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Finger millet (*Eleusine coracana* L. Gaertn) a climate resilient food crop for livelihood security of small and marginal farmers of Odisha

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INTRODUCTION

Small grained cereals belonging to family *Poaceae* and cultivated as food crops are known as millets. India is the largest producer of two groups of millets like large and small millets. Among the various small millets, finger millet (*Eleusine coracana* L. Gaertn.) cultivated over an area of 1.19 million hectares with a production of 1.98 million tonne and productivity of 1661 kg/ha contributes 85% of the total production of small millets. In India Karnataka, Tamil Nādu, Uttarakhand, Maharashtra and Odisha are leading finger millet producing states. Finger millet is the most dominant millet crop in Odisha. It contributes more than 75% of total millet production and cultivated in 1.14 lakh ha area having 1.01 lakh tons production with average productivity of 880 kg/ha (Odisha Agricultural Statistics 2021). The climate and soils of Odisha is suitable for finger millet cultivation and grown under various seasons and ecologies. Koraput, Ganjam, Rayagada, Malkangiri, Kandhamal and Gajapati are major millet growing districts of Odisha. But the adoption of finger millet also slowly improving in different parts of western and Coastal Odisha.

Finger millet is a short duration crop maturing in 85-120 days depending on varieties and season. The crop is non-thermos and photo sensitive and have wider adaptability to temperature. It can be grown from coastal ecosystem to hilly regions of Odisha. Water requirement of finger millet is 250-350 mm which is very low as compared to rice. The crop can be grown in marginal soils under rainfed ecology with pH varying from 4.5 to 8.0. Ragi can be grown as pure crop, inter crop, various cropping sequences and responded well under late planting condition. It is thus well fitted to different contingent crop planning (Fig 1) under drought and flood situations. Ragi showed adaptability and stability even under the adverse ecologies thus have the ability to sustain the production by coping with the climate change.

Ragi crop has wider utility as staple food, fodder and industrial raw materials and popular as nutri-cereals. Ragi grains are store house of nutrients having carbohydrates (65%–75%), protein (6%–13%), dietary fiber (18%), minerals (2.5%–3.5%), calcium (0.38%), phytates (0.48%) and other several antioxidants. Finger millet flour is utilized in the preparation of traditional foods, such as roti, thin porridge, mudde and other several delicious foods. Consumption of ragi provides health benefits like anti-diabetic, chronic diseases and have antimicrobial effects to its regular

consumers. Ragi stubbles are very pleasant and can be used as fodder for livestock.

The suitability of finger millets for growing under wider physical, ecological and climatic variation, adaption to adverse soil conditions and possibility of growing under diverse cropping systems, multiple utilisation value and several soil, environment and human health benefits, the finger millets are considered as climate resilient super food crop for different agroecological regions of Odisha. The productivity, profitability and sustainability of finger-millet based production system can be enhanced by adoption of suitable varieties with adequate crop management practices, post-harvest care, value addition and marketing.

CAUSES OF LOW PRODUCTIVITY AND LOW ADOPTION OF FINGER MILLET IN ODISHA

- Finger millet is mostly grown under marginal and sub-marginal soils under rainfed ecology thus suffers from terminal drought.
- Non availability of location specific and farmers friendly high yielding varieties
- Non availability of disease-free quality seeds at right time.
- Broadcasting method of sowing mostly leading to poor crop establishment.
- Poor weed management at critical period of crop-weed competition leads to severe reduction in grain yield.
- Lack of suitable Integrated Disease and Pest Management practices for millet production system.
- Lack of proper knowledge on water management options under various millet production system.
- Non availability of advanced nursery management practices in finger millet.
- Poor mechanization such as sowing, transplanting, weeding, harvesting and threshing of finger millets.
- Poor infrastructure facilities for milling of finger millets and its value addition.
- Lack of awareness about the food, fodder and industrial importance of finger millet

