Agronomy – Kharif Crops

Millets

Sorghum (*Jowar*)
Pearl Millet (Bajra)
Finger Millet

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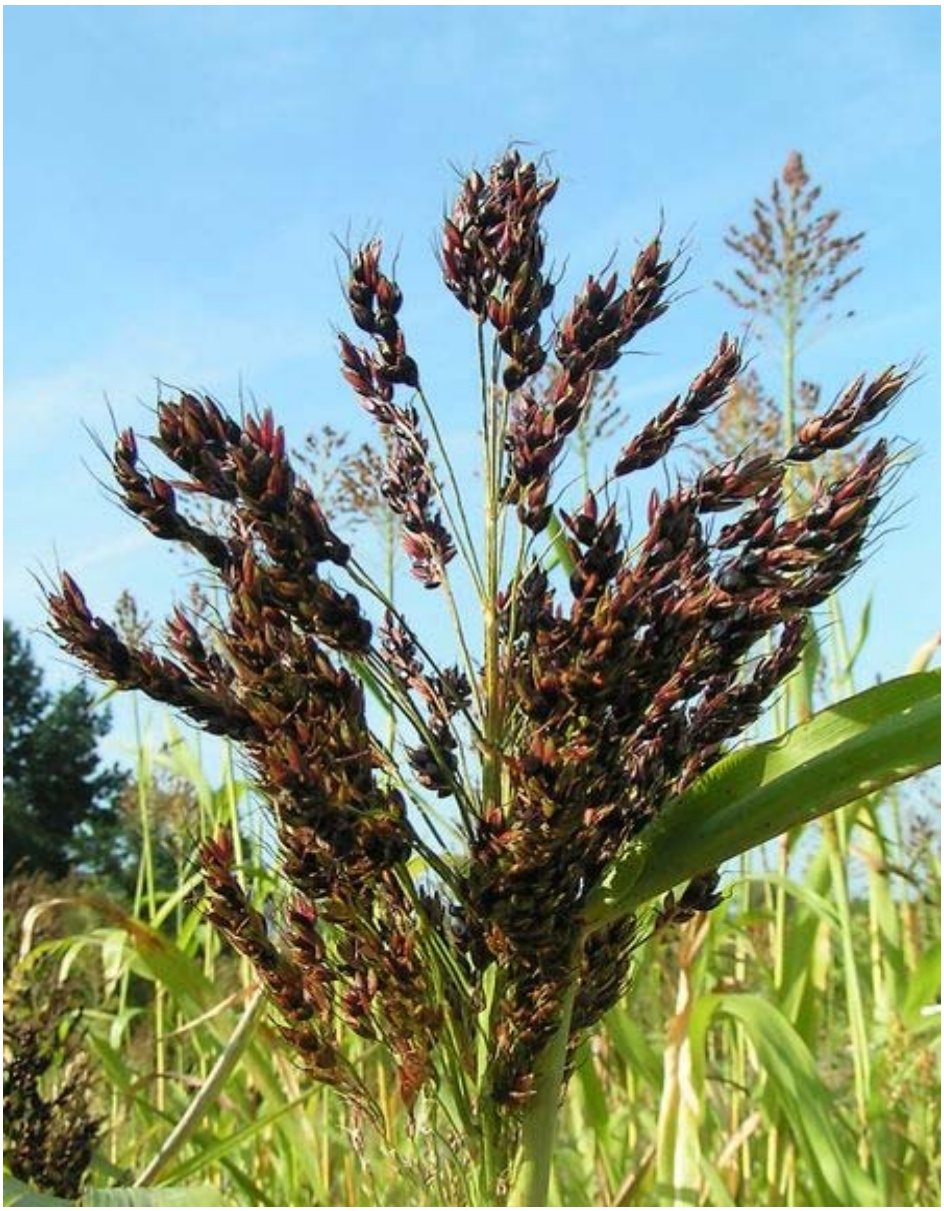
SORGHUM (*Jowar*)

Botanical name: *Sorghum bicolor* (L.) Moench

Chromosome number: 2n=20

Sorghum ranks third in the major foodgrain crops in India, whereas it is the fourth foodgrains of the world. Millions of people in Africa and Asia depend on sorghum as the staple food. In addition, the fodder and stover is fed to millions of animals providing milk and meat for man. It is also used as industrial raw material in various industries in the USA and other developed countries. It has potential to compete effectively with crops like maize under good environmental and management conditions. Sorghum grain contains about 10-12% proteins, 3% fat and 70% carbohydrates. Therefore, it can satisfactorily replace other grains in feeding programme for dairy cattle, poultry and swine. Over 55% of grain produced globally is used for human consumption in the form of flat breads and porridges (thick or thin) and about 33% of grain used in feeding livestock, especially in the Americas.



Origin

Sorghum is considered to be originated in Northern Africa or at the Egyptian-Sudanese border 5,000-8,000 years ago. Indian sub-contigent is its secondary center of origin, where it is cultivated since 4,500 years. After evolution from wild races of Africa, self seeding ability was lost. The crop has also acquired compact panicles and larger seed size. The date of arrival of cultivated sorghum in India is uncertain, but probably it was brought to India from Africa by visitors and merchants.

Geographic Distribution

Globally sorghum is cultivated over an area of about 42.7 million ha with a production of about 58.7 million tonnes. Among the 99 sorghum growing countries of world, India ranks first in terms of acreage and 3rd in terms of production. USA is the largest producer of sorghum (Table 1).

Table 1. The major countries producing sorghum

Country	Area (m ha)	Production (m tonnes)	Productivity (t/ha)
USA	2.64	11.56	4.381
India	9.10	7.70	0.846
Mexico	1.83	7.00	3.822
Nigeria	7.07	8.03	1.135
Sudan	6.00	2.60	4.330
Argentina	0.48	2.16	4.547
China	0.57	2.34	4.102
Australia	0.73	2.01	2.737
Ethiopia	1.34	1.78	1.336
Burkina Faso	1.44	1.40	0.973
World	**42.69**	**58.71**	**1.375**

Source: FAO ProductionYear Book, 2004

In India, it is grown over 9 million ha with total production of about 7.5 million tonnes. During 2002-03, rainy season crop occupied for 4.7 mha (4.5 m tonnes), while post-rainy season crop had 5.0 m ha (2.9 m tonnes). Maharashtra, Andhra Pradesh, Karnataka, Madhya Pradesh, Gujarat, Tamil Nadu, Rajasthan and Uttar Pradesh are the important sorghum growing states. Since independence, the area (18.73 mha), production (12.90 m tonnes) and productivity (982 kg/ha) was the highest in 1968-69, 1989-90 and 1992-93, respectively.

