrates on commodity development projects financed from its resources, which are voluntary contributions, capital subscriptions by Member Countries. Through cooperation with order development institutions, the private sector and civil society, the Fund endeavors to achieve overall efficiency in and impact on commodity development.

About FAO

The Food and Agricultural Organization (FAO) of the United Nations is an autonomous intergovernmental organization established in 1945, which leads international efforts to defeat hunger. Serving both developed and developing countries, FAO acts as a neutral forum where all nations meet as equals to negotiate agreements and debate policy. FAO is also a source of knowledge and information to modernize and improve agriculture, forestry and fisheries practices and ensure good nutrition for all. The main functions of FAO include collection, analysis, interpretation and dissemination of information relating to nutrition, food and agriculture. It promotes, disseminates and, where appropriate, recommends national and international action with respect to scientific, technological, policies, marketing and distribution, conservation of natural resources, social and economic research relating to nutrition, food and agriculture. It also undertakes the function of to furnishing technical assistance to the governments on request, in cooperation with the governments concerned.

About ICRISAT®

Science with a Human Face

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is a nonprofit, non-political organization that does innovative agricultural research and capacity building for sustainable development with a wide array of partners across the globe. ICRISAT's mission is to help empower 600 million poor people to overcome hunger, poverty and a degraded environment in the dry tropics through better agriculture. ICRISAT belongs to the Alliance of Future Harvest Centers of the Consultative Group on International Agricultural Research (CGIAR).

Contact Information

ICRISAT-Patancheru (Headquarters)
Patancheru 502 324
Andhra Pradesh, India
Tel +91 40 30713071
Fax +91 40 30713074
icrisat@cgiar.org

Liaison Office
CG Centers Block
NASC Complex
Dev Prakash Shastri Marg
New Delhi 110 012, India
Tel +91 11 32472306 to 08
Fax +91 11 25841294

ICRISAT-Nairobi (Regional hub ESA)
PO Box 39063, Nairobi, Kenya
Tel +254 20 7224550
Fax +254 20 7224001
icrisat-nairobi@cgiar.org

ICRISAT-Niamey (Regional hub WCA)
BP 12404
Niamey, Niger (Via Paris)
Tel +227 722529, 722725
Fax +227 734329
icrisatsc@cgiar.org

ICRISAT-Bamako
BP 320
Bamako, Mali
Tel +223 2223375
Fax +223 2228683
icrisat-w-mali@cgiar.org

ICRISAT-Bulawayo
Matopos Research Station
PO Box 776,
Bulawayo, Zimbabwe
Tel +263 83 8311 to 15
Fax +263 83 8253/8307
icrisatzw@cgiar.org

ICRISAT-Lilongwe
Chitedze Agricultural Research Station
PO Box 1096
Lilongwe, Malawi
Tel +265 1 707297/071/067/057
Fax +265 1 707298
icrisat-malawi@cgiar.org

ICRISAT-Maputo
c/o IIAM, Av. das FPLM No 2698
Caixa Postal 1906
Maputo, Mozambique
Tel +258 21 461657
Fax +258 21 461581
icrisatmoz@panintra.com

Visit us at www.icrisat.org

Science with a Human Face

International Crops Research Institute for the Semi-Arid Tropics

Patancheru 502 324, Andhra Pradesh, India

Common Fund for Commodities

Post: 74656, 1070 BR Amsterdam
The Netherlands

Food and Agricultural Organization of the United Nations

Viale delle Terme di Caracalla

308–06