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Understanding the dimensions of guinea grass for its invasiveness, adaptability and persistence

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ABSTRACT

Guinea grass (Panicum maximum) an important forage and pasture crop poses a threat to biodiversity and conservation as it is found to invade and persist in different soil, land types, agroclimatic conditions, soil moisture availability, etc. Though this crop is economically important in the livestock sector, the extreme tolerance for stress, competitive ability, resistance to chemicals, ratooning ability, robustness, morphological adaptation, ecotypes, reproductive nature, etc has led this crop as a pantropical crop. Due to its strong invasiveness and persistence, the economic and ecological impact it causes in the agricultural sector is serious. As the invasiveness and persistence of the guinea grass population have been observed throughout the year at the livestock farm complex, TANUVAS, this paper has been reviewed to understand the strategies that guinea grass possesses for its invasion, adaptation, and persistence.

Keywords: *the livestock sector, the extreme tolerance for stress, competitive ability, resistance to chemicals, ratooning ability, robustness, morphological adaptation, ecotypes, reproductive nature, etc has led this crop as a pantropical crop.*

Introduction

Ecosystems are being altered by various factors such as land use patterns and variable climatic conditions. The vegetation distribution is mainly influenced by climatic conditions at regional and global levels. The major drivers of climate change are changes in temperature and CO_2 concentrations that witnessed a constant change. The agricultural production system is meant to provide food and nutritional security to the population's demand. However, the agricultural system is influenced by climatic conditions (Pannacci*et al*., 2017). The variation in incidence, occurrence, persistence, spread, population dynamics, and life cycle of pests are greatly influenced by agronomic management and climatic variability. The composition, shift, and population dynamics of weeds, a major pest in agricultural production are significantly influenced by cropping system, habit, habitat of the weed species, ecosystems, temperature, humidity, carbon dioxide concentration, etc. Weeds are economically important and considered a major biotic limitation in crop production as they incur huge loss in quantity and quality of crop produce. Different management practices adapted to control/manage weeds lead to weed shift and resistance, yielding the persistence of weeds (Anil Shrestha, 2022). Weed persistence is made possible by the prolific seed production ability, dissemination, seeds in soil bank, and duration of weeds (annual/perennial nature), which are influenced by climate change, microbial communities, seed predation, agronomic practices, allelochemicals and theirtheir ability to evolve successfully (Bagavathiannanand Norsworthy, 2012).

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Furthermore, exotic species that are used for various purposes such as pest management, ornamentals for landscape, forages, etc in due course time, when not managed properly adapt to the agro-climatic conditions dominate the ecosystem, and alter the soil dynamics. Guinea grass (*Panicum maximum*Synon. *Megathyrsusmaximus*) an important fodder crop is found obnoxious when it`s not grown for a specific purpose and in an inaccurate place. Guinea grass, a native of Africa was introduced to India in the early 1930`s for its forage value. Among the various exotic crops introduced, guinea grass has been found as a weed and is widely distributed throughout the tropical world (Wied*et al*. 2020). The infestation with guinea grass in field crops had reported yield loss of up to 40% in field crops (Rhodes *et al*., 2021). The population of this crop remains in the field crops, roadsides, vacant areas, urban places, etc., and persists in the field for a longer duration causing considerable loss to economic produces and ecology. The mechanisms that facilitate the widespread success of introduced species are their competitive abilities, escape mechanism from predators (biotic and abiotic), and production of biochemicals toxic to the native population (Friedel et al., 2011). Hence, this paper attempts to understand the establishment and persistence of guinea grass, influenced by biotic and abiotic factors, so as to enable the purpose of managing invasions.

Morphology of Guinea grass

Perennial plants have broad morphological and agronomic variability (Cook et al., 2005). Guinea grass, C4 perennial, grows in densely tufted clumps with very short rhizomes, erect cylindrical stems, slightly flattened at the base, streaked with white wax at the nodes and internodes, glabrous internodes, hairy nodes, infrequently branched. Plants are tall, usually 1-2 m with light green, green or bluish-green leaves, leaf sheath green with hairy junction, leaf blades linear to narrowly lanceolate, wide in the middle, narrow at the base, acuminate, herbaceous, pilose to pubescent, ligules membranous, serrated leaf margin, with smooth dorsal and serrated ventral surface. Short rhizomes or rooting at the nodes helps in the formation of new plants. Possess a deep root system depending on the -agro-climatic conditions (Gajaweeraet al., 2011). Guinea grass possesses wider adaptability to climatic conditions as indicated by Nawaz et al. (2014). The study conducted under different agro-climatic conditions in India revealed that guinea grass is well adapted to different agro-climatic conditions as the taxonomy, morphology, and physiology of guinea grass have been altered for its adaptation. Panicum sp. exhibited higher fresh biomass and dry biomass (Langer, 1979) due to its growth pattern and morphology (M A Ullahet al., 2006).