Table 2. Area, production and productivity of jowar in important states of India in 2004-05

State	Area (000 ha)	Production (000 t)	Productivity (q/ha)
Andhra Pradesh	500.0	516.0	10.32
Bihar	3.8	3.8	10.00
Chattisgarh	6.6	4.4	6.67
Gujarat	179.8	207.5	11.54
Haryana	96.0	26.0	2.71
Jammu & Kashmir	6.0	3.6	6.00
Jharkhand	2.2	1.7	7.73
Karnataka	1662.0	1435.0	8.63
Kerala	0.7	0.3	4.29
Madhya Pradesh	659.0	630.6	9.57
Maharashtra	4756.0	3624.0	7.62
Orissa	10.1	5.5	5.45
Rajasthan	573.0	265.9	4.64
Tamil Nadu	376.7	252.1	6.69
Uttar Pradesh	247.3	252.3	10.20
West Bengal	1.5	0.6	4.00
India	9092.3	7244.0	7.97

Source: Fertilizer Association of India, 2006.

Classification

Three species of sorghum have been recognized *Sorghum halkepense* (L.) Pers.; *S. propinquum* (Kunth.) Hitche; and *S. bicolor*. The first two species are wild. *S. bicolor* is further divided into 3 sub species viz. ssp. *bicolor*, ssp. *drummondii* and *verticilliflorum.* The former one is cultivated and the later two are annual weedy types. Harlen and de Wet (1972) classified genus *sorghum* based on spikelet types into 5 basic races (*bicolor, guinea, caudatum, kafir* and *durra*) and ten hybrid races [*guinea-bicolor, caudatum-bicolor, kafir-bicolor, durra-bicolor, guinea-caudatum, guinea-kafir, guinea-durra, kafir caudatum, durra-caudatum* and *kafir durra*]. ssp *bicolor* is the most primitive and low yielding one. ssp *guinea* is cultivated in West Africa in areas with >1,000 mm rainfall and is low yielding. ssp. *caudatum* is dominant in Sudan, Chad, Nigeria and Uganda. ssp. *kafir* is cultivated in Northern Nigeria and Ghana. It is high yielding one and originated recently. ssp. *durra* is

widely cultivated in Arabia, Asia Minor, India, Myanmar, along the Nile valley and in Ethiopia. The Ethiopian *durra* is excellent source of stay green trait.

www.hear.org/.../html/sorghum_bicolor.htm **www.fao.org/docrep/008/y5831e/y5831e06.htm**

Courtesy : "Forest & Kim Starr"

Climatic Requirements

Sorghum requires warm climate but can be grown under a wide range of climatic conditions. The plant can tolerate high temperatures throughout their life-cycle better than any other cereal crop. The minimum temperature for germination of sorghum seed is 7-10^{o}C. It needs 26-30^{o}C temperature for its optimum growth. Though it can withstand temperatures up to 45^{o}C, but the lower temperatures (<8^{o}C) limit its cultivation owing to impaired flowering and pollination. Hence, its *rabi* cultivation is not possible in north India. Temperatures below 13^{o}C at blooming stage are detrimental to seed setting in *rabi*. It is a short day C_4 plant. The time of heading in sorghum is influenced by temperature as well as photo-period. It can also tolerate drought conditions very well, because it remains dormant during moisture stress conditions and resumes growth when favourable conditions reappear. It is grown from sea level to as high as 3,000 m elevation. It can also tolerate waterlogging conditions better than any other cereal except rice. Therefore, it can be grown successfully in areas having average annual rainfall between 40 and 100 cm.

Sorghum cultivation during *kharif* is declining in the country as prolonged rains at flowering stage aggravates grain mould incidence and the infected grains are unfit for human consumption.

Soil

Sorghum is grown on a variety of soil types. In India, it is mainly grown in alfisols (red) and vertisols (black). The red soils are derived from coarse crystalline acidic granite and are light-textured and shallow. These soils have high infiltration rate of 5-15 cm/hr, with pH ranging from 6.5 to 7.5 coupled with low N and P and rich in non-exchangeable potash. Surface crust is serious problem in these soils. These soils are mostly found in Andhra Pradesh and Karnataka.

Black soils are clayey in nature with varying depths. These are erodable due to presence of montmorillonite. These have low infiltration rate (about 0.1 cm/hr) leading to salt accumulation, and are generally deficient in N and P.

During *kharif* season, water logging is a problem vertisols with high clay content. In general, vertisols with 90-120 mm of stored moisture can support reasonably good rainfed *rabi* crop. However, in soil with low water storage capacity, winter showers or irrigation is necessary.

Land Preparation

The field is prepared by deep off-season ploughing every year in shallow to medium deep soils, and once in 3 years in deep to very deep soils. This should be done soon after harvest of *rabi* crop in double cropped regions, immediately after cessation of west monsoon. This leaves the field cloddy, exposing weed and other pests propagules to high temperatures. The cloddy field also aids in moisture conservation by increased opportunity time for runoff.

With the onset of monsoon, the field is ploughed or harrowed 2-3 times to break the clods followed by planking. In heavy soils prone to water logging, levelling is also done for easy drainage.

Seed rate and Spacing

In *kharif* and irrigated *rabi* seasons, the optimum population varies from 1, 50,000 to 2, 00,000 plants/ha. In rainfed *rabi* crop, the optimum population is little lower i.e. 1, 35,000/ha. These plant populations are achieved by planting at 45 cm x 15 cm or 60 cm x 10 cm. A seed rate of 8-10 kg/ha is required to achieve these plant populations. After germination, plants in the rows are thinned at the desired spacing.

Time of Sowing

It is mainly a *kharif* season crop in north India. In south India, it can be grown in *kharif*, *rabi* as well as summer seasons. In *kharif* under rainfed situations, the onset of monsoons is the single most factors deciding sowing time. Last week of June to first week of July is the optimum time of sowing. However, under irrigated conditions, the crop establishment before onset of monsoon is ideal. Thus 1-2 weeks advance sowings before monsoon are adopted. Too early or delayed sowings are not good as the flowering time may coincide with rains leading to grain mold incidence in the former case and moisture stress in the later.

Rabi sorghum is cultivated in the states of Maharashtra and Karnataka. In Andhra Pradesh, it is called *Maghi* season. The optimum time of sowing of *rabi* sorghum under rainfed conditions is second fortnight of September to mid October. Under irrigated conditions, as in Dharwad (Karnataka), sowings can be delayed and second week of October is the optimum time. For *Maghi* season of Andhra Pradesh, last week of September to first week of October is ideal.