TIPS TO ENHANCE POPULARIZE FINGER MILLET CULTIVATION AND CONSUMPTION IN ODISHA

- Selection of improved location and season specific local varieties.
- Development of high yielding varieties and high breeds suitable to farmers with consumer preference and market values.
- Ensure the availability of quality seeds at appropriate time and reasonable cost by development of location specific seed villages.
- Timely sowing of millets particularly under rainfed ecology.
- Optimum crop establishment by using seed drill in direct seeded crop or adopting system of millet intensification in transplanted crop.
- Raising of healthy seedlings, line transplanting of young seedlings at optimum spacing and depth of transplanting of finger millets in high rainfall areas, rabi and summer irrigated crops.
- Crop intensification by suitable intercrops, cropping sequences and utilisation of rice fallows
- Adoption of integrated nutrient management with emphasises on Consumptive use of organic and inorganic fertilisers
- Mechanisation of inter-cultivation operations and weed management at critical period of crop weed competition by integrated manner with the inclusion of suitable early post emergent herbicides in weed control.

- Adoption of advanced water management options in rainfed as well as irrigated ragi crops.
- Development and popularization of post-harvest management like processing, value addition and marketing of millets.

CROP MANAGEMENT TECHNIQUES TO ENHANCE PRODUCTION, PRODUCTIVITY AND PROFITABILITY OF FINGER MILLETS IN ODISHA

Soil and Climate

Finger millet under rainfed conditions is grown on red soils, shallow black soils, alluvial soils and on hill slopes from 10 metres above sea level to nearly 2000 metres above in the Hill regions. Well drained alluvial and loamy soils are preferred by finger millets. The crop possesses good drought tolerance ability. It can be grown in soils with pH of 4.5-8.0 and have capacity to grow under saline soil. Poorly drained Vertisols and less fertile rocky soils are not suitable for this crop. The crop can grow in areas with rainfall up to 100 cm, but higher rainfall areas it can be grown as transplanted crop. A mean temperature of 26-29 ^{0}C is optimum for growth. Finger millets germinates well at 8-10 ^{0}C.

Growing season

Finger millet is grown mostly under rainfed upland during wet season (June-September) in plain and hilly regions of Odisha. It is also grown during rabi season (October-January) under irrigated ecology in some of the primary millet growing district of Odisha. Now a days summer finger millets (January-May) under irrigated rice production system is gaining popularities due to its implementation under Millet mission.

Varieties

Several improved local varieties and high yielding varieties are available for cultivation in Odisha. Selection of varieties based on safe growing period, growing ecologies and seasons is one of the important factors to be considered for achieving optimum productivity of finger millets. Some of the recommended varieties are tabulated in table 1.

Table 1: Recommended high yielding varieties of finger millets

Variety	Maturity (days)	Average Yield (t/ha)	Special Character
VL 376	103-109	2.9-3.1	Responsive to fertilizer, Moderately resistance to blast
OEB 532	110-115	2.2 - 2.5	Moderately resistance to blast
VL 352	95-100	3.3-3.5	Moderately resistance to blast
OEB 526 (Arjun)	110-115	2.5-2.6	Moderately resistance to leaf neck and finger blast
Chilika	115-120	2.6-2.7	Moderately resistance to blast and stem borer
BM 9-1	103-105	2.5-3.0	Moderately resistance to blast and brown spot
Champabathi	90-95	2.0-2.5	Photosensitive
VL 146	95-100	2.5-3.0	Early
Saptagiri	110-115	2.4-2.6	Moderately resistance to leaf neck and finger blast. Drought tolerant.
Suraj	90-95	2.4-2.6	Moderately resistance to leaf neck

			and finger blast. Drought tolerant.
VL 149	90-102	2.0-2.5	Wider adaptability
KM 13	95-110	2.5-3.0	Moderately resistance to blast
Divyasinga	85		
Neelachal	100		

Crop Establishment methods

Broadcasting of dry seeds in dry soil is the most prevalent crop establishment methods of millets. Line sowing behind the country plough has significantly improved finger millet yield. Sowing by seed cum fertiliser drill at a spacing of 22.5–25 cm apart and 10 cm between the rows ensures optimum crop stand and resulting higher grain and straw yield. The seed should not be sown less than 3-4 cm deep. Planting of ragi by guli ragi method out yields the conventional planting in terms of yield and profit.

