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MILLETS: A SAFE CROP CHOICE UNDER CLIMATE CHANGE AND EL NIÑO CONDITIONS - A REVIEW

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SUMMARY

Climate change is increasingly threatening global agricultural production through rising temperatures, erratic rainfall, frequent droughts, heat waves, and other extreme weather events. These climatic stresses are expected to become more severe during years influenced by El Niño, particularly in rainfed agricultural regions where crop production depends largely on monsoon rainfall. Under such conditions, selecting climate-resilient crops is essential for ensuring stable production, food security, and sustainable livelihoods. Millets have emerged as one of the most climate resilient cereal groups because of their low water requirement, high water-use efficiency, drought and heat tolerance, short crop duration, adaptability to marginal soils, and stable productivity under adverse environmental conditions. Their C_4 photosynthetic pathway further enhances their ability to maintain photosynthesis and yield under high temperatures and limited soil moisture. In addition to their agronomic resilience, millets provide important nutritional, environmental, and economic benefits. This review discusses the impacts of climate change and El Niño on agriculture and highlights the physiological, agronomic, and ecological characteristics that make millets a sustainable crop choice under changing climatic conditions.

Key words: Climate change, El Niño, drought, heat stress, climate resilience, millets and sustainable agriculture

Agriculture is the backbone of rural livelihoods and food security in many developing countries, particularly India. However, agricultural production is becoming increasingly vulnerable to climate change. Rising temperatures, erratic rainfall, frequent droughts, heat waves, and extreme weather events are posing serious challenges to crop production and farm profitability. The Intergovernmental Panel on Climate Change (IPCC) has consistently emphasized that agriculture is among the sectors most vulnerable to climate variability. Crop growth and productivity are strongly influenced by weather conditions, and even small deviations in temperature and rainfall can substantially reduce yields. Rainfed farming systems are particularly susceptible because they depend primarily on seasonal rainfall. El Niño is a naturally occurring climate phenomenon that influences global weather patterns and has historically been associated with below-normal southwest monsoon rainfall, higher temperatures, and prolonged dry spells in many parts of India. Such conditions often result in soil moisture deficits, increased irrigation demand, and reduced crop productivity. Under these circumstances, selecting crops that can tolerate water scarcity and high temperatures is becoming increasingly important. Millets have attracted considerable attention as climate-resilient cereals because of their exceptional tolerance to drought and heat, efficient water use, adaptability to marginal soils, and stable yields under low-input conditions. These attributes make millets well suited to climate-smart agriculture and sustainable food systems. This review summarizes the effects of climate change and El Niño on agriculture and discusses the physiological, agronomic, nutritional, and environmental advantages that position millets as an important crop for enhancing agricultural resilience under changing climatic conditions.

CLIMATE CHANGE AND AGRICULTURAL RISKS

Climate change is no longer a future concern; it is already affecting farming systems worldwide. Several climatic changes are currently being observed:

Rising temperatures-global average temperatures have increased significantly over the past century. Higher temperatures affect crop growth by: Increasing evapotranspiration. accelerating crop development, reducing grain-filling duration, increasing reproductive stress, lowering crop productivity. Heat stress during flowering and grain filling can substantially reduce yields in crops such as rice, wheat, and maize. Irregular rainfall patterns-rainfall distribution is becoming increasingly erratic. Farmers are experiencing: Delayed monsoon onset, early monsoon withdrawal, uneven rainfall distribution, long dry spells between rainfall events, extreme rainfall episodes causing flooding. These irregularities make crop planning difficult and increase production risks. Increased frequency of droughts-many agricultural regions are experiencing more frequent and severe droughts. Drought reduces: Soil moisture availability, crop growth, nutrient uptake, biomass accumulation, final grain yield, rainfed agriculture is especially vulnerable to prolonged dry periods.

HEAT WAVES

Heat waves are becoming more common and intense. Temperatures exceeding 35-40°C are now frequently recorded during crop-growing seasons. Such extreme temperatures negatively affect crop physiology and reproductive processes (Table 1).

