GOOD AGRICULTURAL PRACTICES (GAPS) OF SUSTAINABLE MILLET PRODUCTION

Collaboration project between
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Preface

Millet is a drought-resistant plant that can be grown in almost every area of Thailand. Farmers usually grow it as a second crop after other crops such as corn, and it can be grown as a main crop in some areas where other crops do not do well. In terms of utilization of sorghum, in addition to producing it as animal feed, the seeds can be processed into food, made into brooms, or produced as ethanol. This document is prepared to provide guidelines for Good Agricultural Practice (GAP) of Millet and to be used as a guideline for decision-making in choosing crops to grow.

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Content

Table

1. Introduction

Sorghum is an annual or biennial cereal. It originated in East Africa, where it was first cultivated in the 4th century BC. It is the fifth most widely cultivated crop in the world. Sorghum is very popular because of its low growth requirements and high yield. Sorghum has many beneficial properties that can be used in various industries. Many varieties of sorghum are grown as field crops, industrial crops, and animal feed. In addition, the cultivation of sorghum does not require special machinery and equipment. In addition, sorghum has many beneficial properties, such as being gluten-free, 329 calories/100 grams, 11 grams of protein/100 grams, 7% soluble fiber, keeps you full for a long time, controls weight, vitamin B6, nourishes the nerves, reduces numbness and blood sugar levels, controls diabetes, prevents neurological diseases, skin diseases, antioxidants, flavonoids, phenolic acids, tannins, and magnesium. It reduces the risk of osteoporosis, etc. When comparing the nutritional value with other grains such as quinoa, fenugreek, fonio, rice and wheat, it was found that millet has higher protein, fiber, minerals, iron and calcium than rice (Table 1)

Global Sorghum Production Situation

In 2024/25, the total world sorghum production was 30.2 billion metric tons (USDA, 2024), mainly produced in developing countries in Asia and Africa, including India (12.84 million metric tons), Niger (3.16 million metric tons), China (2.7 million metric tons), Mali (1.94 million metric tons), Nigeria (1.56 million metric tons), Sudan (1.35 million metric tons), Ethiopia (1.1 million metric tons), Senegal (1.35 million metric tons), Burkina Faso (0.861 million metric tons), and Chad (0.634 million metric tons), as shown in Table 2.

Table 1 Nutritional value of millet compared to other cereals

Plant	Protein (g)	Fiber (g)	Minerals (g)	Iron (mg)	Calcium (mg)
Millet	10.0	4.0	1.6	2.6	54
Pearl millet	10.6	1.3	2.3	16.9	38
Finger millet	7.3	3.6	2.7	3.9	344
Foxtail millet	12.3	8.0	3.3	2.8	31
Proso Millet	12.5	2.2	139	0.8	14
Kodo Millet	8.3	9.0	2.6	0.5	27
Little Millet	77	7.6	1.5	9.3	17
Barnyard Millet	11.2	10.1	4.4	15.2	11
Brown top Millet	11.5	12.5	4.2	0.6	0.01
Quinoa	14.1	7.0	*	4.6	47
Teff	13.0	8.0	0..9	7.6	180
Fonio	11.0	11.3	5.3	84.8	18
Rice	6.8	0.2	0.6	0.7	10
Wheat	11.8	1.2	1.5	5.3	41

Table 2 World Millet Production and Percentage, Production Year 2023-2024

Country	2022		2023		2024	
	Production (Mt)	Percentage	Production (Mt)	Percentage	Production (Mt)	Percentage
India	13,506	42.1	12,200	39.6	12.840	42.5
Niger	3,657	11.4	3,400	11.0	3.160	10.5
China	2,700	8.4	2,700	8.8	2.700	8.9
Mali	2,030	6.3	2,000	6.5	1.940	6.4
Nigeria	1,833	5.7	1,800	5.8	1.560	5.2
Senegal	1,675	5.2	1,1600	37.7	1.350	4.5
Ethiopia	942	2.9	1,100	3.6	1.100	3.6
Bukina Faso	908	2.8	1,000	3.2	0.861	2.9
Sudan	1,097	3.4	1,000	3.2	0.684	2.3
Chad	694	2.2	700	2.3	0.634	2.1
Other	3,062	9.5	3,302	10.7	3.371	11.2
Total	32,104	100.0	30,802	100.0	30.200	100.0

Source : FAO (2025), USDA (2024)

