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Germination characteristics of sorghum (*Sorghum bicolor* L.) affected by temperature variation

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Abstract. Germination was essential in preparation for the subsequent few sorghum growth cycles, but increasing the temperature was a major limiting factor. Temperature change effect, provide information on appropriate sorghum cultivation techniques. Sorghum was the principal cereal grown for food, feed, fodder, starch, fiber, dextrose syrup, biofuels, and bioenergy. This study evaluated the effect of temperature variation on the viability and vigor of sorghum seeds. This research applies Factorial Experiment in Completely Random Design, where the first factor is three genotypes of sorghum Numbu, G1Marapi, and G3Marapi. The second factor was the temperature variation of 18 °C–38 °C. Sorghum seeds were germinated for ten days and placed in the growth chamber. The result showed that every 2 °C temperature increase gives a different response to the germination of sorghum. The optimum temperature for sorghum seed germination was 20 °C–32 °C, with good viability and vigor of > 80%. Root and shoot growth was optimal at 24 °C–28 °C, such as Numbu has a root length of 17.0 cm and shoot length of 18.3 cm at 24 °C, but at 38 °C, no seed germination. However, the morphological mechanisms of sorghum response were a basis for information to get tolerant genotype and maximize utilization of its local germplasm to develop improved cultivars.

Key words: denaturation, germination, high temperature, tolerant, vigor.

INTRODUCTION

Temperature is an abiotic factor that affects plant phenological changes during germination, seed emergence, and vegetative and generative growth. Based on the report of the Intergovernmental Panel on Climate Change (2022), global warming reaching 1.5 °C in the near term (2021–2040) would cause unavoidable increases in multiple climate hazards and risks to ecosystems and humans. High temperature is known to disrupt water for imbibition, ion, and organic solute movement across plant membranes. In addition, the denaturation of enzymes interferes with germination and seedling growth. Temperature is also the primary factor for photosynthesis, but excessive temperatures decline plant leaf photosynthesis and decrease in allocation of dry matter to roots and shoots (Krishnan et al., 2011). However, crop species differ in their tolerance to temperature and drought stress. Although sorghum is generally considered tolerant, drought stress still significantly hampers its productivity and nutritional quality across its major cultivation areas (Abreha et al., 2022). Pannacci & Bartolini (2018) also report sorghum drought tolerance, low N input, and low water supply, allowing it to maintain high yields.

Sorghum is an important cereal crop in the world that has many benefits. Whole grains of sorghum have essential health benefits, such as free radical scavenging activity, which is associated with antimicrobial properties, reduced oxidative stress, and anti-inflammatory and anti-cancer activity (Rao et al., 2018). These compounds in cereals have exhibited several health benefits, such as anti-diabetic, anti-tumorigenic, and anti-atherosclerogenic effects (Miafo et al., 2019). Sorghum can grow in tropical and subtropical semi-arid regions with deficient rainfall, and high temperatures predominate (Hernández et al., 2020). This crop is a short-day C4 plant (Mullet et al., 2012), and its easy adaptability to hot and dry agroecology makes it a climate change-responsive crop. Sorghum is self-pollinated by nature, outcrossing up to 6% depending on the genotype and growing conditions (Hariprasanna & Patil, 2015).

Rao et al. (2014) reported that the primary production constraints that reduce sorghum productivity are abiotic (nutrient and drought stresses, excess water, temperature extremities), biotic (shoot fly, stem borer, head bugs, grain mold, foliar diseases, charcoal rot). Kange et al. (2014) also state that the abiotic factors include inappropriate temperature, humidity, and rain. Higher temperature (35 °C) has been favorable for all stages of rice weevil, and relative humidity (65%) encourages weevil development (Aslam et al., 2017).

Sorghum is a climate-resilient crop that is naturally tolerant to abiotic stresses and can grow on marginal lands with minimum input. On the other hand, the increasing human population and changing climate have given rise to frequent drought spells, and surging temperatures pose a severe threat to global food security. At the same time, identifying yielding high, temperature-tolerant genotypes remains a professional approach to cope with these challenges. This study evaluated the effects of varying temperatures on the viability and vigor of sorghum.