Millets are C_4 cereal crops that possess several physiological and morphological characteristics enabling them to perform well under adverse environmental conditions. These attributes make them among the most climate-resilient food crops and a promising choice for cultivation under the increasing frequency of droughts, heat waves, and erratic rainfall associated with climate change and El Niño events. One of the key advantages of millets is their C_4 photosynthetic pathway, which efficiently concentrates carbon dioxide around the enzyme RuBisCO, thereby minimizing photorespiration. This mechanism enables millets to sustain high photosynthetic rates even under high temperatures and low internal CO, concentrations. Consequently, C_4 photosynthesis provides a significant advantage over the C_3 pathway under hot and water-limited conditions. Millets also exhibit several adaptive traits that enhance their resilience. They have a short crop duration, allowing them to escape terminal drought and complete their life cycle before severe moisture stress develops. Their deep and extensive root systems enable efficient extraction of soil moisture from deeper soil layers, thereby improving drought tolerance. In addition, millets can withstand high temperatures (30-45°C) and continue to produce satisfactory yields under conditions that are unfavorable for many other cereal crops. Under drought stress, millets partially close their stomata to reduce transpiration and conserve water. Unlike C_3 plants, however, the C_4 carbon-concentrating mechanism allows photosynthesis to continue efficiently despite reduced stomatal conductance. As a result, millets exhibit high water-use efficiency (WUE), producing greater biomass and grain yield per unit of water consumed. This physiological advantage makes them particularly suitable for rainfed agriculture in arid and semi-arid regions. In contrast, C_3 crops such as rice and wheat generally have an optimum photosynthetic temperature of 20–25°C. Under drought and heat stress, stomatal closure reduces the internal CO, concentration, increasing photorespiration and significantly decreasing photosynthetic efficiency. Consequently, C_3 crops experience greater reductions in growth and productivity under climate stress than C_4 crops. The optimum temperature for photosynthesis in C_4 crops, including millets, ranges from 30 to 42°C (Table 3), enabling them to maintain productivity under elevated temperatures. Combined with their superior water-use efficiency, drought

TABLE 1
Temperature thresholds on millet crop stage

Crop stage	Temperature Range/ Condition (°C)	Effect
Germination	12-18 (Minimum) 20-30 (Optimal)	Below minimum stops sprouting; 20-30°C ensures fast, even emergence.
Vegetative Growth	25-35	Promotes rapid leaf expansion, C_4 photosynthesis, and strong root systems.
Cool Stress (< 20°C)	Below 15-20	Slows down metabolic rates, leaf area growth, and dry matter accumulation.
Heat Stress (> 35°C+)	Above 35	Causes shortened inter nodes, reduced plant height, forced early flowering, and lower grain yields.

Singh *et al.* (2019), Sravanthi *et al.* (2024) and anonymous sources.

tolerance, and shorter crop duration, these characteristics make millets one of the safest and most sustainable crop options under El Niño conditions

UNDERSTANDING EL NIÑO AND ITS AGRICULTURAL IMPLICATIONS

El Niño is a naturally occurring climate phenomenon associated with abnormal warming of surface waters in the central and eastern Pacific Ocean. Although it occurs thousands of kilometers away, El Niño significantly influences weather patterns across the globe, including the Indian subcontinent.

How El Niño Affects India?

During El Niño years, India often experiences: Reduced southwest monsoon rainfall, delayed onset of rains, extended dry periods, increased temperatures, greater frequency of drought conditions.

Agricultural Consequences of El Niño

The impacts of El Niño on agriculture include: Reduced rainfall, lower rainfall leads to soil moisture deficits and limits crop growth. Increased irrigation demand-farmers may need additional irrigation to sustain crops, increasing production costs. Heat stress-higher temperatures affect flowering, pollination, and grain filling. Reduced yields-water-sensitive crops often experience significant yield reductions during El Niño years. Increased production risk-crop failures become more likely in rainfed regions. Given these challenges, drought-tolerant crops become essential for maintaining agricultural productivity.

Why Millets Are Climate-Resilient Crops

Millets possess several characteristics that enable them to perform well under adverse environmental conditions. Low water requirement one of the most important advantages of millets is their low water demand (Table 2).

Pearl millet is among the most heat-tolerant millets and is well suited to hot, dry climates. At 42°C, its yield reduction under heat stress is generally lower than that of other millets.