Sorghum Production Situation in Thailand

For the sorghum planting area in Thailand, the 2018/2019 crop year (Department of Agricultural Extension, 2019), the planting area is approximately 29,879 rai (Table 3) in Nakhon Sawan, Lopburi, Sukhothai, and Saraburi provinces, with an average yield of 200 kilograms per rai, most of which is sorghum seed. According to the Department of Foreign Trade (2025), Thailand has exported sorghum seed to the Asian region, with an export volume since 2011 of 7,095.94 tons, valued at 80.14 million baht, with the main importing countries being the Philippines, Japan, Taiwan, Kuwait, Bahrain, the United Arab Emirates, the United Kingdom, and Qatar. After that, exports decreased until 2014, when exports increased in line with the planting area, with an export volume of up to 10,571.70 tons, and the export volume has been decreasing continuously. According to the decrease in planting area, approximately 1,100.53 tons of sorghum are currently exported, valued at 12.75 million baht (Tables 4 and 5). The reason for the decrease in sorghum planting area is that there are competing crops that provide higher returns than sorghum, namely cassava, sugarcane, and animal feed corn. The three crops have returns of 3,727, 3,400, and 2,830 baht per rai, which are 93, 76, and 47 percent higher than sorghum, respectively (Table 6).

Table 3 Planting area, harvested area, production and average yield of millet in Thailand on 2018/2019

Province	Planting area (ha)	Harvested area (ha)	Yield (Ton)	Average Yield (kg/ha)
Nakhon Sawan	4,641.60	4,641.60	5,664.50	1,218.75
Lop Buri	108.00	100.00	274.04	2,737.50
Sukhothai	28.32	28.32	19.00	668.75
Sara Buri	2.72	2.72	8.50	3,125.00
Total	**4,780.64**	**4,772.64**	**5,966.04**	**1,250.00**

Table 4 Thai millet export volume on 2011-2024

Country	Export volume (Ton)													
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Grade 1														
Philippines	345.00	-	66.25	100.00	-	-	-	46.00	-	367.90	150.00	75.00	-	125.00
Japan	66.00	-	154.00	836.00	154.00	-	43.00	-	129.00	-	42.00	-	-	-
Total Grade 1	411.00	-	220.25	936.00	154.00	-	135.00	46.00	129.00	367.90	192.00	75.00	-	125.00
Grade 2														
Taiwan	4,550.28	70.01	881.29	6,182.15	24.50	-	-	-	-	-	-	200.00	200.00	299.88
Kuwait	1,805.00	-	-	221.00	47.73	-	-	-	-	-	-	-	-	-
Philippines	-	70.01	1,606.85	2,795.69	356.75	635.58	1,512.00	-	690.66	1,632.00	997.90	1,189.00	542.00	675.65
Japan	-	-	176.00	-	-	-	-	-	-	-	-	-	-	-
United Arab Emirates	191.86	-	-	-	-	-	-	-	-	-	-	-	-	-
United Kingdom	23.94	120.00	-	-	-	-	-	-	-	-	-	-	-	-
Qatar	71.86	-	-	-	-	-	-	-	-	-	-	-	-	-
Bahrain	42.00	-	21.00	21.00	18.00	95.00	63.00	-	-	23.00	23.00	-	-	-
Saudi Arabia	-	-	-	-	1,103.88	377.24	-	-	-	-	-	-	-	-
Total Grade 2	6,684.94	120.00	2,685.14	-	-	1,107.82	1,931.30	-	690.66	1,655.00	1,020.90	1,389.00	742.00	975.53
Total	7,095.94	190.01	2,905.39	10,571.70	1,752.86	1,107.82	2,066.30	46.00	819.66	2,022.90	1,212.90	1,464.00	742.00	1,100.53

Source: Department of Foreign Trade (2025)

Table 5 Value of Thai sorghum exports on 2011-2024

Country	Export Value (million baht)													
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Grade 1														
Philippines	3.87	-	0.85	1.10-	-	-	0.85	0.54	-	4.31	1.71	1.06	-	1.86
Japan	0.86	-	1.95	10.40	2.03	-	0.39	--	1.48	-	0.50	-	-	-
Total Grade 1	4.73	-	2.80	11.50	2.03	-	1.24	0.54	1.48	4.31	2.21	1.06	-	1.86
Grade 2								-						
Taiwan	50.87	0.78	9.19	59.10	0.26	-	3.31	-	-	-	-	2.71	2.89	3.98
Kuwait	-	-	-	2.10	0.49	-	-	-	-	-	-	-	-	-
Philippines	19.82	-	19.15	28.71	3.97	6.80	13.51	-	7.48	16.12	10.99	15.12	8.33	8.77
Japan	-	-	2.21	-	-	-	-	-	-	-	-	-	-	-
United Arab Emirates	2.03	1.35	-	4.16	0.51	-	-	-	-	-	-	-	-	-
United Kingdom	0.24	-	-	-	-	-	-	-	-	-	-	-	-	-
Qatar	0.78	-	-	-	-	-	-	-	-	-	-	-	-	-
Bahrain	0.48	-	0.26	0.23	0.23	1.05	0.63	-	-	0.25	0.23	-	11.23	12.75
Saudi Arabia	-	-	-	-	12.18	3.96	-	-	-	-	-	-	-	-
Total Grade 2	74.22	2.13	30.81	94.30	17.64	11.81	17.45	-	7.48	16.37	11.22	17.83	22.45	25.50
Total	80.14	2.14	33.63	105.79	19.68	11.81	18.68	0.54	8.96	20.68	13.44	18.89	11.23	12.75