Panicles are much-branched effuse, oblong, or pyramidal panicles measuring around 30-45 cm, branching to 18 cm long, whorls at a lower node, alternating above. lax, glossy, long, oblong spikelets (Ecoport, 2009). Pink-coloured stigma, grains 1.5 mm long, and ovate with approximately 1,600,000 per kg. The seed yields are low due to shattering ability and smaller size seeds (Sukhchain and Sidhu, 1992) with a poor germination rate of only 10-20% (Mishra *et al*., 2008). Seed dormancy also varies from 6 months to 3 years, and remains viable for a longer period (Muir and Junk, 2004). Muir and Jank, (2004) reported that less moisture in soil results in increased seed viability. Seeds produced drop over in three weeks likely through birds, mechanical dispersal, or anthropogenic (CABI, 2020).

Guinea grass possesses numerous ecotypes such as Makeuni, Hamil, Colonial, Tobiatumetc resulting in good productivity and persistence (Jack*et al*., 1995). Moreover, naturally evolved is mostly polyploidy apomict with predominant apospory and psuedogamy, producing maternal clones permitting vegetative reproduction through seeds resulting in variable morphology and hence aiding in adaptation to different climatic conditions (Sukhchain, 2010).

Several morphotypes occur in guinea grass, two forms occur sympatrically in populations in the introduced and native range. Both short and tall form occurs. Tall forms occur in moisture lands (>50%) than shorter forms. The morphological differences might be due to hybridization between genotypes (Usberti-Filho*et al*. 2002) or/and facultative to strict apomictic tetraploids and higher ploidy levels (Kaushal*et al*. 2015). Short forms are more invasive due to their leaf form and the nodes in the stolon are found to produce three individuals (Francis and Parrotta, 2006). Seeds of guinea grass germinate well at 19.1-22.9°C, however, possess a positive correlation to biomass production with an increase in temperature explained well with the linear relationship of shoot and root growth (Muir and Jank, 2004), further associated with mycorrhizal fungi, leading to higher phosphorus uptake by plants (Řezáčová*et al*., 2018).

Habitat preference

Guinea grass, a native species of Africa widely introduced due to its forage value both purposively and accidentally at the beginning of the 17th century (CABI 2020), Guinea grass grown in diverse conditions leads to persistent ecotypes across varied climatic conditions, now become a pantropical crop Fig (1) (Jank*et al*. 2014). As a forage crop, introduced in India as early as 1793 and research was carried out for its forage quality (Parsons 1972). However, due to its ecological tolerance and adaptiveness, it has invaded the cultivated area and become an economically important crop due to its economic benefits and the ecological pressure it causes. Leonard and Judd (2006) reported that this crop species borne for rapid expansion on the roads and in the lands that are foraged less.

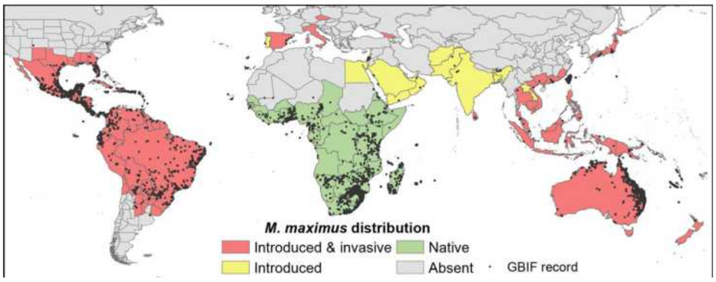

Fig. (1). Distribution and status of M. maximus.(CABI, 2020)

Guinea grass with wide adaptability, adapts to a wide range of environmental conditions, grows well in different soil types ranging from calcareous types to heavy soils. However, requires well-drained soil. Adapted to varied rainfall ranges of 1000 to 3000 mm (Keoghan, *et al*., 1992), 750 mm to 1700 mm as well as frost for a few days (Maciel*et al*. 2018). Further, the dry biomass and fresh biomass of guinea grass are determined by the rainfall amount and soil moisture availability as these possess a direct effect on the number of tillers per plant (Islam and Thakuria 2002, Penelope Holland*et al*., 2022). Though guinea grass is found to tolerate drought for a longer period, if drought persists for more than 4 months results in high mortality rates. Grows in varied ecosystems from savannahs to field crops and plantation crops such as sugarcane, and citrus (Chandramohan*et al*. 2002).

