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POTENTIAL AND SCOPE OF SORGHUM CULTIVATION IN RICE-FALLOWS -AN IDEAL STRATEGY UNDER CLIMATE CHANGE: A REVIEW

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SUMMARY

As global population continues to increase, crop yield must increase proportionally to meet the demand for food and nutritional security. Atmospheric carbon dioxide (CO_2) concentration is increasing rapidly and is expected to surpass 550 ppm soon. Mean annual temperature has significantly increased by 0.4°C over the last one hundred years. Global warming is expected to affect plant growth and soil ecosystems. Sorghum is a major staple food of millions of people in arid and semiarid regions of the world. It has the cheapest source of nutrition and energy. The area under grain sorghum cultivation has drastically declined from 18.5 m ha to 4.48 m ha from 1970 to 2020. *Kharif* sorghum cultivation is decreasing rapidly due to poor grain quality than *rabi* sorghum. Sorghum is considered to be climate resilient. Late rabi sorghum cultivation in rice-fallows is an ideal strategy for food, fodder, nutritional security, and livestock sustainability under changing climate scenario.

Key words: Climate change, rice-fallows, late *rabi* sorghum

Global food and nutrition security focuses on unique interventions to feed the projected population of nine billion by 2050, equitably, healthily, and sustainably. The increased atmospheric concentration of carbon dioxide (CO_2) is the major factor responsible for global warming. During higher temperatures, drought may occur quickly. Global warming affects plant growth and soil ecosystems. Increasing CO_2 concentration in the atmosphere leads to escalation in temperature, affecting most of the physiological processes in plants. Elevated temperature stress and drought are the important abiotic stresses, which limits productivity of food and fodder crops. Several climate models project that the ambient air temperature will rise between 1°C and 3.4°C by the end of this century, depending on population growth and greenhouse gas emissions scenarios (IPCC 2014).

In addition, it is expected that crops in future climatic scenario will be exposed not only to higher mean air temperatures but also to more frequent short episodes of high temperature stress. Arid and semi-arid regions are particularly vulnerable to changes in climate and extreme temperature events. Climate resilient crops such as grasses: guineagrass, bajra - napier hybrids and tri-specific hybrids,dinanath grass, (Dheeravathu *et al.,* 2018, Singh *et al.,*2020, Dheeravathu *et al.,* 2021a, Dheeravathu *et al.,* 2021b, Dheeravathu *et al.,* 2021c., Dheeravathu *et al.,* 2022a, Antony *et al.,* 2021, Dheeravathu *et al.,* 2022b), pulses: cow pea,berseem, clitoria, centrosema, siratro (Dheeravathu *et al.,* 2017a, Dheeravathu *et al.,* 2017b, Dheeravathu *et al.,* 2022c), forage cereals including millets: pearl millet and sorghum(Singh *et al.,* 2010, Malathi *et al.,* 2022,Amrutha, *et al.,* 2023), have been proven to be climate smart. Considering the adverse effect of accumulated salts in soil and irrigation water, elevated CO_2 and temperature on soil health as well as forage yield and productivity, it is high time for in depth understanding of physiological and biochemical changes in forage crop varieties/ genotypes/ lines in response to climate change.

Sorghum (*Sorghum bicolor* L. Moench) is the world's fifth most important cereal crop, after maize, rice, wheat, and barley. Sorghum popularly known as Jowar in India, is an important staple food for millions of people in the semi-arid tropics of Asia and Africa. India contributed 13 per cent of the total world area (44.20 m ha) under sorghum with 8.00 per cent of total world production (67.87 m t) during 2014-15. In India, Maharashtra state ranks first in area and production followed by Karnataka, Madhya Pradesh, and Telangana. It is called great millet based on its gain size which is better than all other millets. The area has declined drastically from 10.25 m ha in 1999-

2000 to 4.82 m ha in 2019-2020. The total production also declined from 8.68 m t to 5.39 m.t. But the productivity has increased from 847kg/ ha to 907 kg/ ha during the same period due to adoption of improved production technologies by the farmers (Chapke *et al.* 2019). Compared to other major cereals, sorghum requires less water, less inputs, resistant to pests and diseases.

It is a multi-purpose C_4 crop which plays an essential role in food, feed, fodder security and bio-fuel in dryland agriculture. In Asia, India is the main producer of sorghum despite the crop being mostly cultivated by small and marginal farmers in the stress-prone semi-arid regions. In 2019, the country's area under sorghum cultivation was 4.1 million hectares, with a production of 3.5 million tons and a productivity of 849 kg/ha (Sridhara *et al*., 2020). Compared to the global average (Rs. 1,481 kg/ha), sorghum productivity in India is low, mostly because the crop is often cultivated under rainfed conditions (Yadav *et al.,* 2011; DACNET, 2016; FAOSTAT, 2020). Additionally, heat, water stress and lack of crop management options lower the crop productivity.