For summer cultivation in the states of Tamil Nadu, Andhra Pradesh and Karnataka, January-February is the optimum sowing time.

Method of Sowing

In north India, sorghum is sown either by broadcast or in rows behind the plough. The seeds of hybrids and improved varieties should always be sown in rows for obtaining higher yields. Sowing in rows is common in black cotton soils. Sorghum is a tall growing crop, and to avoid mutual shading, sowing in sun rise and sun set direction is ideal.

Under moisture limiting environments, paired row planting pattern has been found promising. The paired row planting systems include 30/60 cm and 45/90 cm.

Thinning

In rows, plants should be thinned out to maintain 15-20 cm plant spacing at 2 stages. First thinning should be done 10-15 days after emergence and the second at 20-25 days after sowing. All diseased and insect infested plants should be removed in thinning.

Varieties

A number of varieties (since 1930) and hybrids (since 1964) have been developed in sorghum both for *kharif* and *rabi* seasons. *Kharif* cultivars are essential to be of short duration, short stature and photo-insensitive to ward off grain mould menace. The *rabi* (post-rainy) cultivars, on the other hand, should be tall, temperature insensitive with high degree of terminal drought tolerance, photo-insensitive besides having resistance to charcol rot and lodging. The varieties for ethanol production have also been evolved in recent times. The sorghum varieties and hybrids suitable for *kharif, rabi* and ethanol production for different states of India are given below.

Recommended sorghum varieties and hybrids for *kharif* in different states

State	**Varieties**	**Hybrids**	**Remarks**
Andhra Pradesh	CSV 15	CSH 6, CSH 4	Low rainfall areas
	CSV 10, CSV 11, SPV 62, CSV 13, CSV 15	CSH 5, CSH 9, CSH 10, CSH 16, CSH 18	Normal rainfall areas
	CSV 10, CSV 11, Moti	CSH 5, CSH 9, CSH 13	Late *kharif*
Gujarat	CSV 10, CSV 13, CSV 15, GJ 35, GJ 36, GJ 37, GJ 38, GJ 39, GJ 40, GJ 41	CSH 1, CSH 5, CSH 4. CSH 6, CSH 9. CSH 11, CSH 13, CSH 15, CSH 16, CSH 17, CSH 18	
Karnataka	CSB 1066, DSV 1, DSV 2	CSH 1, CSH 6, CSH 14, CSH 17	Low rainfall areas
	CSV 10, CSV 11, CSV 13, CSV 15, SPV 462, DSV 3 (midge resistant)	CSH 10, CSH 13, CSH 16, CSH 18	Normal rainfall areas

State	Varieties	Hybrids	Remarks
Madhya Pradesh	CSV 10, CSV 11, CSV 13, CSV 15, SPV 235, JS 741, JJ 938, JJ 1041	CSH 1, CSH 9, CSH 10. CSH 11, CSH 13, CSH 16, CSH 17, CSH 18	
Maharashtra	CSV 10, CSV 11, CSV 13, CSV 15, PVK 400, SPV 699, CSV 17	CSH 1, CSH 6, CSH 9, CSH 10, CSH 11, CSH 13, CSH 14, CSH 16, CSH 18, SPH 388	
Rajasthan	SPV 245, SPV 96, SPV 346, CSV 13, CSV 15, CSV 17	CSH 1, CSH 5, CSH 6, CSH 9, CSH 10, CSH 11, CSH 13, CSH 16, CSH 18	
Tamil Nadu	BSr1, SPV 346, SPV 96, CSV 10, CSV 13, CSV 15	CSH 1, CSH 5, CSH 11, CSH 13, CSH 14, CSH 16, CSH 17, CSH 18	
Uttar Pradesh	CSV 10, CSV 11, CSV 13, CSV 15, CSV 17	CSH 9, CSH 10, CSH 11, CSH 13, CSH 14, CSH 16, CSH 18	

Recommended sorghum varieties and hybrids for *rabi* season in different states

State	Varieties	Hybrids	Remarks
Andra Pradesh	SPV462, Moti, NTJ-2	CSH-5,CSH-10, CSH-12R	Early sown *rabi*
	M-35-1	CSH-8R,	Timely sown *rabi*
	CSV8R, CSV-14R	CSH-13R, CSH-15R	Early and timely sown *rabi* (both)
Gujarat	CSV 8R, CSV-14R	CSH-8R, CSH-12R, CSH-13R, CSH-15R	
Karnataka	M-35-1, DSV-5	CSH-12R, CSH-13R, CSH-14R	Dry zones
	CSV-8R, CSV 14R		Transitional and irrigated zones
Maharashtra	CSV 8R, M-35-1, CSV 14R, Phule Yasoda, CSH 216 R	CSH 8R, CSH 12R, CSH 15R, CSH 13, CSH 19R	Dry areas
	CSV 8R, Swati (SPV 504)	CSH 8R, CSH 13	Irrigated areas
Tamil Nadu	CO 24, CO 25, CSV 14R	CSH 10, K. tall, CSH 13R	Entire *rabi* zone
	CSV 8R, CSB 14R, CO 26, CO 24, CO 25	COH 13R, COH 3, CSH 15R, CSH 5	Summer irrigated zones

Varieties for ethanol and jaggery production and their characteristics:

***SSV-84*:** A selection from IS 23568, released in 1991 for rainy season cultivation matures in 123 days.

***NSSH 104 (CSH 22SS)*:** It is developed by crossing SSV 84 (male) x ICSA 38 (female)

For jaggery preparation, high total soluble solids and sucrose: reducing sugar > 9 are ideal. The alcohol production from sorghum grain is about 380 litres/tonne, while the starch production is 592 kg/tonne (Gluclose production = starch production x 1.11). The earheads are harvested at physiological maturity, and within 12 hours, the canes should be harvested and crushed immediately. The yield characteristics of sweet sorghum cultivars are given below.charactes

Character	**Variety/hybrid**		
	SSV-84	**NSSH104**	**RSSV16**
Green cane (t/ha)	36.0	41.0	38.0
Grain yield (t/ha)	2.3	2.3	2.0
Juice brix	18	19	20
Jaggery yield (t/ha)	3.0	3.1	3.3
Ethanol yield (l/ha)	1850	1950	2100

Manures and Fertilizer

Sorghum is an exhaustive crop, but needs moderate fertilizer application owing to its moisture limiting conditions. The area under irrigated conditions has increased enormously in recent years and under such conditions, liberal fertilization is done. Fertilizer requirement of hybrid/ composite varieties of sorghum is higher than *desi* cultivars.