Millet crops: Dates of sowing, seed rate, spacing and fertilizer dose - For millet cultivation in semi -arid regions of India. The recommended practices vary with millet to millet. The following are general agronomic recommended name of improved millet varieties dates of sowing, seed rate, spacing and fertilizer doses showed in Tables 4, 5, 6, 7 and 8.

TABLE 2
Comparative Water Requirement of Major Crops

Crop	Water Requirement (mm)
Rice	1,250
Maize	500
Pearl millet	350
Finger millet	350
Foxtail millet	300
Sorghum	400
Sugarcane	2,100
Cotton	600
Pulses	300

Richard G. Allen and *et al* (1998).

TABLE 3
Optimum Temperature Range for Millets

Millet crop	Optimum temperature (°C)	
	Germination	Vegetative Growth
Banyard millet	25–30	25–35
Brown top millet	25–30	25–35
Finger millet	25–30	24–32
Foxtail millet	25–30	25–35
Kodo millet	25–30	25–35
Little millet	25–30	25–35
Pearl millet	25–30	30–40
Proso millet	20–30	25–35
Sorghum	21-30	26–35

Singh *et al.* (2019), Sravanthi *et al*. (2024) and anonymous sources.

TABLE 4
Time of Sowing

Season	Recommended Sowing Time
Kharif	First fortnight of July with the onset of the monsoon
Rabi	September to October
Summer	January to February (South india) 15 February to March (North india)
Irrigated catch crop	Mid-March to mid-May in Bihar and Uttar Pradesh

Benefits of early maturity

Flexibility in sowing-farmers can adjust planting dates when monsoon rains are delayed. Reduced exposure to drought, short-duration crops escape terminal drought stress. Lower weather risk-

TABLE 5
Seed Rate

S. No.	Crop	Method of sowing	Seed rate (kg/ha)
1	Sorghum	Line sowing	7–8
2	Pearl millet	Line sowing	4–5
		Transplanting	2
3	Finger millet	Line sowing	5–6
		Transplanting	4
4	Small millets	Line sowing	5–6
		Broadcasting	8–10

Tara Satyavathi *et al* (2023).

Recommended Spacing: General Recommendation

- Row-to-row spacing: 20–30 cm
- ` Between ridges: 45–60 cm
- Plant-to-plant spacing: 10–15 cm

TABLE 6
Crop-wise Spacing

S. No.	Crop	Spacing (Row × Plant)
1	Sorghum	45 × 15 cm
2	Pearl millet	40 × 15 cm
3	Finger millet	22.5 × 10 cm
4	Small millets	20 × 10 cm

Tara satyavathi *et al.* (2023)

Nutrient Management

- Apply compost or farmyard manure (FYM) @ 8–10 t/ha before sowing.
- Soil test-based fertilizer application is recommended.
- Apply the entire quantity of phosphorus (P_2O_5) and half of the nitrogen at sowing.
- Apply the remaining half of nitrogen at the first irrigation or during the active tillering stage.

Recommended Fertilizer Dose (RDF).

TABLE 7
The recommended fertilizer dose varies depending on soil fertility and moisture availability

Nutrient	Recommended Dose (kg/ha)
Nitrogen (N)	20–100
Phosphorus (P_2O_5)	20–40
Potassium (K_2O)	20–40

Sukanya *et al*. (2022).

General Recommendation

- Major millets (Sorghum, bajra, and finger millet) : 80:40:40 kg N:P_2O_5: K_2O/ha
- Small millets (Brown top, Barnyard, Foxtail, Kodo, Proso, Little millet) : 20:20:0 kg N:P_2O_5: K_2O/ha