Rice fallows imply to those lowland *kharif* sown rice areas which remain uncropped during *rabi* (winter) due to several reasons such as lack of irrigation, cultivation of long-duration varieties of rice, early withdrawal of monsoon rains leading to soil moisture stress at planting time of winter crops. India accounts for 79% (11.65 million ha) of the total rice fallows of South Asia (15.0 million ha). Farmers cultivate sorghum during late *rabi*, in rice fallows in the states of Andhra Pradesh, some parts of Tamilnadu, south Bihar, Chhattisgarh, Jharkhand, parts of Odisha, (Chapeke *et al.,* 2019). Previously under rice fallow, black gram and maize crops were the major cropping system of the coastal areas of Andhra Pradesh, but these two crops declined drastically due to infestation of yellow mosaic virus and parasitic weeds. Also, these crops require more number of irrigations and input, which make them non- profitable to rice fallow cropping system compared to sorghum. The coastal region of Andhra Pradesh, has developed into a rice fallow ecology. *Kharif* (rainy) sorghum is primarily used for poultry feed, animal feed industries and alcohol (Patil *et al.,* 2014), whereas *rabi* (post-rainy)/ late *rabi* sorghum is grown for human consumption, fodder purposes, fibre, and fuel (Kumara *et al.,* 2014). In order to meet domestic demands of food, feed, fodder and biofuel, there is huge scope to promote sorghum in unconventional areas. The rice fallows offer good scope for area expansion and intensification of sorghum. ("In rice fallows – an IIMR case study – Research Gate"). The fallow land (lean season) utilization can overcome social and economic problems like unemployment, labour migration, fodder availability and low income.

Development and popularization of improved hybrids of sorghum suiting to rice fallows (late *rabi*) for different agro-ecological regions coupled with improved crop management technologies can boost production, and thus, improve income and livelihood security of farming community. Usually, short duration *kharif* hybrids were found to be more suitable/ are opted for late *rabi* rice fallow cultivation which results in higher yields and higher grain quality even under high-temperature and drought.

Kharif sorghum hybrid (CSH16) performed very well and yielded 8.00t/ha of grain out of 17 public and private cultivars (Photo 1 and 2, Fig. 1 and 2). Due to its short height, it had no lodging problem like tall hybrids. It opens avenues for export. Rice fallow offer opportunities to expand sorghum area. Sorghum in rice-fallows in coastal Andhra Pradesh, especially in Guntur and adjoining districts is gaining popularity among farmers. Sorghum cultivation in rice fallows is an ideal strategy for sustainable livestock production, productivity, food, fodder, biofuel and nutritional security under changing climate in arid and semi-arid regions to tackle future climate change.

CONCLUSIONS

Sorghum is inherently a sturdy crop which is grown with low input requirement and high resilience to abiotic stress. Rice fallows are better utilized by cultivating sorghum during the late winter season in South India. Identification of promising cultivars and breeding for rice fallow ecology will be a profitable preposition with wider impact on socio-economic status of farmer. Strengthened breeding programme is needed for the development of high yielding and medium height, drought/temperature stress-tolerant varieties in sorghum hybrids to tackle the future climate change in arid and semi-arid regions. Whereas the requirement of production technologies varies as per the different agro-ecologies. Therefore, it needs to develop location specific sorghum production technologies for different regions and locations.

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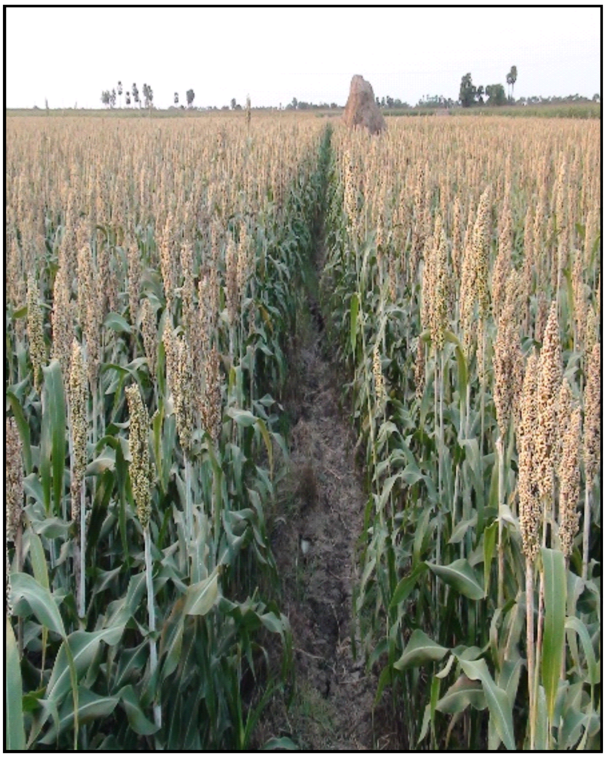

Photo 1 and 2. Rice fallow sorghum field.

