Chapter

Underutilized Grasses Production: New Evolving Perspectives

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Abstract

Globally, over-reliance on major food crops (wheat, rice and maize) has led to food basket's shrinking, while climate change, environmental pollution and deteriorating soil fertility demand the cultivation of less exhaustive but nutritious grasses. Unlike neglected grasses (grass species restricted to their centres of origin and only grown at the subsistence level), many underutilized grasses (grass species whose yield or usability potential remains unrealized) are resistant and resilient to abiotic stresses and have multiple uses including food (*Coix lacryma-jobi*), feed (*Eragrostis amabilis* and *Cynodon dactylon*), esthetic value (*Miscanthus sinensis* and *Imperata cylindrica*), renewable energy production (*Spartina pectinata* and *Andropogon gerardii Vitman*) and contribution to ecosystem services (*Saccharum spontaneum*). Lack of agricultural market globalization, urbanization and prevalence of large commercial enterprises that favor major grasses trade, improved communication means that promoted specialization in favor of established crops, scant planting material of underutilized grasses and fewer research on their production technology and products development are the prime challenges posed to underutilized grasses promotion. Integration of agronomic research with novel plant protection measures and plant breeding and molecular genetics approaches for developing biotic and abiotic stresses tolerant cultivars along with the development of commercially attractive food products hold the future key for promoting underutilized grasses for supplanting food security and sustainably multiplying economic outcomes.

Keywords: agronomy and food sciences, plant protection and breeding, new crops, entomology, plant pathology

1. Introduction

Grasses biodiversity constitutes one of the critical primary sources for securing sustainable supplies of food, feed, fiber, medicines, aromatic stuffs and shelter [1–3]. Globally, humans have put to use a very limited number (less than one-third) of plant species from the recognized pool of species which diversified generations of varying cultures have been aware of for multiple uses. The origins and regions of diversification for numerous underutilized grasses have been investigated recently, but information pertaining to genetic diversity and agro-botanical traits of many species having local pertinence has remained scant. One of the underlying reasons for over-focussed staple crops might be attributed to overwhelming reliance on prime food crops which has led to food basket's shrinking across the globe [4, 5]. This phenomenon finds its roots in the simplification and intensification of agricultural production systems. These have historically favored major grasses over others owing to their comparative and competitive advantages regarding successful production in a wider range of pedo-climatic conditions, feasible cultivation requirements, grower-friendly processing, economical storability, unmatched nutritional properties, high market demand, superior revenue generation and preferable taste [6–8].

It is also pertinent to mention that the simplification process of agricultural production systems has abruptly lowered the quality of agricultural produces over time. However, this approach has reduced the risks of complete crop failure and multiplied successful harvests opportunities. This in turn has boosted survival human's survival through limited but sufficiently produced yields by major grasses. The commercial-oriented farming systems focussing major grasses have caused serious decline in intra and interspecific diversity of crops. In addition, other disadvantages of over-emphasis on major grasses include higher vulnerability among growers and end-users, for whom grasses diversity have become survival necessity rather than a matter of choice due to changing climate and crop failures owing to a bunch of biotic and abiotic stresses [9, 10].

2. What are underutilized grasses?

Among agriculture terminologies, perhaps underutilized term has given rise to wider discussions and debates since long. It is normally applied to grass species whose yield or usability potential remains unrealized. However, this definition might be declared inconclusive owing to missing information regarding underutilization in what sort of geographical regions, cultures and economic feasibilities. Thus, using this term inevitably needs a clarification to explicitly describe the exact meanings and applicability of the term. For instance, with respect to geographical implications of the term, a grass species might be underutilized in some regions compared to others. Regarding economic applicability, some grass species might constitute as vital component of masses daily diet, but these may largely remain underutilized in other regions owing to poor marketing conditions and lower economic turnout for growers. As far as time factor is concerned, dynamic marketing systems might improve the degree of underuse due to vigorous attention in few regions while the same species could continue to witness poor marketing owing to lesser attention of growers and researchers in some regions. For example, hulled wheat which represents the collective name of *Triticum monococcum*, *Triticum dicoccum* and *Triticum spelta* has attained the status of a speciality crop in Italy along with many other European countries, whereby numerous ex situ and in situ techniques for its conservation are being developed through integrated research efforts. However, the same grass constitutes the status of a life support crop in Turkey's remote areas. Few underutilized grasses are being marketed as new crops. However, the fact is that different commercial companies and researchers have recently started working on them for boosting their productivity and nutritional value. The reality is that local populations have used underutilized grass species for generations while these remained unattended historically. It is worth mentioning that locally based knowledge and traditional uses of underutilized grasses at limited scale have contributed to portray such underutilized grasses as new crops [1, 4, 11].