reduced exposure to extreme weather events during crop growth. Multiple cropping opportunities. Early harvest allows cultivation of additional crops within the same year (Table 9). Yield stability under rainfed conditions: Yield stability is critical for smallholder farmers. Research across semi-arid regions has consistently shown that millets maintain more stable yields under drought conditions than many other cereals. Reasons for Yield Stability: Efficient water use, deep root systems, drought tolerance, heat resistance, short crop duration, even when rainfall is below normal, millets often produce acceptable yields while other crops may fail. This stability provides farmers with greater confidence and livelihood security. Adaptation to Marginal Soils: Large areas of agricultural land suffer from low fertility, Poor soil structure, Limited, moisture-holding capacity, Nutrient deficiencies, Millets perform remarkably well under such conditions. Soil Adaptability: Millets can grow successfully in: Sandy soils, Shallow soils, Low-fertility soils, Dryland regions. Their ability to produce reasonable yields under marginal conditions expands cultivation opportunities and enhances food security. Millets and Sustainable Agriculture: Millets contribute significantly to sustainable farming systems. Reduced Water Use: Lower irrigation demand helps conserve groundwater resources. Lower Input Requirement. Millets generally require: Less fertilizer, Less irrigation, Lower energy inputs, Improved Resource Efficiency, Millets utilize available resources efficiently and produce more output per unit of water consumed. Environmental Benefits: Millet cultivation contributes to: Reduced water extraction, lower carbon footprint, enhanced climate resilience, Sustainable land management. Nutritional and economic benefits-In addition to climate resilience, millets offer substantial nutritional advantages. Nutritional benefits: Millets are rich in: dietary fiber, protein, iron, calcium, zinc, antioxidants. They contribute significantly to nutritional security and healthy diets.

Economic Benefits

Millet cultivation often involves: Lower production costs. Reduced irrigation expenses. Lower risk of crop failure. Growing consumer awareness regarding healthy foods is creating expanding markets for millet-based products. Farmers can benefit from increasing demand for: Millet grains. Value-added products. Health foods. Organic millet products. Policy support and future prospects. Governments and international organizations increasingly recognize the

TABLE 8
Improved Varieties of Different Millets

S. No.	Crop	Improved Varieties
1	Sorghum (Jowar/Jonnalu)	CSH 14, CSH 16, CSH 23, CSH 25, CSV 15, CSV 17, CSV 20, CSV 23, CSV 27, Maldandi Suprime (SPH-2036)
2	Pearl millet (Bajra)	Dhanashakti, GHB 538, RHB 173, MPMH 17
3	Finger millet (Ragi)	VL 376, KMR 204, VL 352, GNN 6, GPU 28, KMR 301, MR 6, KMR 340, GPU 67, GPU 48
4	Foxtail millet (Korralu)	SiA 3088, SiA 3156, SiA 3085, Krishnadevaraya, CFXMV2
5	Proso millet (Varigalu)	GPUP 21, TNAU 164, TNAU 145, GPUP 8
6	Little millet	OLM 203, JK 4, JK 8, DHLM 36-3, BL 6, BL 4, GV 2
7	Kodo millet	RK 390-25, RBK 155, GPPUK 3, JK 76, TNAU 86, JK 137, Indira
8	Browntop millet	HBR-2
9	Barnyard millet	DNBM 93-3, VL 172, DHBM 23-3, VL 249

TABLE 9
Crop duration and Medium to Early Maturity duration varieties/Hybrids

S. No.	Crop	Crop duration in days (Average)	Medium to Early Maturity duration varieties/Hybrids	Duration in days (Average)
1	Sorghum (Jowar/Jonnalu)			
	Hybrids	105	CSH30	100
	Kharif varieties	115-120	CSV-17	95-100
	Forage	60-80 (1st cut)	-	-
	Rabi variety	115-125	1) Maldandi Supreme 2) CSV29R 3) CSV26R 4) SPV2217	115
	*Sweet sorghum	126	-	-
2	Pearl millet (Bajra)	75	MPMH-35 ICMA 04999 ICMB 04999	75 75 75
3	Finger millet (Ragi)	117	VL 376	100 to 105
4	Foxtail millet (Korralu)	80	1) SiA 3088, 2) SiA 3156, 3) SiA3222	70-75, 80-85 and 60-65
5	Proso millet (Varigalu)	65-75	1) IIMR-PM25G2) CPRMV-1	60-65,62 to 67
6	Little millet	107	JK8	80
7	Kodo millet	105-110	CKMV-1	100
8	Browntop millet	95-100	GPUBT-2	85-90
9	Barnyard millet	95	CBYMV-1	82

*alternate to sugarcane crop.

importance of millets. Recent initiatives promoting millet cultivation include: Climate-smart agriculture programs. Nutritional security missions. Sustainable farming initiatives. Dryland agriculture development programs. These efforts are expected to further strengthen millet production and marketing opportunities. With increasing climate uncertainty, millets are likely to play a crucial role in future food systems.