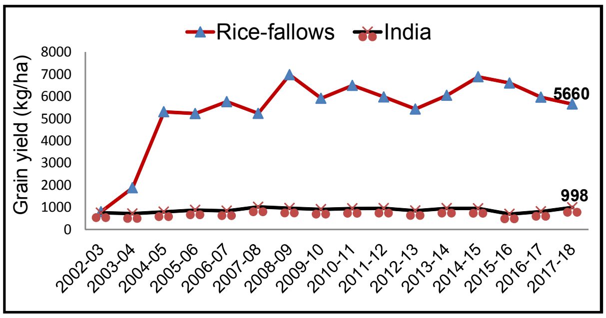

Fig. 1. Productivity of sorghum in rice-fallows (Guntur Dist-AP).

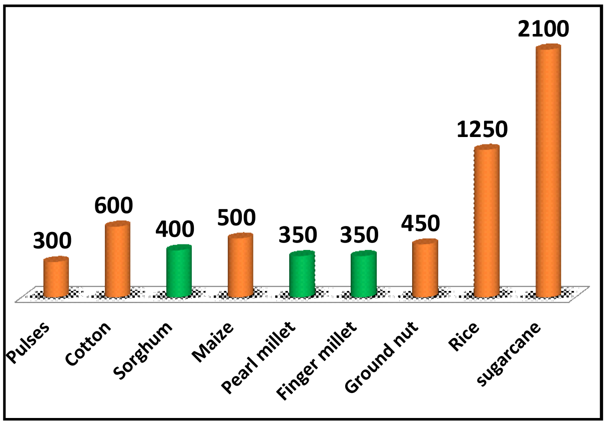

Fig. 2. Water requirement of millets & other crops (in mm).

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REFERENCES

Amrutha, V.A, T.B. Vadithe, S. Avinash, T.N. Usha , N. Dikshit, M.V. Malathi, S.N. Saida, R. Venkateswarlu, R. Srinivasan and S.N. Dheeravathu, 2023: Molecular mechanism of salt tolerance in millets - a review. *Forage Res*., **48**(4): 430-434.

Antony, E., A. B. Kawadikai, S. Hullur, K. Sridhar, S. Nayak, and V. K. Yadav, 2021 : Biomass repartitioning, tiller regeneration and salt secretion through leaf micro hairs for salinity tolerance in guinea grass (*Megathyrsus maximus* Jacq.). *Range Mgmt and Agroforestry*, **42**: 246-254.

Chapke, R. R., and V. A. Tonapi, 2019 : Adoption and socio-economic benefits of improved post-rainy sorghum production technology. *Agric. Res*., **8**: 270–278. doi: 10.1007/s40003-018-0359-x.

DACNET 2016. Department of Agriculture Cooperation, Government of India. Available online at: https://eands.dacnet.nic.in/PDF/Glance-2016.pdf.

Dheeravathu S. N., M. H. Hanamant, T. B. Vadithe, S. N. Vadithe, K. Singh, N. Dikshit, T. N. Usha, T. Singh, Reetu, and R. Gajghate, 2021c: Salinity tolerance of forage cowpea (*Vigna unguiculata* (L.) walp.) during germination and early seedling growth. *Forage Res*., **47**: 213-221.

Dheeravathu S. N., T. Singh, and A. Radhakrishna, 2017b: Effect of drought stress on biomass and drought adaptive traits in Berseem (*Trifolium alexandrinum* L.), National symposium-new directions in managing forage resources and livestock productivity in 21st century : challenges and opportunity: 4-17.

Dheeravathu, S. N., E. Antony., R. V. Koti, and M. B. Doddamani, 2017a: Salinity tolerance of Forage range legumes during germination and early seedling growth. *Progressive Res. J.*, **12**: 1357-1360.