3. Differentiation of underutilized and neglected grasses

The underutilized grasses might be defined as grasses that were traditionally grown widely in localized production systems but now their cultivation and use have seriously decline owing to cultural, genetic, agronomic, climatic, economics, globalization and market related factors. Their cultivation and consumption have reduced significantly for their being non-competitive with staple grasses in the same agro-environmental conditions. The net result is the eroding of the grass genetic pool which has narrowed down the choice of crops for improvement as well as adaptation under changing climatic scenarios.

Contrastingly, neglected grasses tend to remain restricted in their centres of origin and are primarily grown by local farmers at the subsistence level. It may be noted that few grass species could be globally; however, tend to prevail in few special niches within local ecology and traditional agricultural systems. Thus, these types of grasses have continued to be grown on limited scale under socio-cultural choices, however these have remained inadequately characterized and historically neglected by researchers, agronomists and conservationists [12].

4. Agro-botanical superiority and multipurpose utilization of underutilized grasses

Many of underutilized grasses have been recognized to be resilient to numerous abiotic stresses including heat stress, drought, water logging, salinity, heavy metal toxicity etc. These also offer multiple uses including food, renewable fuel, feed, fiber and contributions to ecosystem services. A variety of underutilized grasses including reed canary grass (*Phalaris arundinacea* L.), miscanthus (Miscanthus × giganteus Greef et Deuter), giant reed (*Arundo donax* L.), switchgrass (*Panicum virgatum* L.) etc. have the potential to serve as an excellent raw material source for modern biorefineries for producing numerous high-added value products including nutrient supplements, biopharmaceuticals, biopolymers, biomaterials for mulching, building infrastructure, phonic insulating, biodegradable products for utilization in animal bedding and gardening, energy carriers including advanced biofuels, many by-products including green chemistry products and soil organic fertilizers, along with a bunch of ecosystem services such as soil erosion and degradation protection, C-sequestration, restoration and preservation degraded and contaminated soils. It has indicated that underutilized grasses have the potential to thrive well under variable agro-environmental conditions including degraded and marginal lands without being in competition with food crops. Besides higher environmental sustainability, bio-energy potential has also been recognized as a plus point of underutilized perennial grasses which are established once and provide harvest on a yearly basis over a period of 10–25 years resulting in greenhouse gas balances. The lignocellulosic structure of grass cell walls constitutes one of the critical sustainability characteristics which impart natural resistance against various pests and diseases [13].

Additionally, grasses tend to have higher resource-use efficiency for having C-4 photosynthetic pathway which is characterized by substantially higher solar radiation capture and moisture utilization, along with being lesser nutrient demanding and have potential to conserve nutrients in underground roots during harsh climatic conditions like chilling temperatures during winters. Furthermore, many underutilized grasses by virtue of their vigorous biomass production add crop residues to the soil due to senescence, and thus provide natural mulch for controlling weeds