In rainfed crop, 10 t/ha of FYM with 40-60 kg N/ha and 20-30 kg P_2O_5/ha is applied as basal. Under irrigated conditions, the crop should receive 80-100 kg N and 30-40 kg P_2O_5/ha. All P along with 50% N is applied as basal at the time of sowing. Rest 50% N is top-dressed by band placement 30 days after sowing at flower primordial initiation stage. Seed inoculation with *Azotobacter chrooccum* or *Azospirillum lipoferum* or *A. brasilense* has been found effective in 10-20 kg/ha N economy under rainfed conditions.

The response to K fertilization in India is rare. The deficiency of zinc and iron (in calcareous soils) is increasing day by day. Soil application of 25 kg zinc sulphate once in 3 years or foliar spray (2 times) of 0.2% zinc sulphate is promising in zinc deficient soils. In case of iron deficiency, foliar spray (twice) of 0.1% ferrous sulphate is recommended.

Water Management

It is predominantly grown as rainfed crop in *kharif*, and on conserved moisture in *rabi*. The water requirement of sorghum varies from 300-500 mm (*kharif* and *rabi*) to 600-700 mm (summer). Summer *jowar* is grown exclusively under irrigation. Depending upon availability of water resources for irrigation, *jowar* is provided with protective irrigation in *kharif* and is grown as irrigated crop in *rabi*.

There are four critical stages of growth for irrigation in sorghum i.e. flower primordial initiation (25-30 DAS), flag leaf stage (50-55 DAS), flowering (60-70 DAS) and grain filling (80-90 DAS). Under adequate water supply conditions of *rabi* and summer, irrigation should be given at all these critical stages. If water is available for 2 irrigations only, these should be applied at flower primordial initiation and flowering stages. In *kharif* rainfed crop, with prolonged dry spells, irrigation should be given at these critical stages.

The irrigation water requirement of summer sorghum is the highest (500-700 mm) followed by *rabi* (240-350 mm) and the least in *kharif* (120-250 mm). Similarly deep soils (vertisols) require less water than light soils (sandy, red soils).

Irrigation scheduling at 75% depletion of available soil moisture (DASM) in plough depths during *kharif* and at 50% DASM in *rabi* and summer is optimum for *jowar*. For scheduling irrigation based on irrigation water/cumulative pan evaporation (IW/CPE) ratio, 0.4 in *kharif*, and 0.8-1.0 in *rabi* and summer is ideal.

In rainfed *kharif* and *rabi jowar*, moisture conservation is extremely important. The crop sown in ridge and furrow or flat sowing followed by ridging 30-35 DAS has been found effective in moisture conservation during *kharif*. Organic mulching with crop residues or removed weeds and vertical mulching by digging trenches of 30-40 cm of 15-20 cm width are other effective methods of *in situ* moisture conservation practices recommended for successful *jowar* cropping.

Weed Control

Weeds simultaneously germinate in the crop sown under *kharif* rainfed conditions. The initial 30-45 days after sowing is the critical period of crop-weed competition. The crop should be kept weed free during this period. This is achieved by manual weeding and hoeing in *rabi* and *zaid* seasons. During *kharif* season, intermittent rains may not permit weeding and hoeing. Weeds may cause 20-60% reduction in yield, if not controlled at right time. During *kharif* season both grassy and broad-leaved weeds grow with sorghum crop. These are: *Echinochloa colonum, E. crusgalli* (*sawan*), *Dactyloctenium aegypticum* (*makra*), *E. leusine indica* (*kodo*), *Setaria glauca* (*bandar-bandri*), *Cyperus rotundus* (*motha*), *Sorghum halepanse* (*banchari*), *Cynodon dactylon* (*doob*), and *Phragnutes kakta* (*narkul*).

Weeds should be removed with the help of *khurpi* or hand hoe in 3-week old crop. Atrazine @ 1.0 kg/ha in 800-1000 litres of water as pre-emergence just after sowing could successfully control the weeds. There should be enough moisture in the soil at the time of spraying. Intercropping with cowpea has also been found effective in weed management. Another pre-emergence herbicide recommended for *jowar* is prometryne @ 1 kg/ha. The integration of above herbicides with one hand weeding or hoeing 35-40 DAS may effectively control most of the weeds. Striga (root parasitic weed) menace is observed in Maharashtra, Karnataka and Andhra Pradesh. If striga menace is severe, 2,4-D should be applied as post-emergence @ 1 kg/ha between 20-60 DAS, in addition to above herbicides

Cropping Systems

Mixed cropping of soybean, pigeonpea, blackgram, greengram and cowpea with sorghum has been found profitable in north India. Sorghum hybrid CSH 6 is more suitable for mixed cropping. Most of the high yielding varieties and hybrids mature in about 90-120 days, and fit well in multiple crop rotations. Some of the sorghum based crop rotations with sorghum are given below.

North India	South India
Sorghum-potato/ rape-wheat/ tobacco	Sorghum-cotton-groundnut
Sorghum-wheat-cowpea/ pearlmillet	Sorghum-ragi-groundnut
Sorghum-wheat-greengram	Sorghum-cotton
Sorghum-pea / oat / berseem	Groundnut- sorghum(*rabi*)
Sorghum-gram or barley	Sorghum-tobacco
Sorghum-lentil	Sorghum- sorghum(*rabi*)

Harvesting and Threshing

The crop should be harvested immediately after maturity. There is no need to wait for stalks and leaves to dry as the plants of hybrid sorghum appear green even after the crop maturity. The right time for harvest is when grains become hard and contain less than 25% moisture. Generally 2 methods of harvesting i.e. stalk cut and cutting of earheads by sickles are adopted. However, in foreign countries, sorghum harvesters are used. In case of stalk cut method, the plants are cut from near the ground level. The stalks are tied into bundles of convenient sizes and stacked on the threshing floor. After 2-3 days, the earheads are removed from the plants. In other method, earheads only are removed from the standing crop and collected at the threshing floor for threshing after 3-4 days of sun-drying.

Threshing of earheads is done either by beating them with sticks or by trampling under bullock feet. The later method is quicker and adopted by majority of farmers. Threshing is also done with the help of threshers. The threshed grain should be cleaned and dried in sun for 6-7 days to reduce the moisture content down to 13-15% for safe storage.

Yield

The grain yield of improved varieties under assured water supply ranges between 2.5-3.5 tonnes/ha, and that of hay or *karvi* between 15.0-17.0 tonnes/ha. With improved cultural practices, it is possible to harvest nearly 5.0 tonnes of grain and about 10.0-12.5 tonnes of dry stover from 1 ha under irrigated conditions.

The yield attributes (range) of sorghum are as below.