Under irrigated ecology and high rainfall areas ragi is mostly grown as transplanted crop. Higher yields are obtained in case of transplanted crop as compared to direct-seeded crop. Seeds should be sown in well prepared nursery beds in 20-25 days before transplanting in main field. Three to four weeks old seedlings are ideal for transplanting. Transplant 2 seedlings/hill at a distance of 22.5-25.0 cm x 10 cm at 2-3 cm deep ensures better crop establishment. The beds should be irrigated on the third day after transplanting. Transplanted crop does not lodge during rains. System of Ragi intensification by adopting younger seedlings, square planting of finger millet at 25 x 25 cm followed by mechanical weed control significantly improved the grain yield of finger millet under irrigated ecology.

Seed rate- For line sowing seed rate of 8-10 kg/ha is ideal whereas for broadcasting 12-15 kg/ha is required for obtaining optimum population. For line transplanting a seed rate of 5 kg/ha is optimum for finger millet.

Seed Treatment- Seed treatment with biopriming substances, biocontrol agents and bio-fertilizer are recommended for finger millet to induce hardiness against moisture stress, to control seed and soil borne diseases and to enhance availability of plant nutrients at different crop growth stages for realising the potential yield. Pre-sowing seed treatment with 100 ppm Na_2HPO_4 or KH_2PO_4 or 0.25% $CaCl_2$ was found beneficial to maximize growth and productivity of finger millet. Seed treatment with carbendazim @ 2 g/kg of seeds or Trichoderma dust formulation 5 g/kg of seeds before sowing helps in control of soil and seed borne diseases. Treating seeds with *Azospirillum brasiliense* and *Aspergillus awamori* @ 25 g/kg of seeds is beneficial and reduces requirement of chemical fertilisers by 25%. Treat the seeds with seed treating chemicals first and then go for biofertilizers.

Nutrient Management

Finger millets traditionally grown under organically managed nutrition with less dependence on synthetic chemical fertilisers. Biofertilizers, vermicompost and growth promoters can be used to grow millets under rainfed ecology. But under irrigated ecology integration of organic manures with soil test-based inorganic fertilises enhances farm productivity and profitability. Results of several field experiments revealed that finger millet responds well to nutrient management. For Odisha general blanket recommendation is 40:20:20 kg of NPK/ha for rainfed and 60:20:20 kg of NPK/ha for irrigated crop. Half of nitrogen and full amount of phosphorous and potash are recommended

as basal dose during final land preparation. Rest half of nitrogen may be applied at 20-20 DAS/ DAT after first interculture.

In micro nutrient deficient soils application of 15 kg borax ha^{-1} + 100 kg gypsum ha^{-1} as basal dose under irrigated ecology helps in realising the higher grain and straw yield. It is also beneficial for higher water use efficiency, higher microbial activity and organic carbon content in soil. Under stress condition spraying of 2% urea minimises loss due to moisture stress and has positive role on production of finger millet. Finger millet may be benefited by deep rooted pigeon pea by bio-irrigation when biofertilizer inoculation was done with arbuscular mycorrhizal fungi (AMF) and plant growth-promoting rhizobacteria (PGPR) under dryland conditions.

Weed management

Crop-weed competition in finger millet causes loss in grain yield up to 50%. Early stage weed control at 2-3 weeks after germination or transplanting is optimum for realising optimum yield. Two hand weeding at 15 and 30 DAT resulted in higher grain yield and straw yield. To minimise labour requirement one hand weeding at 15 DAT followed by one mechanical weeding at 30 DAT resulted in highest B:C ratio. In assured rainfall and irrigated ecology spraying of 2,4-D @ 0.750 kg/ha at 20 DAS/DAT effectively controls the weeds. Under rainfed ecology pre-emergence application of Metoxuron (0.75 kg/ha) at sufficient soil moisture followed by one hand weeding manages weeds and results optimum grain yield.