MATERIALS AND METHODS

The study was carried out at Seed Science Technology Laboratory, Faculty of Agriculture, Andalas University, West Sumatera, Indonesia from August until October 2021. This research applies Factorial Experiment in Completely Random Design, where the first factor was three genotypes of sorghum (Fig. 1), and the second factor was temperature variation 18 °C, 20 °C, 22 °C, 24 °C, 26 °C, 28 °C, 30 °C, 32 °C, 34 °C, 36 °C and 38 °C. Each experimental unit consisted of 50 seeds and was repeated three times (90 units) using the paper test method and placed in the grow room under normal light. The F test analyzed the data in 5% and descriptive qualitative data.

Genotypes G1Marapi and G3Marapi were local sorghum explored in Agam Regency, West Sumatera Province, Indonesia, and Numbu was a superior national variety with high adaptabilities to the environment, such as drought.

Figure 1. Morphology sorghum grain of (a) G1Marapi (b) G3Marapi (c) Numbu.

The sorghum seed quality test observes based on seeds germinating after the radicles had emerged to a length of 2 mm on the following formula.

a. Germination Phenology

Observations were made from 1–10 days after germination (ISTA, 2004) by evaluating and measuring the growth of the sprouts. The data shown only observed the germination steps of the Numbu variety and was not compared to other genotypes because it gives the same results.

b. Germination (%)

Germination Test was calculated from the first observation (I) four days after germination and the second observation (II) ten days after germination (ISTA, 2004),Normal seedlings were collected and calculated with the following formula:

$$G = \frac{\sum Seeds\ that\ germinate\ normally\ \ I+II}{\sum All\ seeds\ germinated} \times 100\% \qquad (1)$$

c. First Count Test (%)

First Count Test (FCT) is calculated based on the percentage of regular sprouts on the first count observation (I) four days after they germinated;

$$FCT = \frac{\sum Seed\ germinate\ normally\ count\ I}{\sum All\ seed\ germinated} \times 100\% \qquad (2)$$

d. Root and Shoot Growth Test (cm)

The physiological seed quality approach is carried out by observing the growth of sprouts, such as root and shoot growth, ten days after germination. Root and shoot growth describe seed vigor.

RESULTS AND DISCUSSION

Germination Phenology of Sorghum

Germination, or the plant's initial growth, dramatically determines the plant's survival at the next stage. The phenology and growth stages of sorghum start from germination (Fig. 2). The seed germination process begins with the imbibition process, enzyme reactivation, embryo germination initiation, seedcoat cracking, radicle emergence, and plumule emergence (Kamil, 1986).

For a successful germination, seeds should reach an adequate level of hydration during the imbibition phase, to reactivate the seed metabolic processes and stimulate the growth of embryonic axis. Based on Fig. 2, the emergence of plumula begins two days after germination. On the third day, more than 2 mm of plumule and radicle appeared, meaning germination was successful. The growth and development of sorghum sprouts, such as the appearance of the first leaves, can be seen from the fourth day and fully developed ten days after germination. Plants subjected to severe drought stress require more time to adjust the internal osmotic potential in accordance with the external environment (Abreha et al., 2022).