Attribute	Value
Panicle length	20-30 cm
Grain weight/panicle (g)	30-50
1,000 grain weight (g)	25-30

Additional reading Material:

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Agronomy – Kharif Crops

Pearl Millet (Bajra)

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PEARL MILLET (Bajra)

Botanical name: (*Pennisetum glaucum* L.) R. Emend stuntz

Chromosome number: 2n=14

Pearl millet, a C_4 plant, is the major coarse grain crop of world. It is mostly grown in Africa and Asia since the pre-historic times. In Asia, it is an important cereal crop of India, Pakistan, China and South-eastern Asia. It is highly drought-tolerant crop among cereals and millets. It provides staple food for the poor in a short period in the relatively dry tracts of the country. It is also used as feed for poultry and green fodder or dry *karvi* for cattle. Pearl millet grains are eaten cooked like rice or '*chapaties*' are prepared out of flour like sorghum or maize.

Origin

Pearl millet is originated from its wild progenitor of *Pennisetum* ssp. *violaceum* in western Africa and was domesticated 4,000 years ago. India is considered as the secondary center of diversity of pearl millet after its introduction over 3,000 years ago.

Geographic Distribution

Pearl millet is grown globally in 29 million ha in more than 40 countries. Its cultivation is mainly confined to semi-arid and arid climates of tropical and sub-tropical regions of South Asia (primarily India), Africa and Latin America. In Africa, it is cultivated in Nigeria, Niger, Mali, Chad, Tanzania, Sudan, Senegal and Burkina Faso. The west and central Africa accounts for about 16 mha. It is also grown in Oceania and the Americas on a small scale.

In the country it is grown on 9.23 mha with Rajasthan alone accounting for 50% acreage and 38% of production. The area (13.93 mha), production (12.11 mt) and productivity (11.41 kg/ha) was the highest in the country during 1973-74, 2003-04 and 2003-04, respectively. The distribution of pearl millet in the country is given in Table 1.

Table 1.Area, production and productivity of *bajra* in important states of India (2004-05)

State	Area (000 ha)	Production (000 t)	Productivity (q/ha)
Andhra Pradesh	94.0	81.0	8.62
Gujarat	925.2	1084.7	11.72
Haryana	569.0	749.0	13.16
Karnataka	494.0	267.0	6.01
Madhya Pradesh	176.5	241.5	13.68
Maharashtra	1529.0	1126.0	7.39
Rajasthan	4564.6	3002.2	6.58
Tamil Nadu	97.6	124.3	12.74
Uttar Pradesh	797.6	1223.9	15.34
India	9232.9	7931.3	8.59

Source: Fertilizer Association of India, 2006

Climatic Requirements

Pearl millet grows well under warm climatic conditions with 500-600 mm of rainfall during the growth period. However, it is also grown in areas with rainfall ranging from 400 – 750 mm. For proper vegetative growth, moist weather is needed. It can not tolerate waterlogging. High rainfall at reproductive phase is not conducive, as it aids in spread of fungal diseases especially ergot. It is susceptible to frost damage and is predominantly grown as a rainfed *kharif* crop. However, its summer cultivation is also popular in the states of Tamil Nadu and Karnataka.

The optimum temperature for growth is 25-30^{o}C. High temperatures at early stages induce flowering, while low temperatures promote ergot incidence. India has been divided into the following 4 ecological zones of pearl millet.

- **Ecological Zone I**: Adequate to abundant rainfall and fertile zone (Punjab, Delhi, Uttar Pradesh, Haryana and adjacent Madhya Pradesh).
- **Ecological Zone II**: Limited rains, but heavy to light loamy soils (Gujarat, Maharashtra and Madhya Pradesh).
- **Ecological Zone III**: Low rainfall and light soils (Karnataka, north-central Andhra Pradesh and Rajasthan).
- **Ecological Zone IV**: Limited but well-distributed rainfall (Tamil Nadu, coastal Andhra Pradesh).

Soils and land preparation

Pearl millet can be raised on a variety of soils, but prefers light textured soils of low inherent fertility and mild salinity. The soil should be deep and free from stones and concretes. Crop does not tolerate soil acidity. It is grown successfully on black cotton soils, alluvial soils and red soils of India.

The crop needs fine tilth as the seeds are too small. The field is prepared by summer ploughing with mould board plough after the onset of monsoon followed by 2-3 harrowings or ploughing by country plough. Clods must be broken by planking the field after every ploughing so that fine tilth may be obtained to facilitate the sowing and proper distribution of seed at an appropriate depth. Adequate moisture in the seed bed at the time of sowing is conducive to good and quick germination.

Varieties

Initially, improved cultivars of *bajra* were evolved by selection (mass/pure line) from land races such as RSK, RSJ and Jakrana (Rajasthan), N-28-15-1 and Avsari (Maharashtra) and Mainpuri (Uttar Pradesh). Some of the introductions from Africa also served as varieties (Jamnagar Giant, Improved Ghana and Pusa Moti). Hybridization was also explored in evolving varieties in the country. HB 1 was the first cytoplasmic male sterile (CMS) hybrid evolved in 1965 at Ludhiana, Punjab. Since then many varieties and hybrids have been evolved.

The pearl millet regions in India are regrouped into two major zones in recent years.

Zone A: North west zone comprising the states of Rajasthan, Gujarat, Haryana, Plains of Uttar Pradesh, New Delhi, Madhya Pradesh (Bhind, Morena, Gwalior and adjoining areas)

and Punjab. Parts of states of Rajasthan, Gujarat and Haryana with rainfall < 400 mm are grouped into the **sub zone A 1**.

Zone B: South central zone consisting of state of Maharashtra, Andhra Pradesh, Karnataka and Tamil Nadu.

The varieties and hybrids recommended for different zones and states are given below.