Dheeravathu, S. N., K. Singh, P. K. Ramteke, Reetu, N. Dikshit, M. Prasad, D. Deb, and T. B. Vadithe, 2021b : Physiological responses of Bajra-Napier hybrids and a tri-specific hybrid to salinity stress. *Trop. Grassl. Forrajes Trop.*, **9**: 337-347.

Dheeravathu, S. N., P. Singh, R. Srinivasan, and V. K. Yadav, 2022 a: Open Top Chamber: Aninnovative screening technique for temperature stress tolerance in forage oat (*Avena sativa*). *Forage Res.*, **47** : 513-516.

Dheeravathu, S. N., T. B. Vadithe, N. Dikshit, T. N. Usha, S. N. Vadithe, R. Venkateswarlu, V. Manasa, and S. Bandeppa, 2022b: Effect of elevated CO_2 and temperature on physiological and biochemical changes in forage crops: A review. *Forage Res.*, 48 : 22-27.

Dheeravathu, S. N., T. Singh, A. Radhakrishna, Reetu, R. Gajghate, S. R. Kantwa, and H. A. Bhargavi, 2021a: Effect of salinity stress on different seed vigour indices in single and multicut berseem (*Trifolium alexandrinum*) varieties. Forage Res.46: 368-373.

Dheeravathu, S. N., V. C. Tyagi, C. K. Gupta, and A. Edna, 2018: Manual on Plant Stress Physiology. ICAR - Indian Grassland and Fodder Research Institute, Jhansi. Stress assessment formulas and stress related terminology: 1-87.

Dheeravathu, S.N., M. Chaudhary, N. Dikshit, V. Manasa, R. Srinivasan, T.N Usha, T.B Vadithe, S.N. Vadithe, G. Vijayakumar, S. Bandeppa, and Satpal, 2022c: Effect of elevated CO_2 and temperature on soil health and forage crops -A review. *Forage Res.*, **48**(3): 285-289.

FAOSTAT, Food and Agriculture Organization of the United Nations. 2020: Available online at: https://www.fao.org/faostat/en/#data/QCL (accessed on March 20, 2021).

IPCC 2014: In Climate Change2014: Synthesis Report. Contribution of Working Groups I, II and III to the fifth Assessment Report of the Intergovernmental Panel on Climate change (eds Core Writing Team, Pachauri R.K. & Meyer L.A.), p. 151. IPCC, Geneva, Switzerland

Kumara, C. D., Bantilan, M. C. S., Rajalaxmi, A., Reddy, B. V. S., Borikar, S. T., Kumar, A. A., et al. 2014. Development and Diffusion of Sorghum Improved Varieties in India: Impact on Growth and Stability in Yield (Working Paper Series no. 50). Patancheru: International Crops Research Institute for the Semi-Arid Tropics.

Malathi, M. V., S. N. Dheeeravathu, R. Venkateswarlu, T.N. Usha, T. B. Vadithe, S. N. Vadithe, D. Venkateshwarlu, G. Vijayakumar, N. Dikshit, and Satpal, 2022 : Climate change: Molecular adaptation strategies in cereals and forage crops–A review. Forage Res., 48(2): 137-145.

Patil, J. V., Reddy, S. P., Prabhakar, A., Umakanth, V., Gomashe, S., and Ganapathy, K. N. 2014: History of post-rainy season sorghum research in India and strategies for breaking the yield plateau. Indian J. Genet. Plant Breed. 74, 271–2285. doi: 10.5958/0975-6906.2014.00845.1.

Singh, B., S. N. Dheeravathu, and K. Usha, 2010: Micronutrient Deficiency: A Global Challenge and Physiological Approach to Improve Grain Productivity under Low Zinc availability, In: Plant stress. Global science book UK, (Special issue -2) **4**: 76-93.

Singh, K., S. N. Dheeravathu, P. W. Ramteke, Reetu, N. Dikshit, and T. B. Vadithe, 2020: Effect of salt stress on morpho-physiological and green fodder yield of Bajra Napier Hybrids and Tri Specific Hybrid. *Forage Res.*, **46**: 241-247.

Sridhara, S., Ramesh, N., Gopakkali, P., Das, B., Venkatappa, S. D., Sanjivaiah, S. H., et al. 2020: Weather-based neural network, stepwise linear and sparse regression approach for rabi sorghum yield forecasting of Karnataka, India. *Agron.*, 10: 1645. doi: 10.3390/agronomy101 11645.

Yadav, J., Ojha, A. K., George, C., Sajeevan, R., Singh, G., Bhargav, H., et al. 2011: All India Report on Agriculture Census 2010–2011. Available online at: https:// agricoop.nic.in/sites/default/files/ air2010-11complete.pdf (accessed: March 20, 2021).