Source: Department of Foreign Trade (2025)

Table 6 Production cost, income and profits of various plants

Plant type	**Cost (baht/ha)**	**Income (baht/ha)**	**Profit (baht/ha)**	**Percentage Comparison**
Millet	7,806	19,875	12,069	100
Maize	27,938	45,625	17,688	147
Sunflower	7,156	18,563	11,406	95
Mungbean	11,775	24,175	12,400	103
Sugarcane	75,000	96,250	21,250	176
Cassava	41,706	65,000	23,294	193

Source: OAE (2025)

2. Cultivation

Sorghum production in each country is highly dependent on weather conditions, particularly rainfall, as farmers often plant drought-resistant sorghum instead of corn if rainfall is low. The environment for growing millet: millet is very adaptable to soil and climate conditions, which makes it widely distributed, from tropical, desert and semi-desert climates to warm and humid climates. Millet seeds begin to germinate at 10 °C, and the optimum temperature for germination, growth and development of seeds is 25-30 °C. Excessive temperatures, especially during the period from germination to tillering, when a strong root system has not yet formed, have a detrimental effect on sorghum. During inflorescence development, the plant can withstand temperatures up to 40-45 °C, making it a heat and drought-resistant plant. However, sorghum is sensitive to low temperatures and frost, especially during flowering. The plant dies at -2 °C. Millet is more tolerant of dry weather and soil, dry winds and high temperatures than many other cultivated crops. Being a tropical plant, it has developed a great ability to adapt to conditions without moisture. Sorghum is a remarkable plant due to its special anatomical and physiological structure that cannot be compared with any other agricultural crop. Millet can grow in fertile, sandy loam, light sandy loam, and well-drained clay soils that are free of weeds. Millet also has a strong root system, so it can produce good yields for many years in poor soils where other crops cannot be grown. Sorghum does not tolerate cold, soggy soils, and does not grow well in acidic soils. One of the major advantages of millet growing conditions is that millet can thrive in saline soils. Millet can grow normally when the soil salt concentration is twice as high as corn.

2.1 Types of Millet

There are 3 main principles for classifying millet:

1. Classification by botanical characteristics
2. Classification by utilization
3. Classification by commercial seed color

Classification by botanical characteristics divides millet into 2 main parts: millet currently grown, which has 5 types, and wild millet.

The characteristics of millet varieties currently grown can be separated by the characteristics of the flower (spikelet) alone. There are 5 types as follows:

1) Bicolor The seeds are quite long, sometimes oval-shaped. The lower part of the seed is oval. The seeds are almost completely inside the seed coat, or 1/4 of the seed protrudes from the seed coat.

2) Guinea The lower part of the seed is flat. When fully ripe, the seed coat is at a right angle to the seed.

3) Caudatum When millet seeds are cut in half, they are almost completely different because the seed pods attached to the lower seed coat are relatively flat, but the surface of the seed on the opposite side is curved almost semicircular. The seed coat is about 1/2 the length of the seed.

4) Kafir The seeds of sorghum are quite round. These sorghums are grown in northern Africa, in areas such as Nigeria and northeastern Ghana.

5) Durra The seeds are round. The lower part of the seed that is attached to the seed coat is larger than the upper part. These sorghums are grown in Arab countries.

The classification according to the characteristics of use, which is the current classification, can be divided into 5 types according to the use as follows:

1) Grain sorghum is a type of sorghum that is grown for animal feed or consumption. However, long-lived sorghum can be grown for silage and dry grass for animal feed. The seeds are about 4-8 millimeters in diameter and come in various colors such as white, yellow, brown, and red. In Thailand, grain sorghum is the most popular.

2) Sweet sorghum (or sorgos) This type of sorghum has a relatively high sugar content in the stem, making it suitable for making silage. And used for planting to make syrup, sugar or fermented to produce alcohol.

3) Grass sorghum, including Sudan grass and Johnson grass, is a herbaceous sorghum with tall stems, spreading panicles, and many branches. Used for raising animals, making hay and silage. Most are perennial plants, propagated by the rhizome.

4) Broom corn This type of sorghum has long inflorescences. After threshing the seeds, the inflorescences can be used to make brooms. The inflorescences are approximately 40-65 centimeters long and the stems are 2.0-3.5 meters high. This type of sorghum originated in Africa. Later, it was planted in Europe. In China, this type of sorghum was improved to produce a liquor called Gaoliang.