Varieties of pearl millet recommended for different zones

Zone	***Hybrids***	**Varieties**
Zone A	*MH 518, MH 497, RHB-127, HHB-146, GHB-577, HB-4*	MP 258, MP 266, JBV-3, JBV-2, Pusa bajri, Pusa Composite 383, Pusa safed PCB-15. CZP 9802*
Zone B	*MH 515, MH 552, SAMH-166*	ICMV 155, AP Composite (MT), Composite 3, BD-163, BD-111, CJ-104
Both Zones	*HC-4, GHB-558, BK 560-230*	ICTP 8203, WCC 75, ICMS 7703, Raj bajra chari-2, ICMV-221, Raj-171, Pusa-334

* For Zone A1

State-wise recommended varieties of pearl millet

State	***Hybrids***	**Varieties**
Uttar Pradesh & Uttarakhand	*HB 5, PHB 10, PHB 14, PHB 47, MBH 110, MH 36, BJ 104, BK 560, BD 111, BD 163, CM 46, ICMH 356*	PSB 8
Bihar & Jharkhand	*PHB 10, MH 143, MH 169, BJ 104. BK 560, BD 111, BD 163, ICMH 356*	
Madhya Pradesh and Chattisgarh	*BJ 104, BK 560, BD 111, BD 163, CM 46, CM 5, ICMH 356*	RCB 2, Vijay Composite
Rajasthan	*BK 104, BK 560, BD 111, BD 163, CM 46, ICMH 356, GHB 526*, PB 180**	
Haryana and Punjab	*HB 5, PHB 10, PHB 14, PBH 47, MH 67, MH 169, MH 190, MH 208, HHB 67, BJ 104, BK 560, BD 111, CM 46, BD 183, HHB 68, HC 10, HHB 117*	HS-1**. PCB-164
Andhra Pradesh & Tamil Nadu	*HB 4, HB 5, PHB 10, PHB 14*	
Gujarat & Maharashtra	*PHB 10, PHB 14, BJ 104, MBH 110, GHB 526*, PB 180**	PPC 6
Karnataka	*BJ 104, MBH 110*	RCB 2

* Summer; ** Synthetic

Sowing

The time of sowing in *kharif* under rainfed conditions depends on the onset of monsoon. First fortnight of June to mid July is the optimum time of sowing. In Tamil Nadu, pearl millet is grown as *rabi* rainfed crop in regions with north-eastern monsoon from September-December. Irrigated summer crop is seeded in February-March. Delayed sowing up to

August results in high seedling mortality, quick reproductive life cycle and low yield owing to incidence of diseases like ergot. If delay in sowing is anticipated, transplanting of seedlings is advised.

Too early sowings hamper germination and emergence and also washing of pollens if late rains continue in the season. A seed rate of 4-5 kg/ha is required for line sowing behind a drill or country plough. The optimum row spacing is 50 cm and the plant to plant spacing varies from 10-12 cm. The optimum plant population varies from 1.5 to 2.0 lakh plants/ha. The seed should not be sown deeper than 4 cm for proper germination.

In case of transplanting, 2 kg seed/ha is sufficient to provide desired number of seedlings/ha. Seeds are sown on flat bed in 10 cm rows at 2 cm depth in 500 m^2 nursery. 30 kg N/ha is applied at the time of sowing. The seedlings are ready in 3 weeks for transplanting in a field, which is irrigated previously. However, under rainfed conditions, transplanting is advised after the receipt of rains only. The benefits of transplanting include: i) early maturity, ii) escaping from low temperature effect on grain filling iii) ensuring optimum plant stand and iv) producing more tillers and earheads as compared to direct seeding. However, the limited moisture periods available in rainfed situation and high labour requirement often limit its wider adaptability.

Manures and Fertilizers

Application of 10-15 tonnes/ha of FYM or compost can easily meet requirement of local varieties of pearl millet. This should be applied at the time of land preparation. Hybrid and composite varieties are applied 100-120:50:40 kg/ha of N:P_2O_5:K_2O in addition to organic manures. *Deshi* varieties are applied 50-40-20 kg/ha of N-P_2O_5-K_2O. *Azospirillum brasilense* a bacterial biofertilizer has been found promising for pearl millet. Its effectiveness is relatively more when applied along with lower dose of N (10-40 kg/ha).

Two splits (basal + 3 weeks after sowing) of N prove better than basal alone. The top dressing, however, should be done under favourable moisture conditions only i.e. coinciding with rainfall up to flag leaf stage. If moisture is not favourable, avoid N fertilization as top dressing. 30 kg/ha each of P_2O_5 and K_2O is general recommendation for pearl millet. For low and medium rainfall areas, 40-30-30 and 60-40-40 kg/ha of N-P_2O_5-K_2O is recommended.

Basal application through placement of full doses of P and K along with 50% N before planting is recommended. Foliar fertilization of N as urea has been found advantageous for rainfed pearl millet.

Water Management

Pearl millet is predominantly a rainfed *kharif* crop. Water requirement of pearl millet is much lower (250-350 mm) than maize, sorghum and finger millet (500-600 mm). It requires, on an average 140-150 mm of water/ tonne of grain produced. Although it is a rainfed crop, but irrigation at anthesis or flowering stage is beneficial. As many as 3-4 irrigations may be required in the event of complete failure of rainfall. Flowering and grain filling stages are the critical stages of irrigation. As a rainfed crop under normal rainfall distribution, it hardly needs any irrigation.

Pre-sowing seed treatment with 0.2% KNO_3 has been found effective for seed hardening for sustaining moisture stress conditions.Reduction in plant density is one of the important mid way correction techniques followed to save drought hit pearl millet. Removal of plants within row is advantageous than removing alternate rows. The removed plants may be used as mulch, while keeping 1.25 lakh plants/ha. Modified land configurations like bunding or ridge and furrow systems are promising than flat sowing in moisture conservation. Ridge and furrow system is promising in light soils or sloppy lands in particular. Deep summer

ploughing coupled with application of FYM @ 10 t/ha may help in moisture storage and conservation.

Weed Control

Being a rainy season crop, it suffers heavily due to weed infestation. The crop suffers most during 3-5 weeks after sowing. Competition with weeds could reduce yields by 25-50%. Therefore, timely weed control is very essential to get higher yields. The important weeds of Pearl millet are : Anjan grass (*Echinochloa colonum*); *doob* (*Cynodon dactylon*); *motha* (*Cyperus rotundus*); *sathi* (*Trianthema portucalastrum*); *kewal* (*Digitaria sanguinalis*), *makra* (*Decteloctenium aegyptium*).

The crop needs 2-3 intercultural operations between 3-6 weeks after sowing. At the time of first interculture, thinning or gap filling should be done along with removal of weeds. An integrated weed control measure like hand weeding, inter row cultivation and pre-emergence application of atrazine @ 0.5 kg/ha may take care of most of the weeds. Proper weed management is also needed for conserving precious moisture.

Cropping Systems

In rainfed areas of north India, pearl millet is raised mixed with blackgram, greengram and sesame. Intercropping of groundnut or castor with hybrid pearl millet has also shown promise at Hisar (Haryana). Intercropping of greengram with pearl millet (2 rows of greengram in between 2 rows of pearl millet) may give an additional 2-3 q/ha of greengram grain. Two rows of cowpea in place of mungbean may produce about 90 q/ha of green fodder within 45 days.