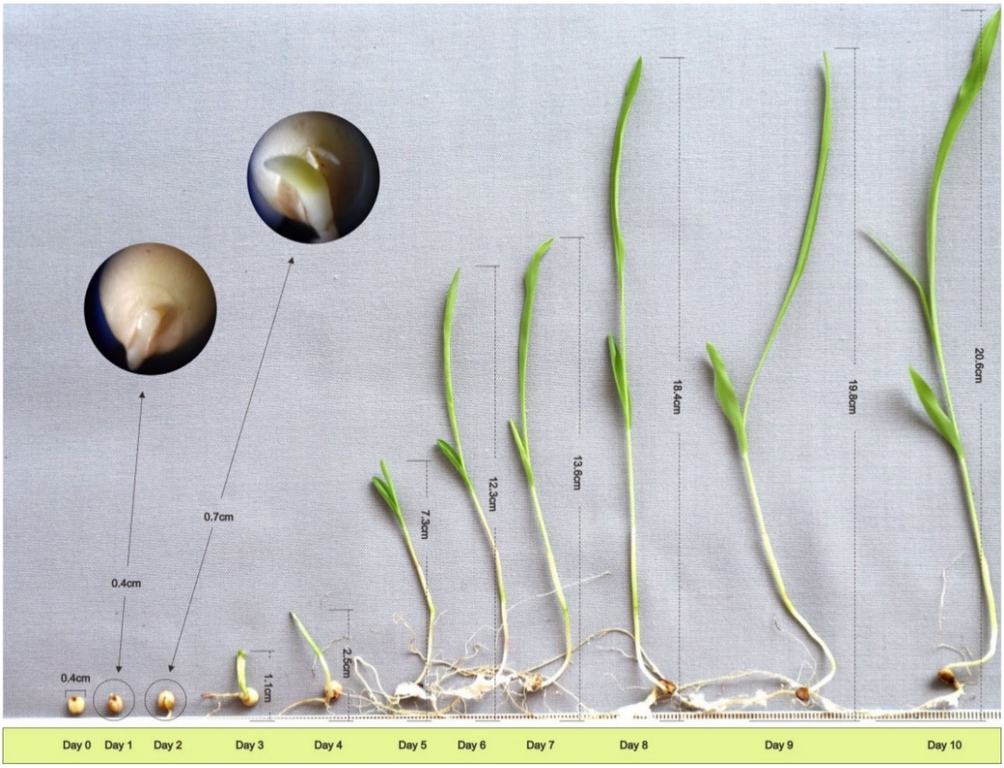

Figure 2. The germination phenology of sorghum varieties Numbu (0–10 Days After Germinating).

Germination and First Count Test (%)

Viability and vigor was necessary to determine seed quality. Germination was an indicator of the viability index, while the first count test indicates the seed vigor index. The difference in genotype also determines the level of tolerance to high-temperature stress, such as the percentage of germination and the first count test (FCT) in Fig. 3 below.

Based on the percentage of normal germination and first count test, the seeds of sorghum Numbu, G1, and G3 Merapi have good viability and vigor (≥ 80%) only at a temperature of 20–32 °C, at a temperature of 18 °C and 38 °C, none of the seeds can germinate. In contrast, Chadalavada et al. (2021) reported that more than 80% of the sorghum seeds germinate at 15 °C. However, Vanderlip (1993) reported that cool temperatures with high humidity favor the growth of disease organisms; at soil temperatures of 20 °C or more, coleoptiles appear above ground after 3–4 days after germinating and last longer if temperatures decrease.