5) Other sorghums (special purpose sorghum) This type of sorghum includes sorghum that is used in other ways, such as elephant tail sorghum, roasted sorghum, and sweet grain sorghum.

Commercial classification of millet by seed color is divided into 4 groups:

1) Yellow seeds: The color of millet seeds in this group includes yellow, golden yellow, orange, red, pink, etc.

2) White seeds: The color of millet seeds in this group includes shiny white, cloudy white, light cream

3) Brown seeds: The color of millet seeds in this group includes reddish brown

4) Mixed seeds: Millet seeds with seeds of many colors mixed together

2.2 Suitable environment for growing millet

- Land conditions

Suitable land conditions for growing millet must be high or low, no flooding, flat and even, with a slope of no more than 5 percent, and convenient transportation.

- **Soil characteristics**

Can grow well in almost all types of soil, from sandy soil, sandy loam soil and clay soil, but the soil suitable for growing millet to get high yields should be clay loam soil with good drainage and air circulation, with a pH between 5.0-7.5. Millet is a plant that can tolerate saline soil better than corn.

- **Temperature**

Although millet seeds can germinate at temperatures between 7-10 degrees Celsius, the appropriate temperature for millet growth and seed production is 27-30 degrees Celsius. If the temperature is higher than 30 degrees Celsius, it will affect seed production, resulting in low yields of millet in Thailand.

- **Light**

By nature, millet is a short-day plant, and most commercial varieties do not respond to photoperiods, whether planted during short or long days. When it is time to flower, millet will flower differently depending on the variety. and environment

- **Rainfall and distribution of rain**

Sorghum requires 450-650 millimeters of rainfall throughout the growing season, especially during pregnancy, flowering and milk stages. Water shortages should not occur. Water or moisture requirements decrease during the mature seed stage until harvest. High humidity in the mature seed stage causes mold to grow on the seed, reducing seed quality. In addition, sorghum is not resistant to waterlogging during the early stages of growth (seedling stage). This will cause yellow leaves and stunted growth, which may eventually lead to death.

- **Water source**

Sorghum is grown in rainfed areas because it is a plant that uses little water.

2.3 Varieties

Currently, there are many types of millet grown in Thailand. There are millet that is used as animal feed, human feed, and industrial feed. In addition, the types of millet also have different colors depending on the characteristics of each variety.

- **Selection of varieties**

Select varieties with high yields, seed colors that meet market demand, are suitable for planting at the end of the rainy season, and have low tannin content.

- **Popular varieties**

- **Suphan Buri 1** (UT203-2 B: M 91019xWAE) is a pure red millet variety certified by the Department of Agriculture in 1993. The harvest period for fresh plants is approximately 60 days and is not sensitive to light. Fresh plants have low hydrocyanic content, so fresh plants can be used to feed animals as well as grass.

Plant height:	230 centimeters
Inflorescence characteristics:	relatively open
Seed color:	red
Stem:	brown or straw color, Tan plant
Disease resistance:	Tolerant to foliar diseases
Seed yield:	2.5-3.0 t/ha
Fresh plant yield:	37-62 tons/ha
Juice:	Low hydrocyanic acid content (7.28 mg%) and sweet juice stems
Tannin in seeds:	0.408%
Flowering:	55-60 days to flowering with long semi-compact elliptic heads
Maturity:	Early maturity 90 days
Purpose:	Dual purpose (Grain or Stem)
Release:	1963 by Department of Agriculture (DOA)

- **Suphan Buri 60** (UT573 B: U-Thong 1xSW240) is a pure red sorghum variety certified by the Department of Agriculture in 1987. It has a harvest period of approximately 90 days. It has an upright, strong stem. It is a variety that is not sensitive to light. The seeds have a low tannin content.

Plant height:	150-160 centimeters
Inflorescence characteristics:	Large panicle size, relatively open panicle
Seed color:	Red
Stem:	Resistant to breaking
Disease resistance:	Moderate resistance to seed rot
Seed yield:	2.5-3.0 t/ha
Tannin in seeds:	0.164%
Flowering:	55-56 days to flowering with semi-compact elliptic heads
Maturity:	Medium maturity 95-100 days
Purpose:	Grain purpose
Release:	1987 by Department of Agriculture (DOA)

- **U Thong 1** (DA80: Ce 151.262 $A_1P_1A_1$) is a pure sorghum variety with a short stem and a short harvest period of approximately 90 days. The seeds are yellow. Certified by the Department of Agriculture in 1982, average seed yield of 550 kilograms per rai, suitable for planting at the end of the rainy season, good drought resistance.