Some of the most important crop rotations are:

Pearl millet-wheat-greengram

Pearl millet-wheat- pearl millet

Pearl millet-barley/ gram/ pea/ wheat / berseem

Pearl millet-potato-mungbean or blackgram

Pearl millet-potato-wheat

Pearl millet-mungbean or blackgram

Pearl millet-rape-wheat

Pearl millet-berseem

Pearl millet-*toria*-wheat

Harvesting and Threshing

The grain crop should be harvested when the grains become hard enough and contain about 20% moisture. Generally 2 methods for harvesting the crop are adopted, viz. (i) cutting of earhead first from the standing crop followed by cutting the remaining plants later, and (ii) cutting the entire plant by sickles and staking the harvested plants for 5-6 days in sun for drying.

The grains are separated either by beating the earheads by sticks or trampling by bullocks. The threshed grain should be cleaned and dried in sun to bring about 12-14% moisture for safe storage.

Yield

A well managed irrigated crop gives about 3.0-3.5 tonnes (hybrids) and 2.0-2.5 tonnes (composites) of grain and 10.0 tonnes stover/ha, while unirrigated crop yields about 1.2-1.5 tonnes grain and 7.0-7.5 tonnes of dry stover/ha.

The yield attributes (range) of pearlmillet are:

Attribute	Value
Earhead length (cm)	20-35 cm
Grain weight/earhead (g)	8-18
1,000-grain weight	5-13
Protein (%)	11.6
Fat (%)	5.0
Fibre (%)	1.2
Carbohydrates (%)	67.5

Additional Reading :

http://en.wikipedia.org/wiki/Pearl_millet

Agronomy – Kharif Crops

Finger Millet

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FINGER MILLET

Botanical name: *Eleusine coracana* L. Gaertn
Chromosome number: 2n =4x=40

Finger millet, also known as *ragi*, is valued as staple food in south India (Karnataka, Tamil Nadu, Andhra Pradesh) and hilly regions of the country. The straw has immense utility as fodder. Silage is also made from *ragi* forages at flowering stage. It is a rich source of calcium (0.344%) for growing children and aged people. It is usually converted into flour, which is used for preparation of cake/puddings/porridge. Straw makes valuable fodder for both draught and milch animals. It is wholesome food for diabetics.

Origin and History

The cytomorphological studies indicate that finger millet (*E. coracana*) might have originated from *E. africana* through selection in Ethiopia and highlands of Africa. It was introduced into India about 3,000 years ago, and became the secondary center of finger millets diversity.

Geographic Distribution

Finger millet is grown in more than 25 countries in Africa and Asia. Uganda, India, Nepal, and China are the major *ragi* producers of world. In India, it is extensively grown in Karnataka, Tamil Nadu, Andhra Pradesh, Orissa, Bihar, Gujarat and Maharashtra and the hilly regions of Uttar Pradesh and Himachal Pradesh. The area under finger millet has declined from 2.6 million ha in early sixties to around 1.66 million ha in 2003-04. However, the annual production is maintained around 2.6 million tonnes with a productivity of around 1400 kg/ha (Table 1).

Table 1. Area, production and productivity of *ragi* in important states of India in 2004-05

State	Area (000 ha)	Production (000 t)	Productivity (kg/ha)
Andhra Pradesh	69.0	87.0	1261
Bihar	15.6	10.5	673
Chattisgarh	10.3	2.7	262
Gujarat	24.3	25.8	1062
Himachal Pradesh	3.0	3.0	1000
Jharkhand	18.0	11.0	811
Karnataka	893.0	1733.0	1941
Kerala	0.5	0.6	1200
Madhya Pradesh	0.5	0.1	200
Maharashtra	145.0	147.0	1014
Orissa	78.0	44.9	576

State	Area (000 ha)	Production (000 t)	Productivity (kg/ha)
Tamil Nadu	108.9	154.1	1415
Uttarakhand	167.0	190.0	1138
Uttar Pradesh	0.7	0.9	1286
West Bengal	12.4	15.1	1218
India	1552.7	2432.4	1567

Source: Fertilizer association of India, 2006

Botanical description

Finger millet is an erect, tufted annual growing to 60-120 cm height with profuse tillers. The tillers have earheads consisting of whorl of finger like spike (2-8 in numbers). The spikelets in spike are arranged closely on both sides of a slender rachis. The spikelet are crowded into 2 over-lapping rows on the outsides of the spike. Each spikelet has 4-5 flowers and may take 6-8 days to complete flowering. Flowering takes place simultaneously in all fingers. The spikelets possess 3-8 seeds which are tiny in size and generally reddish brown in colour. Its grain contains 9.2% protein, 1.29% fat, 76.32% of carbohydrates, 2.24% minerals, 3.99% ash and 0.33% calcium.

Source: **www.payer.de/mahavamsa/chronik32.htm**

Climatic Requirement

Finger millet is a crop of tropics and sub-tropics and can be raised successfully from sea level to an altitude of 2,300 m on hill slopes, as well as plains. It grows best in moist climate. It is grown in areas with rainfall up to 100 cm. In regions of higher rainfall and under irrigation, it can also be grown as a transplanted crop. It is also raised as summer crop, and as *rabi* crop in south India, but mainly as *kharif* crop in north India.

Finger millet prefers warm climate. The minimum temperature required for germination is 8-10^{o}C. A mean temperature of 26-29^{o}C is optimum for growth. Crop yields are reduced at temperatures below 20^{o}C. The crop possesses good drought tolerance but is highly sensitive to frost.

Soils

It is grown on wide range of soils with varying fertility. It prefers porous and well drained soils. It has the best ability to tolerate salinity among cereals. Alluvial and loamy soils are suitable for this crop. Deep vertisols and rocky soils are not suitable for this crop owing to poor drainage and low fertility. It can be grown in soils with pH of 4.5-7.5.

Land preparation

Varieties

A number of varieties have been evolved utilizing native and exotic germplasm under the aegis of All India Coordinated Millets Improvement Project (AICMIP) since 1969. The improvement has got further impetus with establishment of separate Small Millets Improvement Project (AICSMIP) in 1986. Development of high yielding, drought and blast resistant varieties/hybrids is the focus of the improvement in finger millet. The important varieties recommended for cultivation in different states are given below.