Recommendations for farmers EL Nino conditions

Considering anticipated climatic risks, farmers are advised to: Prioritize drought-tolerant millet crops. Select short-duration millet varieties. Adopt moisture conservation practices. Use climate-resilient crop management techniques. Diversify cropping systems with millets. Utilize weather-based advisories. Explore value-added millet markets. Such measures can significantly reduce climate-related production risks.

Resilient millets and forage and other crops

Several millets and forage and other crops have been identified as climate-resilient due to their capacity to tolerate abiotic stresses, including forage cereals and millets, including pearl millet, kodo millet, and sorghum, have also been reported to possess

adaptive traits that confer resilience under variable climatic conditions (Singh *et al.*, 2010; Malathi *et al.*, 2022; Amrutha *et al.*, 2023; Dheeravathu *et al.* (2024a and b), Sravanthi *et al.*, 2024, 2025). Legumes species such as cowpea (*Vigna unguiculata*), berseem (*Trifolium alexandrinum*), *Clitoria ternatea*, *Centrosema spp.*, and Siratro (*Macroptilium atropurpureum*) have shown tolerance to multiple stresses, including excess soil moisture (Dheeravathu *et al.*, 2017a, 2017b, 2021a, 2021c, 2022c, 2023). Among grasses, Guinea grass (*Megathyrsus maximus*), Bajra–Napier hybrids, trispecific hybrids, and Dinanath grass (*Pennisetum pedicellatum*) have demonstrated adaptability under adverse moisture conditions (Singh *et al.*, 2020, Singh et al. (2021), Dheeravathu *et al.*, 2021a, 2021b, 2022a, 2022b).

CONCLUSION

Climate change, characterized by rising temperatures, erratic rainfall, increasing water scarcity, and more frequent extreme weather events, is posing significant challenges to agricultural production worldwide. During years affected by El Niño, these climatic stresses may become even more pronounced in many rainfed regions, increasing the risk of crop failure and reducing farm productivity. Millets have emerged as one of the most climate-resilient cereal crops owing to their low water requirement, high water-use efficiency, drought and heat tolerance, short crop duration, adaptability to marginal soils, and stable yields under adverse environmental conditions. Their C_4 photosynthetic pathway provides an additional physiological advantage by maintaining photosynthetic efficiency under high temperatures and moisture stress. Beyond climate resilience, millets contribute to nutritional security, environmental sustainability, and improved farm profitability through reduced input requirements and lower production costs. These characteristics make them well suited for climate-smart agriculture and sustainable farming systems. Promoting millet cultivation through improved varieties, appropriate crop management practices, supportive policies, and value-chain development can strengthen agricultural resilience, enhance food and nutritional security, and improve farmers' livelihoods under changing climatic conditions. As climate variability continues to increase, millets are likely to play an increasingly important role in building resilient and sustainable agricultural systems.

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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.

Dheeravathu, S. N. and T. B. Vadithe, 2024a : Potential and scope of sorghum cultivation in rice fallows – An ideal strategy under climate change: A review. *Forage Res.*, **50**(1): 1–4.

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

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

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

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

Dheeravathu, S. N., Singh, P., Srinivasan, R. and Yadav, V. K. 2022a : Open top chamber: An innovative screening technique for temperature stress tolerance in forage oat (*Avena sativa* L.). *Forage Res.*, **47**: 513–516.

Dheeravathu, S. N., Singh, P., Srinivasan, R. Anup, K, Deb, D., Vadithe, T. B. and Yadav, V. K. (2023). Open top chamber: an innovative screening technique for temperature stress tolerance of

morpho- physiological and fodder yield traits in forage cowpea varieties. *Range Management and Agroforestry*, 44:58-65.