Plant height:	150-160 centimeters
Inflorescence characteristics:	quite open
Seed color:	light yellow
Stem:	resistant to breaking, Tan plant
Disease resistance:	resistant to rust disease, but not resistant to seed mold
Seed yield:	3.0-4.0 t/ha
Tannin in seeds:	0.104%
Flowering:	50-60 days to flowering with semi-compact elliptic heads
Maturity:	Early maturity 90 days
Purpose:	Grain purpose
Release:	1982 by Department of Agriculture (DOA)

- **Late Hegari** is a pure sorghum variety with tall plants and white seeds. The Department of Agriculture (Department of Agriculture) has recommended farmers to plant it since 1963. It is a variety that is sensitive to light, suitable for planting at the end of the rainy season, around August. Harvesting age is about 120 days. Planting in the early rainy season will cause a lot of stem and leaf growth. Tall plants.

Plant height:	180-250 centimeters
Inflorescence characteristics:	Quite dense
Seed color:	White with brown inner shell
Stem:	Easily broken, Purple plant
Midrib	Light green midrib
Photosensitive:	Photo-sensitive
Disease resistance:	Not resistant to leaf diseases
Seed yield:	200-500 kilograms/rai
Tannin in seeds:	0.190%
Flowering:	60-70 days to flowering with compact elliptic head
Maturity:	Late maturity 100-120 days
Purpose:	Grain purpose
Release:	1963 by DOA

• **Early Hegari** is a pure millet variety. White seeds, short plants, short lifespan. The Department of Agriculture (Department of Agriculture) has recommended that farmers plant it since 1963. It is a variety that is not sensitive to light periods. Suitable for planting in the early rainy season, March-May.

Plant height:	150-200 centimeters
Inflorescence characteristics:	Quite dense
Seed color:	White with brown inner shell
Stem:	Easily broken, Purple plant
Midrib	Light green
Photosensitive:	Non- photosensitive
Disease resistance:	Not resistant to leaf diseases
Seed yield:	2.0-2.5 t/ha
Tannin in seeds:	0.35%
Flowering:	50-60 days to flowering with compact elliptic heads
Maturity:	Early maturity 85-100 days
Purpose:	Grain purpose
Release:	1963 by Department of Agriculture (DOA)

- **KKU 40**

Plant height:	259 centimeters
Seed color:	Brown
Stem:	Tan plant
Seed yield:	2.94 t/ha
Fresh Stem Yield:	48.3 t/ha
Ethanol Yield:	1.28 kl/ha
Juice content:	39.2%
Sweetness:	13.7 Brix at 20 days after 50% flowering
Flowering:	60 days to flowering with long semi-compact elliptic heads
Purpose:	Dual purpose (Syrup or Ethanol)
Release:	By Khon Kaen University (KKU)

- **Suwan Sweet Extra**

Plant height:	280 centimeters
Seed color:	Brown
Stem:	Tan plant
Seed yield:	2.3 t/ha
Fresh Stem Yield:	25-38 t/ha
Juice content:	46.8%
Sweetness:	Sweetness 16.5-18.0 brix at 20 days after 50% flowering
Flowering:	71 days to flowering with long semi-compact elliptic heads
Purpose:	Dual purpose (Syrup or Ethanol)
Release:	By Kasetsart University (KU)



- **Kinnaree 1**

Plant height:	135 centimeters
Inflorescence characteristics:	
Seed color:	Yellowish
Stem:	Green plant
Photosensitive:	Photo-sensitive
Seed yield:	1.56 t/ha
Fresh Stem Yield:	9.7 t/ha
Flowering:	54 days to flowering
Maturity:	Early maturity 75 days
Purpose:	Dual purpose (Grain or Stem)
Release:	By Kasetsart University (KU)

- **Kinnaree 2**

Plant height:	149 centimeters
Seed color:	Black
Stem:	Green plant
Photosensitive:	Photo-sensitive
Seed yield:	1.6 t/ha
Fresh Stem Yield:	12.2 t/ha
Flowering:	58 days to flowering
Maturity:	Early maturity 80 days
Purpose:	Dual purpose (Grain or Stem)

- **Local 1**

Plant height:	135 centimeters
Seed color:	Yellowish
Stem:	Green plant
Seed yield:	1.25-1.87 t/ha
Flowering:	60 days to flowering
Maturity:	Early maturity 95-100 days
Purpose:	Grain purpose




- **Pacific 99** It is red millet from Pacific Seeds Co., Ltd.

Plant height:	145-175 centimeter
Seed color:	Dark red
Stem:	Green plant
Resistance:	Lodging resistance
Seed yield:	4.85 t/rai
Flowering:	55 days to flowering
Maturity:	100-105 days
Purpose:	Grain purpose
Release:	Pacific Seeds Co., Ltd.



2.4 Planting

- Planting season

Sorghum can be planted all year round if the soil has sufficient moisture, using varieties that are not sensitive to the light period. Rainy season plantings are normally done on the uplands, due to the sensitivity of millet to water-logging. Dry season planting of millet is usually done on paddy fields. Traditionally, farmer have grown millet in the early and late rainy and dry seasons. However, millet is usually planted only in the late rainy and dry seasons due to it photo-period sensitivity.