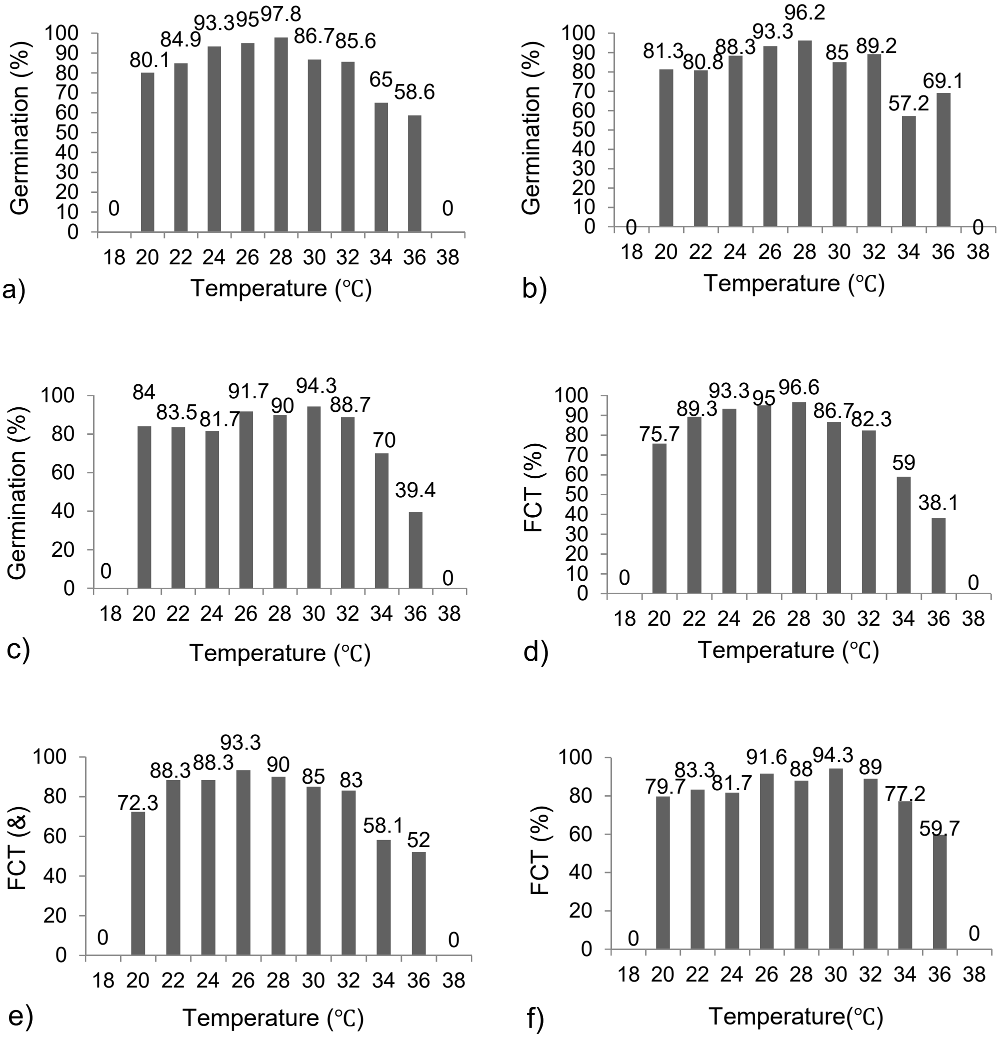

Figure 3. Germination (%) of (a) G1Marapi (b) G3Marapi (c) Numbu and First Count Test (%) of (d) G1Marapi (e) G3Marapi (f) Numbu.

The optimum temperature required for the growth and development of sorghum was 27–30 °C. Growth and yields can be affected beyond 35 °C. It is a short-day plant with a photoperiod requirement of 10–11 h to induce flower formation. Generally, the optimum temperature requirement for sorghum crops was 21–3521–35 °C for germination, 26–34 °C for vegetative growth, and 21–35 °C for reproductive growth (Maiti, 1996). Bartzialis et al. (2020) also explained that the best temperature for sorghum growth is 20–30 °C. However, there is limited information on the availability of resistant sorghum varieties to high temperatures. Sari et al. (2019) reported that the optimum temperature for rice germination was 28–32 °C, and the highest activity of α-amylase was at 40–48 °C but optimum at 48 °C. Mohamed et al. (2009) also reported that on wheat, the α-amylase activity is above 50% at 40–48 °C with the optimal temperature at 50 °C. In contrast, the temperature optima of *Cucurbita pepo* esterases EIc and EII were 40 °C (Fahmy et al., 2008).

The soil emergence test can be identified when the coleoptile is visible at the soil surface, which takes about four days. Furthermore, sorghum emergence will vary depending on the planting depth, soil moisture, temperate conditions, compaction of soil, and seed vigor. The seedling had three fully expanded leaves, and the collar of 3 leaves is visible, which occurred six days after emergence, and the seedling grew to a height of 20 cm. It can be identified by the appearance of the visible collar in all five leaves, continuous visibility of the first leaf with a round tip, and taking 16 days from emergence. The seedling is thus said to be entered into a 'grand period of growth. The plant grew to a 50 cm height (Rao et al*.,* 2014).

Water stress and extreme temperature are two significant forces impacting germination and plants' reproductive phase. Due to the high temperature, there will be a decrease in seed size and glucose concentration and, at the same time increase in sucrose and raffinose concentrations in grain (Chadalavada et al., 2021).