As visualized at the livestock farm complex, TANUVAS, is often found colonizing in the open areas, where soil moisture is favorable, under the storey of the plantation crops, woody perennials, perennial fodder crops, especially with nitrogen fixers like Desmanthus, and grazing lands where foraging is limited. Also acts as a host for various pests and disease-causing organisms. Panicum maximum (*Megathyrsusmaximus*) has been associated with agronomic pests such as *Bipolarisyamadae*, a leaf spot disease infecting sugarcane, serving as a refuge during the otherwise fallow season. In India the species was found to act as a host for a major pest, fall armyworm (*Spodopterafrugiperda*) (Maruthadurai and Ramesh, 2020), that has been observed with guinea grass alongside the roads of the livestock farm complex, TANUVAS.

Influence of Carbon dioxide and temperature

The projection by the Intergovernmental Panel on Climate Change on carbon dioxide concentration and surface temperature is around 600 ppm and 2°C by 2050 (IPCC, 2014). The increase in temperature and availability of carbon dioxide is found to affect crop growth, development, and yield (Streck, 2005). Plant responses have been documented for various species. The response of C3 and C4 plant species is well known as the present-day concentration of CO_2 is below the CO_2 saturation point required for net photosynthesis (Wand *et al*., 1999). The biomass increase in response to elevated CO_2 and temperature is due to its physiological adaptability which can be understood from the anatomical and morphological changes of the plant species (Braz*et al*.,2013). It is found that a rise in temperature stimulates the rate of leaf expansion in C_4 plants resulting in leaf area and biomass (Santos *et al*., 2014). The experimentation with *Panicum maximum* Jacq. 'Mombaça' (C4) grown in field conditions with sufficient water and nutrients to examine the effects of warming and elevated CO_2 concentrations during the winter resulted in expanded leaves with significant improvement in LAR and LER and also had a synergistic effect in accelerating leaf maturation (Britto de Assis Prado *et al*., 2016). The increase in LAR and LER explains the increase in tiller production and its adaptability to higher temperatures and Co_2

concentrations (Da Silva *et al*., 2019). The increase in temperature resulted in a linear relationship with leaf biomass thus indicating changes in the leaf blade anatomy (Batistoti*et al*., 2012).

The increase in leaf nitrogen content has a synergistic effect in relation to leaf maturation and reducing leaf senescence (Rudmann*et al*., 2001). Guinea grass is found to have slighter alterations in the anatomical and morphological traits that make the species adapt to climatic changes (Streck, 2005).

The viability of seeds has been increased under sub-freezing temperatures. The study by Clarence (1986) indicates that the viability and longevity of most of the grasses are not altered and germinate well even when continuously exposed to freezing and sub-freezing temperatures, hence leading to persistence in the soil bank.

a. Guinea grass in Desmanthus field
b. Germination of guinea grass from soil bank
c. Inflorescence with prolific seeds
d. Establishment on roadsides and field bunds

Influence of pH and Electrical conductivity

Guinea grass is found to grow well in a wide pH range, Chew *et al*., 1980 reported that guinea grass grows well in a pH of >8 in Texas, meanwhile with a pH of 5.5-7.7 in Srilanka and 3.0-3.5 in Malaysia. The dry matter yield of guinea grass was equal in cool and rainy seasons and lower in dry seasons when grown in soil pH of 3.68 (Ramírez-Ordoñes*et al*., 2022). Though guinea grass possesses a wide tolerance for pH, the number of tillers and leaves produced was found to fall off with a pH range of > 8 and <4 (Bernardes*et al*., 2018).

Guinea grass tolerates soil salinity well. With moderate salinity in the soil, guinea grass had a simulative effect. It possesses elevated water maintenance ability under salinity stress by reducing transpiration rate thereby increasing water use efficiency, a phenomenon for adaptation (Malaviya*et al*., 2019). It has shown tolerance of salinity up to 11 dS m^{-1} by an exhibition of high hemicellulose levels in plants (Sawen*et al*., 2020), however, photosynthetic performance was reduced.

