

Review Article

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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 CO₂ 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 (Pannacciet *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 their ability to evolve successfully (Bagavathiannan and Norsworthy, 2012).

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DOI: <https://doi.org/10.21276/AATCCReview.2024.12.04.159>

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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. *Megathyrus maximus*) 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 (Wiedet *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 (Gajaweera et 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 Ullah et 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 (Jacket 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 (Kausha 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.

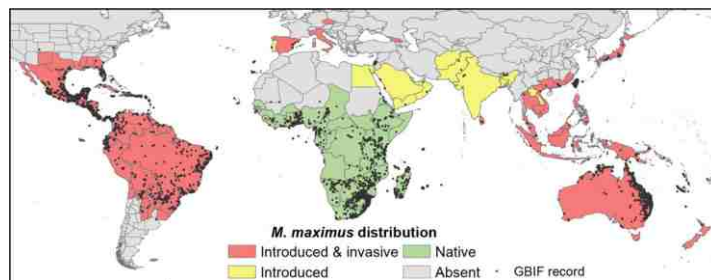


Fig. (1). Distribution and status of *M. maximum*. (CABI, 2020)

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 (Macielet 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* (*Megathyrus maximus*) has been associated with agronomic pests such as *Bipolaris yamadae*, 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 (*Spodoptera frugiperda*) (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 CO₂ is below the CO₂ saturation point required for net photosynthesis (Wand et al., 1999). The biomass increase in response to elevated CO₂ and temperature is due to its physiological adaptability which can be understood from the anatomical and morphological changes of the plant species (Brazet et al., 2013). It is found that a rise in temperature stimulates the rate of leaf expansion in C₄ 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 CO₂ 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 CO₂.

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 (Batistotiet *et al.*, 2012).

The increase in leaf nitrogen content has a synergistic effect in relation to leaf maturation and reducing leaf senescence (Rudmannet *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-Ordoñez *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 stimulative 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 (Sawenet *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 unforged areas and cultivated species (Usuahet *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 Lamberset *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 stimulative 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 (Klaret *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 (Purbajantiet *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). SuphaphanPhengpetet *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 (Gurgelet *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 (Taizet *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.

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