Root and Shoot Grwoth Test

Based on Fig. 4, genotype G1Marapi had root and shoot growth which relatively increased to 24 °C and began to decrease as the temperature rise. Such as the Numbu variety, the growth of roots and shoots surged to 26 °C and declined from 28 °C to 38 °C. Genotype G3 Merapi fluctuates with the highest root (15.3 cm) and shoots (17.3 cm) at a temperature of 28 °C.

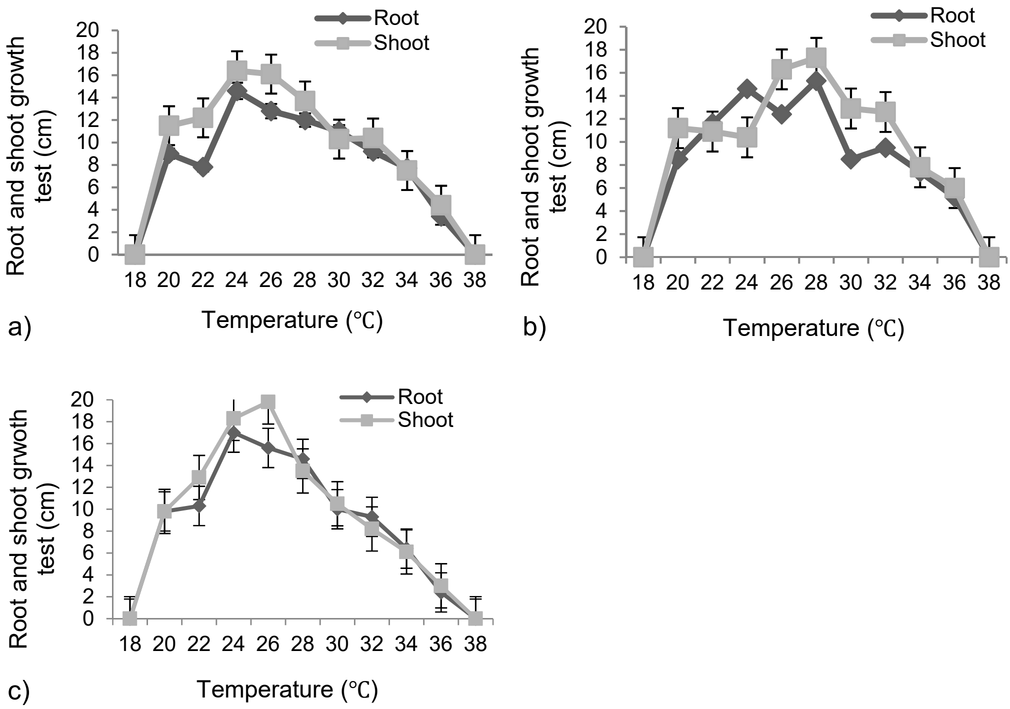

Figure 4. Root and Shooth Growth Test (a) G1Marapi (b) G3Marapi (c) Numbu.

According to Elvira et al. (2015), differences in plant growth are caused by internal influences such as genes and hormones that affect growth through inherited traits. External influences such as nutrients, water, temperature, humidity, and light also affect a plant's characteristics. Taleon et al. (2012) found a strong effect of abiotic stress factors such as light and temperature on the flavonoid content of black sorghum. Heat stress decreases the plant height at maturity, seed set, seed number, and size but does not significantly impact leaf area and dry weight (Chadalavada et al., 2021).