Influence of Light and Shade

Guinea grass has the ability to compete with native species by establishing dense and tall shading patches on the nearby crops, formation of dense tussocks, and deposition of dense accumulations of leaf litter on the soil surface (Baruch,1996). Hence, dominates the native species richness in unforaged areas and cultivated species (Usuah*et al*., 2013). Also, guinea grass adapts to 25-50% shading (Malaviya*et al*., 2020) with a higher nitrogen accumulation in plants (Paciullo*et al*., 2017). As for personal observation, guinea grass thrives well and persists in crops cultivated with species of Fabaceae family like Desmanthus, sun hemp, and Tephrosia, where the soil available soil nitrogen is found higher.

Influence of Nutrients

Nutrients shift especially nitrogen and phosphorous play an important role in the invasiveness of weed species. The greater litter with a faster decomposition rate of guinea grass alters the soil nutrient availability for its competing nature with the native species (Adebisi, *et al*., 2016). Moreover, it has high nitrogen demand and is highly competitive in nitrogen-rich soils producing higher biomass than the co-occurring native species resulting in higher nitrogen content in plants, also alters the soil chemistry, and pH and solubilises the nutrients (Zhou *et al*., 2019). The study conducted at livestock farm complex implies that guinea grass was found to exploit nitrogen from soil and visible from its robust growth and higher nitrogen content in guinea grass leaves collected from cumbunapier hybrid grass and desmanthus fields, in accordance with the findings of Pickett *et al*., (2019). The uptake of nutrients by guinea grass creates nutrient deficiency in the adjoining plants by altering soil chemistry (Hans Lambers*et al*., 2008). The leaf litter rich in malate, and citrate increases phosphorous availability creating a favorable environment for the extension of guinea grass overcasting native species (Belnap and Sherrod, 2008). With a symbiotic relationship with microbes and nutrients, the macronutrient uptake is enhanced from the recalcitrant soil zone (Almeida and Danilo*et al*., 2020). This helps in scavenging and mining nutrients through litter decomposition at a faster rate and aids in persistence (Rocha *et al*., 2020).

Allelopathy effect of guinea grass

The allelopathic potential of the crops is one other important characteristic to outnumbering the native species, richness and altering the weed shift, proliferating successfully in the cultivated environment by forming dense tussocks (Pyšek*et al*., 2020). Either simulative or inhibitive chemicals have been found to be produced by the species of the Poaceae family. *Panicum maximum* has been classified as a species with allelopathic potential (**Carvalho et al., 2006**) with an autointoxication mechanism reducing the yield in the second crop. One allelochemical found was 2-hydroxyphenyl acetic acid, a phenolic compound that inhibits growth and avoids competition with several species such as rice, Fabaceae crops such as alfalfa (Zubair*et al*.,2017), considered to be a destructive weed species in most of the crops such as maize, sugarcane, alfalfa, Desmanthus, plantations, etc. (Silva *et al*., 2018)

Influence of Drought

Guinea grass is a species, widely distributed in tropical and sub-tropical areas with seasonal variation in rainfall, and different soil ranges and produces profusely or sparsely depending on the season. Responds well to irrigation and rainfall during summer and spring seasons. (de Jesus *et al*., 2021). As it is widely distributed in varied ranges, water stress has resulted in reduced leaf elongation, biomass, growth, and other morphological traits (Klar*et al*., 1978). Water stress caused at vegetative and reproductive stages decreases the net photosynthetic rate to zero for its adaptation (Gonzalez and Páez, 1996), and delays stem elongation and flowering (Hussain *et al*., 2020). Leaf water potential and relative water contents were at lower levels when the plants were stressed (Páez*et al*., 1995).

Leaf size, and stomatal conductance i.e. physiological and morphological traits vary with the level of stress, increase the stomatal resistance to decrease the transpiration rate, and preserve membrane stability (Silva *et al.,* 2018). Furthermore, the presence of strong root systems and clumps presents high adaptation to the varied edaphoclimatic conditions. Proline, accumulation is visible in stressed plants, an indicator of stress tolerance, coping with drought stress (Andres Eduardo Moreno-Galván*et al*., 2020). A shorter period of drought is not found to affect survivability (Borjas-Ventura *et al*., 2019). Though water stress causes herbage reduction, it has a more efficient use of water reason out for more tolerance to drought stress (Purbajanti*et al*., 2012).