Grasses	Technical name	Geographical presence	Perspective uses
Feather lovegrass	*Eragrostis amabilis*	Indo-Pak subcontinent, China, South Africa	Alternate forage and preserved feed (hay and silage) for ruminants
Job's tears	*Coix lacryma-jobi*	Philippines	Food products (porridge, coffee, wine, biscuits and variants of bread) and medicinal uses (wounds, blisters, and urinary tract infections)
Bermuda grass	*Cynodon dactylon*	Indo-Pak subcontinent, China, South America	Alternate forage and preserved feed for ruminants
Japanese sweet flag	*Acorus gramineus*	United States of America	Low-cost and environment friendly ornamental grass
Pycreus grass	*Pycreus flavidus*	Indo-Pak subcontinent, China, South Africa, Afghanistan, Iran, Iraq, Israel, Lebanon, Syria, Turkey	Alternate forage and preserved feed for ruminants
Hairy crabgrass	*Digitaria sanguinalis*	Indo-Pak subcontinent, China, South America	Forage and preserved feed (hey and silage) for ruminants
Miscanthus	*Miscanthus sp*	Mediterranean countries	Bioenergy production
Signalgrass	*Brachiaria racemosa*	Indo-Pak subcontinent, China, South Africa, Australia, Southern Europe	Forage and preserved feed for ruminants
Switchgrass,	*Panicun virgatum*	Mediterranean countries	Biomass crops for biofuel production
Wild sugarcane or Kans grass	*Saccharum spontaneum*	Indo-Pak subcontinent, Nepal, Bhutan, Panama	Fencing of houses, vegetable gardens, Thatching of houses or huts roofs
Giant reed	*Arundo donax*	Mediterranean countries	Biomass crops for biofuel production, phytoremediation of soil
Reed canary grass	*Phalaris arundinacea*	Mediterranean countries	Biomass crops for biofuel production
Lemon grass	*Cymbopogon citratus*	Philippines, Indonesia, Srilanka, Indo-Pak subcontinent, United Kingdom, Madagascar, Central America	Brewed into tea, use as herb in cooking for aroma, essential oils extraction and medicinal uses (antipyretic, antibacterial, and antifungal agent)
Chinese silvergrass	*Miscanthus sinensis*	United States, South American countries	Low-cost and environment friendly ornamental grass
Blood grass or cogon grass	*Imperata cylindrica*	United States, South American countries	Low-cost and environment friendly ornamental grass
Eastern gamagrass	*Tripsacum dactyloides*	North America	Bioenergy production
Prairie cordgrass	*Spartina pectinata*	North America	Bioenergy production
Big bluestem	Andropogon gerardii Vitman	North America	Biofuel production
Pink muhly grass	*Muhlenbergia capillaris*	United States of America, South American countries	Ornamental grass with esthetic values

Grasses	Technical name	Geographical presence	Perspective uses
Sand bluestem	Andropogon hallii Hack.	North America	Bioenergy production
Little bluestem	[*Schizachyrium scoparium* (Michx.) Nash]	North America	Biofuel production

Table 1.
Different underutilized grasses, their geographical presence and perspectives uses under varying farming systems and socio-economic perspectives.

and release of nutrients from residues after decomposition. Overall, cultivation of high yielding underutilized grasses can potentially multiply land-use-efficiency and higher productivity per unit of area. In addition, there is a great potential to still improve their performances. However, many of underutilized grasses are either undomesticated or are at earlier development stages, while in-depth studies are needed to develop their production technology package. One of the limitations of traditional breeding is the exceptionally lengthy process which might extend for over 15 years involving collection of germplasm, selection of parental lines, selective crossing to achieve desired traits and allowing evaluation cycles for random genetic mutations.

In addition to bio-energy applications of underutilized grasses, there are diversified uses of perennial grasses such as pulping as well as bleaching potential of giant reed for papermaking due to having moderate strength properties along with bleachability characteristics. In addition, miscanthus which is an underutilized grass has proved its potential and feasibility for producing various types of panel boards, building blocks of various infrastructures and medium-density fibreboard having comparable characteristics as that of wood chips. A significant equity between miscanthus and crops straw for animal bedding preparation could be achieved as far as cow comfort in the barnyard is concerned. However, the superiority of this perennial grass over straw has been established owing to higher biomass production potential compared to many cereals such as wheat, rice etc. Moreover, lignocellulosic biomass yielded by underutilized grasses might be processed into diversified products; however, lack of market development has so far hampered wider-scale implementation of the lignocellulosic biorefinery. It may be noted that lignocellulosic biomass currently fetches around 65 € per dry ton [12–14].