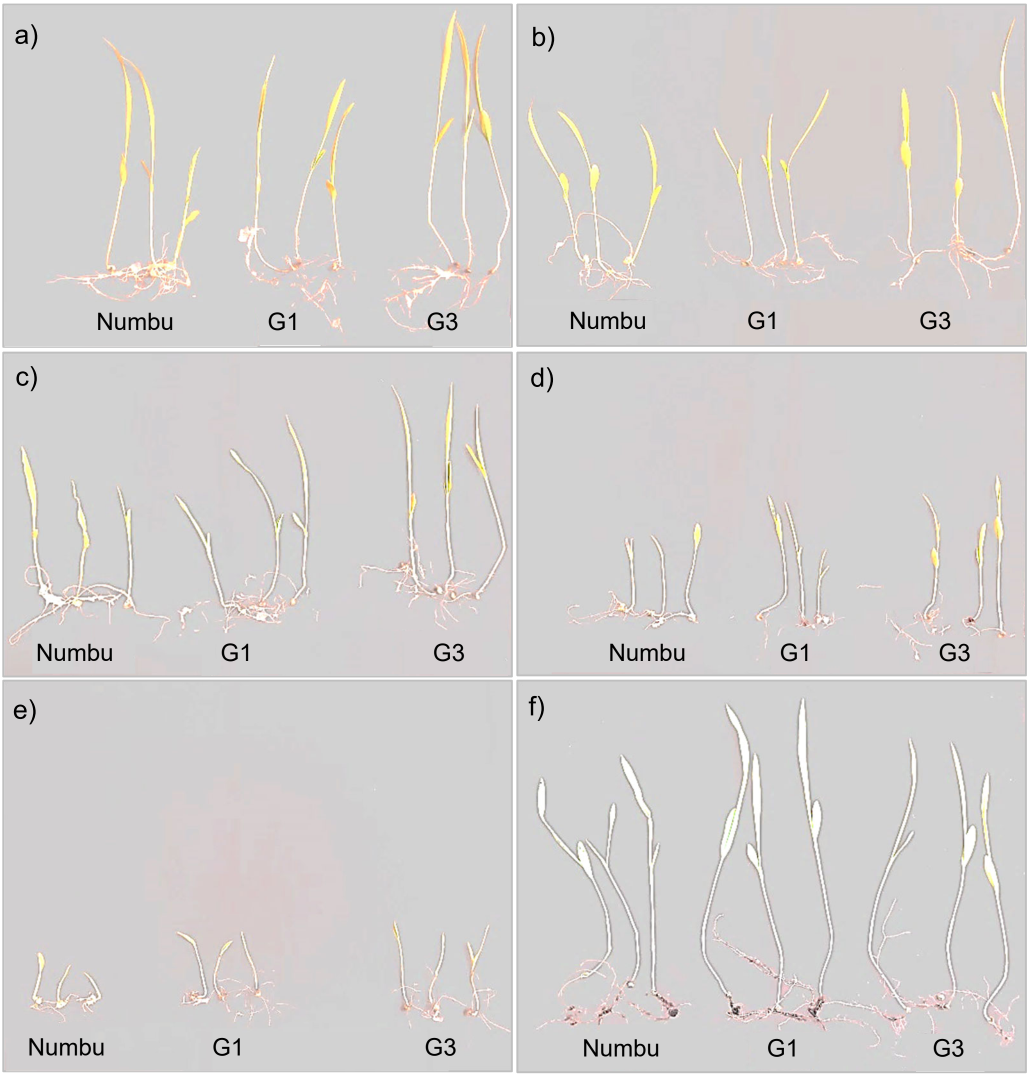

Figure 5. Sprout growth 10 days after seedling (a) 28 °C (b) 30 °C (c) 32 °C (d) 34 °C (e) 36 °C and (f) Soil Emergence Test.

The growth of roots and shoots of sorghum tested was significantly different (Fig. 5). In contrast, the temperature increased beyond the optimum limit, growth decline began to occur, and at 38 °C, no seeds could germinate. If the future temperature increase above 38, this local sorghum not germinate. Kramer et al. (2021) report that extreme conditions may severely disturb several metabolic processes, resulting in diminished photosynthesis, impeding cell enlargement and division, and finally passing on the cells. However, this problem is feared to be further augmented due to climate change. Global warming manifested through rising temperatures can lead to a severe decline in soil moisture-holding capacity.

Crop establishment is an essential prerequisite for successful crop production. It includes optimum germination and vigor seedling growth. Some yield components in sorghum are determined as early as 30 days after germination (Maman et al., 2004; Wrather, 2009). Hence, in addition to fixing the crop stand and reducing weed competition, timely germination and seedling vigor have important agronomic implications (Weerasooriya et al., 2021).