1) Early rainy season planting: May and June are suitable planting times for early rainy season planting. Harvesting will be between July and early August to allow for a following crop, such as corn.

2) Late rainy season planting: This growing season commences between late August and September. In this case millet is planted after field crops, for example, corn.

3) Dry season: Traditionally, millet is planted in the dry season following the rice crop, this is usually done between December and early February. For maximum yields the total amount of water required is around 180-250 mm, with this being spit into irrigation intervals of about 10-14 days with 30-40 mm for each irrigation.

- Soil preparation: The first ploughing should be made to a depth of 12-15 cm. after which the soil should be dried under the sun for 2 weeks. A second ploughing can then be made to break the soil into small pieces. Suitable for seed germination.



- Seed preparation: Select seeds with a germination rate of more than 90%, according to the variety, and without signs of disease or insect damage. Grain sorghum and sweet sorghum have a seed consumption rate of 15.6-18.8 kg/ha for both row and broadcast cultivation. Foxtail millet seed consumption for both row and broadcast seeding ranged from 6.3-9.4 kg/ha.

- **Planting method and planting distance:** Three methods of planting are recommended

1) Uniform Broadcasting: Broadcasting is the method that most often used by farmers. From 13-19 kilograms of seed per hectare is almost a general recommendation. This method is convenient and save time and manpower. However, there are some disadvantages as well. If the seed are not distributed over an area, weed interfere with sorghum by competing for emergency. Broadcasting too much seeds tends to decrease the size of panicle.

2) Drill Planting: Sow in rows by opening a furrow and sprinkling seeds in the furrow and covering with a thin layer of soil to prevent birds from damaging it and to help maintain the moisture of the soil in the area where the seeds are planted. The recommended row spacing is 60 cm. Two weeks after germination, seedlings should be thinned, leaving only 1 plant/hill with the distance between hill being 10 cm.

3) Hill Planting: Sow in holes. Use a hoe to dig or use a sharp stick to poke holes with a distance of 30 centimeters and a distance between rows of 60 centimeters. Sow 6-7 seeds per hole. After the millet has sprouted for 2 weeks, separate it into 3 plants per hole. This is an easy method to maintain, remove weeds and fertilize.

Nowadays, there are machines or tractor-mounted sowing machines. There are both row-spreading and hole-spreading types.



2.5 Maintenance

- **Fertilizer Application:** The recommended fertilizer applications are as follows: fertilizers should be appllied once or twice, depending on the soil type, with the first application being either at planting time and the second application, being giving together with the weeding and hilling up of the soil, which is usually about 4 weeks after germination.

1) Chemical Fertilizer: An application of 31-62 N/ha (150-300 kg/ha of ammonium sulfate or 63-125 kg/ha of urea) is recommended. However, to determine the more accurate amounts of N required, it is necessary to consider the soil analysis data. Soil with less than 10 ppm. available P_2O_5 requires an application of triple super phosphate at 63-125 kg/ha if millet is grown after rice with has already had a 16-20-0 fertilizer application then it is unusually to apply further phosphorus fertilizer. An application of potassium chloride at the rate of 50 kg/ha is recommended on sandy soil.

2) Organic Fertilizer: Since millet is not a high value crop, it might not be economic to use chemical fertilizer in some cases, particularly when it is planed after corn or legume. Organic fertilizers such as cattle manure, chicken manure, compost and green manure many be applied instead at the rate 6 t/ha every 3-4 years. Crop rotations which include legumes can also improve soil fertility.

- **Watering:** Millet is a drought-resistant plant with a short harvest period. It requires a lot of water during pregnancy, flowering, and milky seed stages. After that, the water requirement will decrease, especially when the millet starts to mature. If there is still rain or high humidity, it will cause mold in the seeds. At the same time, if there is a lot of water in the beginning, it will cause the seeds to rot or the young plants to turn yellow, stunted, and stunted growth because the roots lack air to breathe. Growing millet for seeds does not require watering, but for millet planted to cut the plants to feed animals Watering is required during dry spells or droughts to ensure survival and regeneration so that it can be cut several times per year.



Important Diseases and Prevention

- **Head mold or Grain mold**

Causes: Many types of fungi, the most common of which are *Curvularia lunata Alternaria* sp., *Fusarium* sp., *Helminthosporium* sp. and *Phoma* sp.

Symptoms: The causative agent infects millet from the time it flowers until the seed becomes milky, causing the seeds to be covered with black, pink, gray, and orange mold mixed on the seed surface. The color of the mold depends on the type of pathogen, causing the millet seeds to deteriorate and not be desired by the market. In addition, many types of causative fungi can produce toxins, causing the seeds to be contaminated with toxins. The mold also reduces the percentage of seed germination. When there is rain and high humidity, the damage will be very severe.