Dheeravathu, S. N., Singh, T. and Radhakrishna, A. 2017b : Effect of drought stress on biomass and drought adaptive traits in berseem (*Trifolium alexandrinum* L.). In: National Symposium on New Directions in Managing Forage Resources and Livestock Productivity in the 21st Century: Challenges and Opportunities, pp. 4–17.

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

Dheeravathu, S. N., Sravanthi, G., Thulasi Bai, V., Kethavath Madhu Deepika and Saida Naik, V. 2024b : Physiological study of kodo millet under imposed salinity stress at seedling stage. *Forage Res*., 50(3): 330–336.

Dheeravathu, S. N., Tyagi, V. C., Gupta, C. K. and Edna, A. 2018 : Manual on Plant Stress Physiology. ICAR–Indian Grassland and Fodder Research Institute, Jhansi, pp. 1–87.

Dheeravathu, S. N., Vadithe, T. B., Dikshit, N., Usha, T. N., Vadithe, S. N., Venkateswarlu, R., Manasa, V. and Bandeppa, S. 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, usha T.N , Sravanthi G , Kethavath Madhudeepika , Thulasi bai, V, avinash S, Srinivs A., Jyothi , Saida naik V , D. Venkateshwarlu (2026). Cold tolerant forage crops: plant physiology, breeding, and biotechnology approaches to enhance forage yield -A review. *Forage res*., **51**(4) : pp. 441-444.

FAO Irrigation and drainage paper 56: Crop evapotranspiration - Guidelines for computing crop water requirements - Richard G. Allen Utah State University, Logan, Utah, USAMM-56. ISBN 92-5-104219-5 (1998)

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

Singh, B., Dheeravathu, S. N. and Usha, K. 2010 : Micronutrient deficiency: A global challenge and physiological approaches to improve grain productivity under low zinc availability. In: Plant Stress. Global Science Books, UK, **4**: 76–93.

Singh, K., Dheeravathu, S. N., Ramteke, P. W., Reetu, Dikshit, N. and Vadithe, T. B. 2020 : Effect of salt stress on morpho-physiological traits and green fodder yield of Bajra–Napier hybrids and a trispecific hybrid. *Forage Res*., **46**: 241–247.

Singh, R., Kumar P. and Sharma S. 2019 : Temperature effect on germination and seedling growth of small millets. *Indian J. Plant Physiol.* **24**: 629-635.

Singh, T., Dheeravathu, S. N., Dikshit, N., Manjunatha, N. and Sahay, G. 2021 : Collection and evaluation of genetic diversity in dinanath grass (*Pennisetum pedicellatum* Trin.) for forage yield and leaf blight resistance. *J. Environ. Biol.*, **42**(5): 1355–1362.

Sravanthi, G., Dheeravathu, S. N., Latha, P., Avinash, S., Jacob, J., Vijayakumar, G. and Vadithe, T. B. 2024 : Screening of sorghum germplasm for high temperature stress tolerance at seedling stage. *Forage Res*., **51**(1): 144–149.

Sravanthi, G., Dheeravathu, S. N., Latha, P., Avinash, S., Jacob, J., Vijayakumar, G. and Vadithe, T. B. 2025. Effect of heat stress on sorghum lines at seedling stage. *Forage Res*., **50**(2): 189–196.

Sravanthi, G., Saida naik, V., Gupta, S. K., Shaila, O., Thulasi Bai, V[1]., Madhudeepika, K., Srinivas, A., Venkateshwarulu, D., Mukul Kumar., Jyothi, A., and dheeravathu S.N. 2026 : Forage crops as climate-resilient crops under climate change and potential el niño conditions: A review. *Forage Res*., **52**(1): 1-6.

Sukanya, T.S., Prabhakar, Krishne Gowda, K.T., Swarna, R., Hariprasanna, K. and Tonapi, V.A. 2022 : Good Agronomic Practices for Higher Yield in Small Millets, ICAR - All India Coordinated Research Project on Small Millets, ICAR-Indian Institute of Millets Research, Hyderabad.

Tara Sathyavathi, KBRS, Visarada and Sangappa. 2023 : Global Centre of Excellence on Millets (Shree Anna): A brief profile (2023). pp.1-24.