Genotypes should be tested for their temperature tolerance based on phenology, morphology, physiology, and biochemical behavior at different growth stages from germination to maturity (tillering, jointing, booting, anthesis, grain filling, and physiological maturity stages) due to their variable responses. Assembly of new superior varieties, the inheritance of superior traits must be understood to choose the best parents. Kibalnik et al. (2021) explained that understanding the inheritance of agronomic traits is also necessary to create hybrids with given traits. Hybrid sorghum is characterized by superiority over the parent form for productivity and other critical agronomic properties. In this research, some characteristics of West Sumatra local sorghum genotypes were known for assembling new superior varieties.

CONCLUSIONS

The optimum temperature required for germination of sorghum grain Numbu, G1Marapi, and G3Marapi were 20–32 °C, with good viability and vigor above 80%. High temperatures decrease the germination rate and disturb the growth and development of sorghum, such as the root and shoot of sorghum falling by temperature surge and at 38 °C not germinated.

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REFERENCES

Abreha, K.B., Enyew, M., Carlsson, A.S., Vetukuri, R.R., Feyissa, T., Motlhaodi, T., Ng'uni, D & Geleta, M. 2022. Sorghum in dryland: morphological, physiological, and molecular responses of sorghum under drought stress. *Planta* **255**, 20. https://doi.org/10.1007/s00425-021-03799-7

Aslam, A., Jafifir, M., Javen, M.W. & Muhammad, S. 2017. Effect of temperature and relative humidity on development of Sitophilus oryzae (L.). *Journal of entomology and zoology studies* **5**(6), 85–90.

Bartzialis, D., Giannoulis, K.D., Skoufogianni, T., Lavdis, A., Zalaoras, G. Charvalas, G. &. Danalatos, N.G. 2020. Sorghum dry biomass yield for solid bio-fuel production affected by different N-fertilization rates. *Agronomy Research* 1**8**(S2), 1147–1153. https://doi.org/10.15159/AR.20.072

Chadalavada, K., Kumari, B.D.R. & Kumar, T.S. 2021. Sorghum mitigates climate variability and change on crop yield and quality. *Planta* **25**3. 113. https://doi.org/10.1007/s00425-021-03631-2

Elvira, S.D., Yusuf, M. & Mayuslina, M. 2015. Agronomic characteristics of several varieties of sorghum on marginal land in North Aceh. *Jurnal Agrium* **1**2(1), 1–4. https://doi.org/10.29103/agrium.v12i1.371

Fahmy, A.S., Abo-Zeid, A.Z., Mohamed, T.M., Ghanem, H.M., Borai, I.H & Mohamed, S.A. 2008. Characterization of esterases from *Cucurbita pepo* cv. "Eskandrani". Bioresource Technology **99**, 437–443.

Hariprasanna, K. & Patil, J.V., 2015. Sorghum: origin, classifification, biology and improvement. *Sorghum Molecular Breeding,* 3–20. https://doi.org/10.1007/978- 81-322-2422-8_1.

Hernández, P.E., Mónica, L., González, C., Ascacio Valdés, J.A., Dávila-Medina, D., Flores-Nevada, A., Silva, T., Chacón, X.R. & Sepúlveda, L. 2020. Sorghum (Sorghumbicolor L.) as a potential source of bioactive substances and their biological properties. *Critical Reviews in Food Science and Nutrition*. doi: 10.1080/10408398.2020.1852389

Intergovernmental Panel on Climate Change. 2022. Climate change: Impact, adaptation and vulnerability, the woeking group II contribution. Download: https://www.wri.org/insights/ipcc-report-2022-climate-impacts-adaptation-vulnerability#:~:text=The%20IPCC%20estimates%20that%20in,disease%20and%20mental%20health%2 °Challenges.

Kamil, Jurnalis. 1986. *Seed Technology I. Padang*. West Sumatera. Indonesia, 227 pp.

Kange, A.M., Cheruiyot, E.K., Ogendo, J.O., Arama, P.F., Sylvans, O. 2014. Pre- and post harvest factors affecting sorghum production (Sorghum bicolor L. Moench) among smallholder farming communities. *Int. J. Appl. Agric. Res.* **5**(4), 40–47.