Prevention and Prevention:

- Plant millet at the end of the rainy season to avoid the millet from maturing, flowering, and harvesting during the rainy season when there is heavy rain. High humidity is suitable for the growth of pathogenic fungi.
- Plant disease-resistant varieties.

Source: Borikar *et al.*, (2007)

Source: Frederiksen *et al.*, (1986)

- **Leaf Blight**

Cause: Helminthosporium turcicum

Symptoms: Start as small spots on the leaves, then expand along the veins into 4-12 cm long wounds. If severe, the leaves will burn and eventually die.

Prevention and control:

- Use disease-free seeds.
- Burn and destroy diseased stubble, along with weeds and host plants.

Source: Frederiksen *et al.*, (1986)

- **Anthracnose or Red Core Disease**

Cause: *Colletotrichum graminicola*

Symptoms: Infects the entire leaf, stem, and seed. The leaves have small round or oval wounds with dark edges and small black bumps in the center. The upper midrib is a long red or purple wound with small black bumps on the surface. When the stem is cut open, it will be a red circle.

Prevention and control:

- Use disease-free seeds.
- Burn and destroy diseased stubble. And eliminate weeds and host plants

Source: Frederiksen *et al.*, (1986)

- **Rust**

Cause: Puccinia purpurea

Symptoms: Start as small spots, later become raised rust-colored sores. When mature, they will burst into red fungal spores.

Prevention and elimination:

- Use disease-free seeds
- Burn and destroy diseased stubble, and eliminate weeds and host plants.

Source: Frederiksen *et al.*, (1986)

- **Sorghum Dwarf Mosaic**

Cause: Sugarcane mosaic virus (SCMV)

Symptoms: Leaves are mottled with pale green and dark green stripes or yellow spots. In the seedling stage, leaves are pale yellow all over. Young shoots are pale yellow or have spots. Mottled symptoms are small white or yellow lines alternating with green, parallel to the midrib. Plants are stunted. If the disease symptoms are severe, sorghum plants in the seedling stage will dry up and die.

Prevention and elimination:

- Use seeds from disease-free plants or resistant seeds.
- Check for aphids, the vector insects. If an outbreak is found, it should be eliminated to prevent the spread of infection.
- Avoid planting millet during periods of insect vector outbreaks.
- Eliminate plants showing disease symptoms and host plants that are sources of the pathogen.
- Rotate crops

Source: Frederiksen *et al.*, (1986)

Important pests and prevention and control

- **Sorghum shoot fly (*Atherigona soccata*)**

Characteristics and damage Infects sorghum seedlings, 1-2 weeks after germination. The larvae will eat the sorghum shoots, causing the shoots to wither, stunting growth, and reducing yields if there is a large outbreak.

Prevention and control

- Use high-yielding varieties, such as U Thong 1, Suphan Buri 60, KU 439 KU 630, and KU 804.

- Set the planting date of sorghum in each area to be close together. Sorghum planted later will be destroyed by the second generation of insects.

- In areas where insects are commonly found, more seeds should be used to compensate for the damage, and the damaged plants should be uprooted and burned when the sorghum is 2 weeks old.

- Before the planting season, trap adults with non-oil-extracted fishmeal traps, which are used to mix with chicken feed. Use as bait and destroy

- Use insecticides only in areas where severe outbreaks are regularly found, such as coating seeds before planting with imidacloprid 70%WS at a rate of 3-5 grams per 1 kilogram of seeds or spraying with carbofuran 20%EC at a rate of 100 milliliters per 20 liters of water once when the sorghum is 7 days old or has grown to 4-5 leaves.

Source: Chantharasuwan *et al.*, (2008)

Source: Edde (2021)

- **Aphids (Aphid: *Rhopalasiphum maidis*, *Melanaphis sacchari*)**

The damage is caused by small insects, usually found in clusters on young shoots, flower clusters, and undersides of leaves, causing leaves to sag and turn yellow. Plants may stop growing. Aphid outbreaks are common if sorghum is affected by drought for a long time. If the outbreak occurs near the time when the sorghum is about to flower, it will cause fungal diseases in the seeds, affecting the quality of the seeds. Prevention and control should be carried out about 2-3 weeks before flower clusters are formed, and spray only at the areas where the infestation occurs.

Prevention and control

- Normally, it is not recommended to use insecticides because sorghum is quite resistant to aphids. And there are many natural enemies to help control the number of aphids.

- Spray chemicals only at the affected areas. Recommended chemicals include Lambda-cyhalothrin 2.5% EC at a rate of 20 ml per 20 liters of water or spray with Triazophos 40% EC at a rate of 40 ml per 20 liters of water.