Influence of Waterlogging

The duration of waterlogging has a significant impact on grass growth. Guinea grass possesses medium tolerance to water logging for about 20 days with 50% of mortality exhibiting negative effects of root function to waterlogging (Hare *et al*., 2004). SuphaphanPhengpet*et al*., (2016) reported that repeated waterlogging with a recovery period caused yellowish and dried-out leaves, and stimulated the production of adventitious roots, new leaves, and new shoots. Waterlogging once with a recovery period seemed to not harm grasses, but repeated waterlogging with a recovery period seemed to result in reduced total dry weight.

Forage management

Guinea grass, a forage plant is highly recommended for pasture, preservation as silage and hay, and for cut and carry system (Gurgel*et al*., 2020). Guinea grass exhibits a high diversity of forage yield with varied quality (Hare *et al*., 2014). The reproductive inductive photoperiods and low temperatures influence the seasonal growth of guinea grass which reflects on the dry matter production (**Taiz*et al*., 2015**). However, the partitioning of sugars causes internode elongation, and seed production, and reduces leaf stem ratio thereby lowering the quality of forage and the fed intake rate by animals (**Giacomini *et al*., 2009**). However, the yield and quality of guinea grass for forage are dependent on the climatic conditions, soil rhizosphere, and the associated crops. Understanding the correlation between climatic conditions and dry matter production can be highly useful for knowing the peak availability of guinea grass forage for feeding livestock (Pezzopane*et al*., 2014).

Conclusion

Various kinds of literature reviews indicate that guinea grass is a widely distributed, invasive, and persistent species, mediated by prolific seed production, anthropologic dispersal, introduction effort of this species, creating a competitive edge over native species. These are found to reduce the function of the ecosystem and resilience. Rainfall patterns, variation, increased temperatures, carbon dioxide concentration, soil moisture, nutrient availability, etc as a result of climate change, influence the distribution of *Panicum maximum.* Also irrigated fields, and associated crops also increase invasiveness due to the changes in soil chemistry. Hence, understanding the reason for invasiveness can help in early prediction and application of management practices in order to contain the invasiveness of guinea grass, otherwise an economically important forage crop.

References

1. Aaron C, Rhodes, Robert M, Plowes, John A, Goolsby, John F Gaskin, Boaz Musyoka (2021) The dilemma of Guinea grass (Megathyrsusmaximus): a valued pasture grass and a highly invasive species. Biological Invasions 23: 3653-3669.

2. Adebisi, I.A, Ajibike, AB, Muraina, TO, Alalade, JA, Oladepo, O. (2016). Performance and Nutrient Digestibility of West African Dwarf goats fed *Panicum maximum* supplemented with *Gmelinaarborea* leaves mixture. *Niger. J. Anim. Sci.,* 18, 518–524.

3. Almeida, Danilo S. (2020). Exudation of Organic Acid Anions by Tropical Grasses in Response to Low Phosphorus Availability." Scientific Reports,10 (1), 1-8.

4. Anil Shrestha, David R Clements, Mahesh K Upadhyaya (2022) Persistence Strategies of Weeds. Book Editor(s): Mahesh K. Upadhyaya, David R. Clements, Anil Shrestha Applied Soil Ecology: 167, 104039.

5. Bagavathiannan M V, Norsworthy, JK (2012) Late-season seed production in arable weed communities management implications. Weed Science 60: 325 - 334.

6. Baruch, Z (1996).Ecophysiological aspects of the invasion by African grasses and their impact on biodiversity and function of neotropicalsavannas Biodiversity and savanna ecosystem processes. Springer, Berlin, pp 79–93.

7. Belnap, Jayne, and Susan K. Sherrod. (2008). Soil Amendment Effects on the Exotic Annual Grass Bromus Tectorum L. and Facilitation of its Growth by the Native Perennial GrassHilariaJamesii (Torr.) Benth. Herbaceous Plant Ecology. Springer.

8. biomassand specific surface and soil compaction undera rotational

9. BonoJAM,MacedoMCM,EuclidesVBP. 2000. Root system

10. Borjas-Ventura R, Alves LR, de Oliveira R, Martínez CA, Gratão PL (2019) Impacts of warming and water deficit on antioxidant responses in *Panicum maximum* Jacq. Physiol Plant.

11. Braz, TGDS, Fonseca, DMD, Jank, L, Resende, MDVD, Martuscello, JA, Simeão, RM. (2013). Genetic parameters of agronomic characters in *Panicum maximum* hybrids. Rev. Bras. Zootec. 42 (4), 231–237.