Recommended varieties of *ragi* for different states

State	***Variety***
Andhra Pradesh	Godavari, AKP 2, AKP 7, IE 28, EC 4840*, Padmavati (PPR 2230), BM 9-1, Gautami*
Bihar & Jharkhand	RAU 1, RAU 2, RAU 5, RAU 8, BR 2, GPU 45, Birsa Munda-2 (EC-50-90), RM 2, A 404, Indaf-1
Madhya Pradesh & Chattisgarh	BR 407, PR 202, JNR 852, JNR 1008, BM 9-1*, KM 13
Maharashtra	PES 176, HR 376, BR 407, GPU 45, BM 9-1, B1, E3, QA 16
Orissa	PES 176, HR 407, BM 9-1, KM 13
Uttar Pradesh & Uttarakhand	VL 101, VL 102, VL 124, VL 204, VL 146*, Pant Mandua-3 (Vikram), PES-176*, PES 400, KM-13, Nirmal, KM-65
Karnataka	Indaf 1, Indaf 5, Indaf 8, GRU 28, Fingermillet LS, GPU-45*, BM 9-1, GPU-28*, GPU-26, Cauveri, Hamsas, Annapurna, Hagari 1, Hagari 2, MR-1, Shakti Hullubele
Tamil Nadu	GPU 28, Indaf 5, CO 1, CO 2, CO 8, CO 9, CO 7, CO 13, K 1, K 2, TRY 1
Gujarat	GPU 45, GN 3, GPU 28
All States	VR 708**, Akshya [MR2 (as alternative to Indaf 8)], PES-110, PR 202, VL 149*, JNR 852, MR 374

* Blast resistant; ** drought tolerant

Other varieties:

Bharabi, Maruthi, PES-8, Sharda (IE 109)

Seed and Sowing

Source: www.fao.org

Seed Rate

The quantity of seed required for line sowing is 8-10 kg/ha. The crop raised by transplanting need 4 kg seed for raising nursery for 1 ha. Seed should be treated with thiram and agrosan GN @ 2.5 g/kg seed.

Time of Sowing

Kharif crop is sown during May or June. If the rains are not received in time, the sowing time is postponed up to the end of August. However, sowing should be done early in rainfed areas to avoid moisture stress at critical stage of flowering. In areas, where irrigation facilities are inadequate, the sowing should be done soon after onset of monsoon. In higher hills of northern India, the optimum time of sowing for finger millet is the first fortnight of June.

The irrigated crop of finger millet is sown in more than one season in Karnataka, Tamil Nadu and Andhra Pradesh. The rainfed early crop is sown in April or early May. The irrigated *rabi* crop in Karnataka, Tamil Nadu and Andhra Pradesh is sown in September and October.

Method of Sowing

It is always better to sow finger millet in lines instead of broadcast. Line-to-line distance of 20-25 cm and plant to plant distance of 8-10 cm is maintained. The seed should not be sown less than 3-4 cm deep. Line sowing ensures better germination, reduces seed requirement and facilitates intercultural operation as compared to broadcast method of sowing.

Transplanting

In areas with adequate moisture, finger millet can be grown by transplanting. Higher yields are obtained in case of transplanted crop as compared to direct-seeded crop. Seeds should be sown in well pulverized nursery beds during May-June. About 4 kg seed is required for 1 ha

land. Three to four weeks old seedlings should be transplanted in the field. Field should be well prepared before transplanting. Transplant 2 seedlings/hill at a distance of 25 cm x 8 cm or 20 cm x 10 cm. Seedlings should be transplanted 2-3 cm deep. The beds should be irrigated on the third day after transplanting. Transplanted crop does not lodge during rains.

Manures and Fertilizers

The crop responds well to fertilizer application. However, the dose of fertilizers may vary for rainfed and irrigated crop. In addition to 5 tonnes of FYM, 30-30-30 kg/ha of N-P_2O_5-K_2O are applied as basal for rainfed crop. Under favourable rainfall, 30 kg N/ha is top dressed 6 weeks after sowing. Irrigated crop may respond up to 150 kg N/ha. The entire quantity of fertilizers should be applied 8-20 cm deep in soil at the time of sowing. In acidic soils, crop also needs calcium and magnesium fertilization.

Application of 50 kg Mg/ha and 16.8 kg Ca/ha benefits the crop. Application of 75% recommended level of N + 5 tonnes FYM/ha + *Azospirillum* results in higher yield as compared to 100% inorganic N fertilizer. Treating seeds with *Azospirillum brasillence* and *Aspergillus awamori* @ 25 g/kg seed is beneficial.

Water management

As a predominantly rainfed *kharif* crop, finger millet does not require irrigation. However, irrigation at tillering and flowering is conducive for realizing higher yields, wherever long dry spells in the season are experienced. During *rabi* season, the crop requires 2-3 irrigations coinciding with tillering, flowering and grain filling stages. Transplanted crop requires irrigation at 3 days after planting. Drainage is more important in *kharif* season at times of heavy rainfall.

Weed control

Weeds are serious threat to finger millet productivity especially during initial 2-3 weeks from sowing. Two weedings or hoeings at 15 days interval starting from 25 days after sowing are necessary.

In areas of assured rainfall and irrigated areas, spraying of 2,4-D Na salt @ 0.75 kg/ha as post-emergence around 20-25 days after sowing effectively control weeds. Isoproturon @ 0.5 kg/ha or metoxuron @ 0.75 kg/ha as pre-emergence spray is also effective in control of weeds. *Striga* parasitises *ragi* and poses a serious problem in India and Africa.

Cropping Systems

Finger millet is grown under rainfed conditions mixed or intercropped with sorghum, pearl millet and various oilseeds and pulses. In hills, it is also grown mixed with soybean. Under irrigated conditions, it is grown in rotation with crops like chillies, vegetables, turmeric, tobacco, gram, mustard, barley, linseed etc. Some of the common crop rotations adopted in north and south India are given below.

North India	South India
Finger millet-mustard	Finger millet-tobacco
Finger millet-gram	Finger millet-groundnut
Finger millet-barley	Finger millet-potato-maize
Finger millet-linseed	Finger millet-potato- finger millet
Finger millet-tobacco	Finger millet-sugarcane

Harvesting

The crop flowers in 60-80 days, and matures in about 120-130 days depending on the tract and the variety. Harvesting is generally done in 2 stages. The earheads are harvested with ordinary sickles and straw is cut to the ground. Earheads are heaped for 3-4 days to cure and then threshed with hand or bullocks. At some palces under rainfed condition, the whole plant with earhead is cut, heaped and then threshed.

Yield

The average yield of rainfed crop ranges from 1.0 to 1.5 tonnes grain/ha, whereas irrigated crop yields up to 5.0 tonnes/ha. The fodder yield ranges from 3.0 to 9.0 tonnes/ha in case early group and 9.5-10.0 tonnes/ha in late group. The straw of finger millet is a nutritious fodder. It can be conserved by putting up in well-built stakes.

The yield attributes (range) of finger millet are as below.

Attribute	Value
Productive tillers (No.)	2-4.5
Finger number (No.)	5.12
Finger length (cm)	3-14 cm
Grains/finger	22-81
1,000 grain weight (g)	1.0-4.5