Water management

Millet species need relatively less water than the other crops because they have short growth season. During wet season finger millet is mostly grown as rainfed and does not require any irrigation. But if rain is delayed for an extended period during the tillering and flowering stages, irrigation may be required to obtain a satisfactory yield. The peak value of crop coefficient of kharif finger millet recorded 1.02 on 66th day of sowing. Brown finger millet tolerance for water stress better than black finger millet. Under moisture stress situation application of Brassinosteroid (0.3 ppm) or Salicylic acid (100 ppm) to be effective for better yield and yield attributes in finger millet.

During rabi and summer season it is grown under irrigated ecology. Water requirement of summer finger millet is 350-375 mm which can be accomplished by eight to nine numbers of irrigation depending on soil types. Practice of soil mulch followed by irrigation scheduling at 60% soil moisture depletion level (SMDL) is beneficial for higher grain yield and water use efficiency. However, the water-use efficiency increased with the decrease in number of irrigations and finger millet respond well to deficit irrigation. Scheduling irrigation at an IW: CPE ratio of 0.9 along with sugarcane trash mulching at 10 cm thickness gave higher grain yield of finger millet under irrigated ecology.

For transplanted ragi pre-planting irrigation of 70-80 mm, lifesaving irrigation at 3 days after transplanting of ragi seedlings with small quantity of water is needed for proper crop establishment. For encouraging healthy and sound growth and tillering it is better to withheld irrigation for 10-15 days after establishment. Then irrigation at primordial initiation, flowering and grain filling stages ensures optimum grain and straw yield of irrigated transplanted ragi. Drip irrigation is an alternate and effective way of watering in drought-prone areas to generate good yields from finger millet-based farming systems.

Insect Pest and disease management

Blast, seedling blight, foot rot, cercospora leaf spot, downy mildew, smut and damping off are common diseases infest the finger millet field and causes significant yield loss. Management of diseases to bring down the infestation below the economic injury level by integrated manner is the viable option for minimizing yield loss. The integrated management of finger millet diseases are described below.

- Always use disease free quality seeds available at reliable sources like universities, agriculture departments, KVKs, and registered seed agencies.
- Seed treatment with fungicides like carbendazim or Saaf @ 2 g/kg of seeds or dust formulation of biocontrol agents like *Pseudomonas bacillus* or *Trichoderma* @ 5g /kg of seeds before sowing to protect the crop from soil and seed borne diseases at early stage of crop growth.
- Maintain optimum plant population and avoid over crowing of plants in nursery as well as in main field.
- Use balanced fertilizer and avoid excess use of nitrogenous fertilizer.
- Adopt crop rotation with pulses to break the disease cycle.
- Spray fungicide Edifenphos @ 0.1% or Carbendazim @ 0.2% or Mancozeb @ 0.2% in 500 lit of water per hectare for minimizing the yield loss due to blast, seedling blight and leaf spot diseases in ragi.

Army worm, cut worm, stem borers, ear eating caterpillars, shoot fly and leaf aphids are common insect pest which causes considerable yield loss in finger millet. Manage the insect pest population below the economic threshhold level by integration of cultural, mechanical, physical practices along with the need-based application of pest specific insecticides.

- Seed treatment with thiamethoxam 70 WS @ 3 S lt kg of reduce the damage by shoot-fly and to some extent stemborer and sucking pest.
- Application of neem seed kernel extract @ 5% in 500 liters of water or Neem Azal T/S 1% at 1.5 lit/ha helps in control of major insect pests in finger millet.
- To control shoot fly sprayed with Cypermethrin l0 EC (750 ml/ha) or Quinalphos 25 EC (400 g a.i. /ha).