12. CABI,Megathyrsusmaximus (Guinea grass). Cited on 2020. Available from: https:// www.cabi.org/isc/datasheet/ 38666.

13. Carvalho, D, Irving, Louis, Carnevalli, Roberta Hodgson, J, Matthew, C. (2006). Distribution of current photosynthate in two Guinea grass (*Panicum maximum* Jacq.) cultivars. Journal of experimental botany. 57. 2015-24.

14. Chandramohan S, Charudattan R, Sonoda RM (2002) Field evaluation of a fungal pathogen mixture for the control of seven weedy grasses. Weed Sci 50:204–213

15. Chou CH (1980) Allelopathic researches in the subtropical vegetation in Taiwan. Comp PhysiolEcol 5: 222–234.

16. Clarence M Rincke (1986) Germination of grass seeds after 8 years of weekly removal from subfreezing storage. Crop Science 26 (1): 165-166.

17. Cook BG, Pengelly BC, Brown SD (2005) Tropical Forages: an interactive selection tool.

18. Da Silva, SC. Bueno, AAO, Carnevalli, RA. Silva, GP, Chiavegato, MB. (2019). Nutritive value and morphological characteristics of Mombaça grass managed with different rotational grazing strategies. *J. Agric. Sci. 157*, 592–598.

19. de Jesus FLF, Sanches AC, de Souza, DP, Mendonça FC, Gomes EP, Santos, RC, Santos JEO, da Silva JLB (2021) Seasonality of biomass production of irrigated Mombaça 'Guinea grass'. ActaAgricScand Sect B Soil Plant Sci: 1–9.

20. Ecoport (2009) Ecoport database. Available from Ecoport https://www.feedipedia.org/node/1635

21. Francis JK, Parrotta JA (2006). Vegetation response to grazing and planting of Leucaenaleucocephala in a Urochloa maximum-dominated grassland in Puerto Rico. Carib J Sci 42(1):67–74.

22. Friedel MH, Grice AC, Marshall NA (2011). Reducing contention amongst organisations dealing with commercially valuable but invasive plants: The case of buffel grass. Environ Sci Policy 14:1205–1218.

23. Gajaweera CJ, Weerasinghe B, Seresinhe T (2011) Preliminary study on the adaptation of wild Guinea grass (*Panicum maximum*) to different agro-climatic regions in Hambanthota District. Proceedings of International Forestry and Environment 332 Symposium: 16.

24. Giacomini AA, Silva SC, Sarmento DOL, Zeferino CV, Souza Júnior SJ, Trindade JK, Guarda VA, NascimentoJúnior D (2009) Growth of marandupalisadegrass subjected to strategies of intermittent stocking. Scientia Agricola 66: 733-741.

25. Gonzalez ME, Páez A (1996) Effect of water deficit applied at different growth stages of *Panicum maximum* Jacq. RevistaFacultadAgronomía Universidad Zulia 13: 79-93.

26. grazing system of Panicum maximum, Jacq. pastures. Reunia

27. Gurgel ALC, Difante GDS, De Araujo AR, Montagner DB, Euclides VPB, Da Silva MGP (2020) Carbon and Nitrogen Stocks and Soil Quality in an Area Cultivated with Guinea Grass under the Residual Effect of Nitrogen Doses. Sustainability 12: 9381.

28. Hans Lambers, John A Raven, Gaius R Shaver, Sally E Smith (2008) Plant nutrient-acquisition strategies change with soil age. Trends EcolEvol 23(2):95-103.Hare

29. M D, Saengkham M, PattarapornTatsapong, Wongpichet K (2004) Waterlogging tolerance of some tropical pasture grasses. Tropical Grasslands 38(4): 227-233.

30. Hare MD, Phengphet S, Songsiri T Sutin N (2014) Botanical and agronomic growth of two *Panicum maximum* cultivars, Mombasa and Tanzania, at varying sowing rates. Trop. Grasslands-Forrajes Trop 2: 246–253.

31. Hussain T, Koyro HW, Zhang W, Liu X, Gul B, Liu, X (2020). Low Salinity Improves Photosynthetic Performance in *Panicumantidotale* Under Drought Stress. FrontPlant Sci 11: 481.

32. IPCC, (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

33. Islam M, Thakuria K (2002) Seasonal variation in green fodder production of important perennial grasses and legumes intercropping system. J Agric Sci. Soc. North East India 15:192–195

34. Jank L (1995) Melhoramento e seleção de variedades de *Panicum maximum*. In *Proc 12 thSimposioSobreManejo da Pastagem*; FEALQ: Piracicaba, Brazil: 21–58

35. Jank L, Barrios SC, Do Valle CB (2014). The value of improved pastures to Brazilian beef production. Crop Pasture Sci 65:1132–1137.