Source: Michaud (2024)

- **Rice ear-cutting caterpillar or Indra's rice ear-cutting caterpillar** (*Mythimna separata* Walker)

Damage characteristics: The corn earworm is caused by a moth. The larvae have off-white, brown, and light brown stripes running along the length of their bodies. These larvae eat the tops and leaves of sorghum until only the stalks are left. The larvae's excrement can be seen on the tops and leaf sheaths. However, sorghum is very resistant to larvae damage. Even if the leaves are eaten until only the stalks are left, it can still grow by sprouts.

Prevention and elimination

- Normally, it is not recommended to use insecticides. There are many natural enemies that help control the number of cutworms. If there is not much damage, collect and destroy them by hand.

- Recommended chemicals include Carbaryl 85% WP at a rate of 50 grams per 20 liters of water in cases of severe outbreaks.

Source: Kalaisekar *et al.* (2016)

Important weeds and their prevention and control

- Types of weeds

• **Annual weeds** are weeds that complete their life cycle in one season. Most of them reproduce by seed.

1. Narrow-leaved types such as crowfoot grass, pink bird grass, birdfoot grass, buffalo beak grass, and large-flowered kajornjab grass Small-flowered grass, yong grass, and white-flowered grass, etc.

2. Broad-leaved types such as spinach, morning glory, stone purslane, large purslane, hiccup, candles, and galangal, etc.

3. Sedge types such as sand sedge

• **Perennial weeds** are weeds that are mostly propagated by stems, roots, rhizomes, tubers, and runners better than by seed propagation.

1. Narrow-leaved types such as stick grass, sedge grass, and sedge, etc.

2. Broad-leaved types such as tiger's claw and rope vine, etc.

3. Sedge types such as water chestnut

- Prevention and control

1) Plow once, dry the soil for 7-10 days, harrow once, and rake to remove debris, roots, rhizomes, tubers, and runners of perennial weeds from the plot.

2) Harrowing the soil and weeding is usually done when the sorghum is 3-4 weeks old after planting because this is the period that greatly affects the yield of the sorghum. After this, the shade of the sorghum leaves will increase. The growth and competition of weeds are reduced. 3. Use of chemicals If there is a problem with labor or heavy rain that makes it impossible to eliminate weeds in time, weeds should be eliminated with chemicals. The most popular chemicals are pre-emergence herbicides, which are sprayed to cover the soil immediately after planting, before weeds and millet germinate. They can control weeds from germinating for 30.35 days, while millet grows and has leaf canopies covering the soil, covering weeds. Chemical spraying must be done when the soil is sufficiently moist, so that the chemicals can be effective. For sandy soil, chemicals should be used at a low rate because of the high leaching rate. In cases where weeds are eliminated by labor or machinery are not effective enough, herbicides should be used according to the recommendations, such as atrazine at a rate of 240-400 grams/rai.

2.6 Harvesting

The appropriate harvest period. Normally, millet will start to mature when it is 80-90 days after germination or about 30-35 days after flowering, depending on the variety, growing season and environment. Observe the tissue under the seed coat near the base of the flower, called the black layer. If it turns black, it indicates that the seed is physiologically mature. Harvesting when the black layer starts to turn black will result in seeds with the highest percentage of germination, strength and dry seed weight. However, during this period, the seeds will still have a relatively high moisture content. Harvesting seeds for sale as animal feed requires leaving them in the field for a while to reduce the moisture content in the seeds.

Harvesting method. Harvesting by machine can be used with hybrid millet, which has a uniform height and a simultaneous harvest age. For manual harvesting, it can be done by using a knife or sickle close to the base of the millet panicle.



2.7 Post-harvest technology

Post-harvest practices are divided into 2 types:

1) Seed production. Take the harvested millet panicles and dry them in the sun for 2-3 days. Then thresh them with a rice or corn threshing machine at a low speed. Because if high speed is used, the seeds will be damaged. Sort the seeds by size and separate out impurities. Clean them and dry them in the sun for another 3-4 days to reduce the moisture content of the seeds to less than 12%, which can prevent fungi and insects from eating the seeds. Pack the seeds in sacks or thick plastic bags and keep them for future use as seeds.

2) Production for sale as seeds: Dry the harvested millet clusters in the sun for 2-3 days, then thresh them with a rice or corn milling machine. Separate the seeds from impurities by blowing them with an engine or winnowing them. Dry the seeds for another 1-2 days to reduce the moisture content to about 14%. Pack them in sacks for sale.

2.8 Transportation

1) Pack millet seeds in clean jute sacks and sew the openings of the bags with straw rope.

2) The truck must be clean and suitable for the amount of millet. It should not be a truck used to transport soil, animals, animal waste, chemical fertilizers or pesticides because it may be contaminated with germs and chemicals, unless it is properly cleaned before transporting millet.

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Editorial