Harvesting and Post-harvest care

At maturity the ear heads are harvested by sickles leaving the stalks as such in the field. Depending on the maturity of ear heads the harvesting may be done in one or two operations. The harvested panicles are staked on heaps on threshing floor for few days for drying which helps in separation of grains from the panicle. However, harvesting of stalks with panicles is common in most of the ragi growing regions. The mechanical ragi thresher has given the maximum grains output as compared to traditional threshing methods. Harvested stalks are sun dried for few days in the field itself. Threshing of panicles or stalks done by bullock trampling or by stone roller drawn by a pair of bullocks. Tractors can be used for grain separation in finger millets. Grains are cleaned, sundried to bring down the moisture to 14% for prolonged storage of grains. For seed purpose seed moisture of 12% is ideal for prolonged storage. Gunny bags, nylon woven sacs or IRRI super bags can be used for safe storage. Maize weevil (*Sitophilus zeamais*) and Angoumois grain moth (*Sitotroga cerealella*) are major storage pest of finger millets and can be manged by proper storage and suitable insecticide.

Energy requirement

Cultivation of irrigated finger millet required significantly higher energy than rainfed crop. Seedbed preparation, weeding, irrigation and harvesting were found to be most energy intensive operations. The rainfed finger millet required two times more renewable energy than irrigated crop. On the other hand, the irrigated finger millet required three times more non-renewable energy than rainfed crop. Cultivation of rainfed finger millet was found to be more economical in terms of energy input than that of cultivating irrigated finger millet.

Finger Millet based cropping systems in Odisha

Next to rice-based cropping systems, millets-based cropping systems have their own importance in tribal dominant regions of Odisha for food and nutritional security. Ragi is cultivated in Odisha as a sole crop, inter crop, mixed crop and under different cropping sequence. Intensification of finger millets with pulses and oil seeds has significant impact on land utilization, productivity and farm income. Some of the popular finger millet-based cropping systems practised under different climatic zones of Odisha are tabulated under Table 2

Table 2: Agroclimatic zone wise Finger millet-based cropping system in Odisha

Agroclimatic zones	Cropping Systems
North western plateau (SundarGarh,Deogarh)	Ragi, Arhar + Ragi
North central plateau (Keonjhar, Mayurbhanj)	Ragi, Arhar + Ragi
North eastern coastal plain (Balasore, Bhadrak, Jajpur,)	Ragi-Mustard, Ragi-Greengram
East & south-eastern coastal plain (Kendrapada, Jagatsinghpur, Khurda, Puri, Nayagarh, Cuttack)	Ragi, Arhar + Ragi, Ragi-Mustard/ Greengram
North east Ghat (Kandhamal, Rayagada, Gajapati, Ganjam	Ragi + Cowpea, Ragi + Horsegram, Arhar + Ragi, Ragi-Niger
Eastern Ghat highland (Nabarangpur, part of Koraput	Ragi, Minor Millets, Arhar + Ragi, Rice-Ragi
South eastern Ghat (Malkangiri, part of Koraput)	Ragi, Arhar + Ragi
Western undulating zone(Kalahandi, Nuapada	Ragi, Minor Millets, Arhar + Ragi Ragi-Mustard, Ragi-Niger/Sesamum
Western central table land (Baragarh, Bolangir, Boudh, Sonepur, Jarsuguda, Sambalpur)	Arhar + Ragi
Mid-central table land (Angul, Dhenkanal)	Arhar + Ragi

CONCLUSIONS

Among the different millets finger millet is gaining popularity in different agroclimatic zones of Odisha due to its short duration, low water requirement, wider adaptability, economically competitive, environmentally friendly, food and nutritional value and market demand. Availability of location specific farmers friendly high yielding varieties, quality seed materials and modern management practices will ensure the wide adoption of finger millet cultivation in both rainfed and irrigated ecologies. Favourable government policies like implementation of millet mission, minimum support price, inclusion of finger millets in public distribution system helped in revival of millet farming in tribal dominant districts of Odisha. It will play a crucial role in reduction of household vulnerability of small and marginal farmers under the present scenario of climate change. More involvement of women in millet farming will create gender balance in agricultural production system. The millet based mixed farming has also helped in addressing the

problem of malnutrition by taking the care of soil and environment. For sustainable millet production there is a need of development of location specific integrated crop management practices particularly nutrient, weed and water management options for enhancing production, productivity as well as farmers profit.

Finger millet as a contingent crop in flood prone shallow low lands of Nimapada block, Odisha