36. Kaushal P, Dwivedi KK, Radhakrishna A (2018) Ploidy dependent expression of apomixis and its components in guinea grass (*Panicum maximum* Jacq) Euphytica 214:152

37. Kaushal P, Paul S, Saxena S (2015). Generating higher ploidies (7x and 11x) in guinea grass (Panicum maximum Jacq.) utilizing reproductive diversity and uncoupled apomixis components. CurrSci 109:1392–1395.

38. Klar AE, UsbertiJAJr, Henderson DW (1978). Differential Responses of Guinea Grass Populations to Drought Stress Crop Sci 18: 853–857.

39. Langer RHM (1979). Tillering. In R. H. M. Langer (Ed.), How grasses grow: 19–25. Edward Arnold.Longet al (2004).

40. Lonard RI, Judd FW. (2006) Notes on invasive plants in the Rio Grande Delta of Cameron County, Texas. Tex J Sci 58:271–277.

41. Malaviya DR, Roy AK, Kaushal P (2020) Comparative leaf anatomical studies reveal photosynthetic pathways type in guinea grass (*Panicum maximum* Jacq.) accessions and their interspecific lineage. Current science 119(5): 808.

42. Malaviya DR, Roy AK, Anand A, Choubey RN, Baig MJ, Dwivedi K, Kushwaha N, Kaushal P (2019) Salinity tolerance of *Panicum maximum* genotypes for germination and seedling growth. Range Manag. Agrofor. 40: 227-235.

43. Maruthadurai R, Ramesh R (2020) Occurrence, damage pattern and biology of fall armyworm, Spodopterafrugiperda (JE smith) (Lepidoptera: Noctuidae) on fodder crops and green amaranth in Goa, India. Phytoparasitica, 48(1): 15-23.

44. Mishra S, Sharma S, Vasudevan P (2008) Comparative effect of bio fertilizers on fodder production and quality in guinea grass (*Panicum maximum* Jacq.). Journal of the science of food and agriculture 88(9): 1667-1673.

45. Muhammad Arshad Ullah, Abdul Razzaq, Rashid Saleem (2006) Performance of Various Forage Grasses Under Spring and Monsoon Seasons at Pothowar Plateau (Pakistan). International journal of agriculture & biology. 1560–8530/08–3–398–401 http://www.fspublishers.org

46. Muir JP, Jank L (2004) Guinea grass. Warm season (C4) grasses 45: 589-621.

47. Nawaz, A., Farooq, M, Cheema, S, Cheema, Z. (2014). Role of Allelopathy in Weed Management. In: Chauhan, B., Mahajan, G. (Eds.) Recent Advances in Weed Management. Springer, New York, NY.

48. Paciullo D, Gomide CDM, Castro CD, Maurício RM, Fernandes PB, Morenz M (2017) Morphogenesis, biomass, and nutritive value of Panicum maximum under different shade levels and fertilizer nitrogen rates. Grass and Forage Science 72(3): 590-600.

49. Paciullo DSC, P Ires MFA, A Roeira LJM, Morenz MJF, M Auricio RM, G Omide CAM (2014) Sward characteristics and performance of dairycows in organic grass-legume pastures shaded bytropical trees. Animal 8: 1264-1271.

50. Páez A, González, OME, Yrausquín X, Salazar A, Casanova A (1995). Water stress and clipping management effects on guinea grass: I. Growth and biomass allocation. Agron J 87: 698–706.

51. Pannacci E, Lattanzi B, Tei F (2017) Non-chemical weed management strategies in minor crops. A review Crop Prot 96: 44–58

52. Penelope Holland E, Vanessa Thomas, PushpaSoti (2022). Low soil nitrogen and moisture limit the expansion of the invasive grass, *Megathyrsusmaximus* (Guinea grass) in semi-arid soils,Journal of Arid Environments,Volume 204, 104788.

53. Pezzopane JR, Cruz PG, Santos PM, Bosi C, Araujo LC (2014). Simple agrometeorological models for estimating Guinea grass yield in Southeast Brazil. International Journal of Biometeorology 58: 1479-1487.

54. Purbajanti ED, Anwar S, Wydiati, Kusmiyati F (2012) Drought stress effect on morphology characters, water use efficiency, growth and yield of guinea and napier grasses. International Research Journal of Plant Science (ISSN: 2141-5447) 3(4): 47-53.