Kibalnik, O., Kukoleva, S., Semin D., Efremova, I. & Starchak, V. 2021. Evaluation of the combining ability of CMS lines in crosses with samples of grain sorghum and Sudan grass. *Agronomy Research* **19**(4), 1781–1790.

Kramer, P.J. *Water Relation of Plants*; Academic Press: Orlando, FL, USA, 1983; pp. 342–389. Available online: http://www.sciencedirect.com/science/book/9780124250406

Krishnan, P., Ramakrishnan, B., Reddy, K.R & Reddy, V.R. 2011. High temperature stress effects on rice plant growth and yield. *Advances in Agronomy* **111**, Burlington: Academic Press, 87–206. http://www.elsevier.com/locate/permissionusematerial

Maiti, R.K. 1996. *Sorghum science*. Science Publishers, US: 2nd ed.edition. Lebanon, 368 pp. ISBN-13 : 978-1886106680

Maman, N., Mason, S.C., Lyon, D.J. & Dhungana, P. 2004. Yield components of pearl millet and grain sorghum across environments in the central great plains. *Crop Science* **44**, 2138–2145. https://doi. org/10.2135/cropsci2004.2138

Miafo, AP.T., Koubala, B.B., Kansci, G & Muralikrishna, G. 2019. Free sugars and non-starch polysaccharides–phenolic acid complexes from bran, spent grain and sorghum seeds. *Journal of Cereal Science* **87**, 124–31. doi: 10.1016/j.jcs.2019.02.002

Mohamed, S.A., Al-Malki, A.L. & Kumosani, T.A. 2009. Partial purification and characterization of five á-amylases from a wheat local variety (Balady) during germination. *Australian Journal of Basic and Applied Sciences* **3**(3), 1740–1748.

Mullet, J.E., Klein, R.R. & Klein, P.E., 2012. Sorghum bicolor - an important species for comparative grass genomics and a source of benefificial genes for agriculture. *Current Opinion in Plant Biology-Elsevier* **5**(2), 118–121. https://doi.org/10. 1016/S1369-5266(02)00232-7

Pannacci, E. & Bartolini, S. 2018. Effect of nitrogen fertilization on sorghum for biomass. *Agronomy Research* **16**(5), 2146–2155.
Rao, S.S., Elangovan, M., Umakanth, A.V. & Seetharama, N. 2014. Characterizing phenology of sorghum hybrids in relation to production management for high yields. doi:10.13140/2.1.4841.8246.https://www.researchgate.net/publication/252387831
Rao, S., Santhakumar, A.B., Chinkwo, K.A., Wu, G., Johnson, S.K. & Blanchard, C.L. 2018. Characterization of phenolic compounds and antioxidant activity in sorghum grains. *Journal of Cereal Science* **84**, 103–11. doi: 10.1016/j.jcs.2018.07.013
Sari, A., Anwar, A. & Rozen, N. 2019. Viability and vigor of rice varieties (*Oryza Sativa* L.) in high temperature. *Indonesia Journal of Crop Science* **2**(1), 40–49. https://doi.org/10.25077/jijcs.2.1.33-42.2019
Taleon, V., Dykes, L., Rooney, W.L. & Rooney, L.W. 2012. Efect of genotype and environment on favonoid concentration and profle of black sorghum grains. *J. Cereal Sci.* **56**(2), 470–475.
Vanderlip, R.L. 1993. How a grain sorghum plant develops. Contribution No. 1203. Agronomy Department. Kansas Agricultural Experiment Station. Manhattan 66506. http://www.oznet.ksu.edu.
Weerasooriya, D.K., Bandara, A.Y., Dowell, F & Tesso, T.T. 2021. Growth, agronomic characteristics and nutritional attributes of sorghum (*Sorghum bicolor*) genotypes resistant to ALS inhibitor herbicides. *Plant breeding Wiley*, 1–15. doi: 10.1111/pbr.12935
Wrather, A. 2009. The first 40 days after planting are critical for grain sorghum health. Integrated Pest and Crop Management. https://ipm. missouri.edu/IPCM/archive/2009/v19n8.pdf.