55. Pyšek P, Pergl J, Van Kleunen M (2020) South Africa as a donor of naturalized and invasive plants to other parts of the world. BW van Wilgen, J Measey, DM Richardson, JR Wilson, TA Zengeya (Eds.), Biological Invasions in South Africa, Springer, Berlin: 755-782

56. Řezáčová, V, Slavíková, R., Zemková, L, Konvalinková, T, Procházková, V, Šťovíček, V,Hršelová, H, Beskid, O, Hujslová, M. and Gryndlerová, H. (2018). Mycorrhizalsymbiosis induces plant carbon reallocation differently in C3 and C4 Panicum grasses. Plant and Soil, 425(1), pp. 441-456.

57. Rocha, KF, Kuramae, E, Borges, BMF, Leite, MFA, Rosolem, CA. (2020). Microbial Ncycling gene abundance is affected by cover crop specie and development stage in an integrated cropping system. Archives of Microbiology, 202(7), 2005–2012.

58. Rudmann SG, Milham PJ, Conroy JP. 2001. Influence of high CO_2 partial pressure on nitrogen use efficiency of the C4 grasses *Panicumcoloratum* and *Cenchrusciliaris*. Ann Bot 88: 571–577.

59. Santos PM, Voltolini TV, Cavalcante ACR, Pezzopane JRM, Moura MSB and Silva TGF. 2011.Global climatic changes and animal production: future scenarios for the Brazilian tropical semiarid. Rev Bras GeogrFis. 2011; 4, 1176–1196.

60. Sawen D, Lekitoo MN, Kayadoe M, Yoku O, Djunaedi M (2020) Response ProduksiRumput Gajah (*Pennisetum purpureum*), Benggala (*Panicum maximum*) danSetaria (*Setariaspacelata*) terhadapPerbedaanSalinitas. JurnalRisetAgribisnis Dan Peternakan 5: 20–29.

61. Silva ACJr, Goncalves CG, Scarano MC, Pereira MRR, Martins D (2018) Effect of glyphosate on guineagrass submitted to different soil water potential. Planta Daninha: 36.

62. Streck NA (2005). Climate change and agroecosystems: the effect of elevated atmospheric CO_2 and temperature on crop growth, development, and yield. Ciência Rural 35: 730–740.

63. Sukhchain S (2010) Breeding Guinea grass—a review. Range Manag Agroforest 31:109–115

64. SuphaphanPhengpet, Michael Hare, SuwatTerapongtanakorn, KittiWongpichetKhon (2016) Effect of waterlogging on morphological changes and growth of six forage grasses. Kaen AGR J 44 (2): 363-372.

65. Taiz L. Zeiger E, Moller IM, Murphy A (2015). Plant Physiology and Development. Sinauer, Sunderland, MA, USA.

66. Usberti-Filho JA, Usberti R, Paterniani RS (2002). Differential vegetative and reproductive performances among fifteen guinea grass hybrids. PesqAgropBrasileira 37:139–143

67. Usuah, PE, Udom, GM, Edem.ID (2013). Allelopathic effect of some weeds on the germination of seeds of selected crops grown in AkwaIbom State, Nigeria. World Journal of Agricultural Research 1: 59–64.

68. Wand SJE, Midgley GF, Jones MH, Curtis PS (1999) Responses of wild C4 and C3 grass (Poaceae) species to elevated atmospheric CO_2 concentration: a meta-analytic test of current theories and perceptions. Glob Chang Biol 5: 723–741.

69. Wied JP, Perotto-Baldivieso HL, Conkey AAT, Brennan LA, Mata JM (2020) Invasive grasses in South Texas rangelands: historical perspectives and future directions. Invasive Plant SciManag 13: 41–58. doi: 10.1017/ inp.2020.11

70. Zhou S, Chen J, Lai Y, Yin G, Chen P, Pennerman KK, Yan H, Wu B, Zhang H, Yi X, Wang C, Fu M, Zhang X, Huang L, Ma X, Peng Y, Yan Y, Nie G, Liu L (2019) Integrative analysis of metabolome and transcriptome reveals anthocyanins biosynthesis regulation in grass species *Pennisetum purpureum*. Industrial Crops and Products 138: 111470

71. Zubair HM, Pratley JE, SandralGA, Humphries A (2017) Allelopathic Interference of Alfalfa (*Medicagosativa* L.) Genotypes to Annual Ryegrass (*Loliumrigidum*). Journal of Plant Research 130: 647-58.