Thus, it becomes evident that productivity potential and the ability to generate comparable revenues of underutilized grasses would be the key drivers in farmer's perspectives. It also follows that comprehensive real time data pertaining to yield would be critical in order to provide accurate and reliable information to researchers, growers and entrepreneurs. Moreover, underutilized grasses future will be determined on development of consistent, feasible, farmer's friendly and affordable economic plans encompassing economically profitable plantation size and tailor-designed low-tech and easily accessible processing plants for producing market capturing products. At farm scale, advanced research for developing agronomic packages, designing breeding programs, building post-harvest logistics and bioconversion facilities are fundamental aspects that need thorough attention of researchers and governments for harnessing the potential of underutilized grasses. These will follow production of climate resilient genotypes of underutilized grasses having the potential to thrive well in a wider range of agro-environmental conditions on marginal lands without coming into competition with food crops (see **Table 1**).

5. Need of underutilized grasses promotion

Many underutilized grasses if promoted appropriately hold the potential to gain local, regional, national importance in terms of generating economic activity. For promoting underutilized grasses, securing resource base in developing countries is vital for maintaining the safety net comprising of diversified products and food stuffs and thus contributing to ensuring food security strives. Another justification for promoting underutilized grasses is to ensure diversification of agricultural systems and to offer support to fragile social groups having lesser affordability to rely solely on staple commodities [1, 14]. In addition, underutilized grasses cultivation on marginal, degraded and fellow lands can serve as a poverty alleviation strategy by empowering marginal sections of farming community. These also hold bright perspectives by allowing rural communities to adopt resources-based development instead of commodity focussing development. Along with poor segments of farming community, underutilized grasses can offer additional benefits to wider strata of communities through provision of balanced diets, diversified source of income to growers and marketing agents, sustainable preservation of agro-ecosystems and putting into use large swathes of marginal lands without disturbing the cultural identity.

6. Challenges posed to production of underutilized grasses

In designing research works and developing promotion programs for underutilized grasses, researchers and policy makers need to be prepared for coping multitude of problems and hindrances.

1. Lack of agricultural market globalization for novel and new agricultural products and overemphasis on a specific set of trade preferences for a certain number of cash or food crops is one of the key challenges in boosting the demand and utilization of products prepared from underutilized grasses. Lack of globalized market for novel products prepared from underutilized grasses serves as discouraging factors to researchers, growers, funding agencies and policy makers despite the fact that product development follows the market demand and keep on waiting for favorable market factors is bound to serve no purpose.

2. Urbanization and the associated promotion of large enterprises which have replaced small-scale commercial and economic activities can also make the promotion of underutilized grass products a daunting task by offering severe competition.

3. The homogenization of local cultures owing to the intensive interaction of diversified cultures by virtue of improved communication have further promoted specialization in favor of established crops and thus narrowing down the scope for entry of products developed from underutilized grasses having a comparative competitive disadvantage in terms of less market demand and little share in global trade.

4. Species selection of underutilized grasses constitute another big challenge as the right species selection from a broad genetic pool of potential candidates can ensure appropriate use of limited resources. The availability of incomplete and poor-quality information regarding localized grass species have further

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multiplied the complexity on the selection process. It may be suggested that direct involvement of end users might be considered for a successful selection of underutilized grasses species.

5. Another daunting challenge is securing the necessary resource base for developing ex situ and in situ approaches intended for appraising the genetic diversity and running genetic programs in order to bring desired traits enabling the underutilized grasses to survive under changing climate scenarios.

7. Role of agronomy in underutilized grasses promotion

Underutilized grasses hold bright perspectives in improving the food and nutritional security of a rapidly increasing population; enhance the nutritional balance and impart sustainability to modern profit-oriented farming systems. These may also serve as grower-friendly poverty alleviation strategy by generating additional income and that too with the utilization of meager resources. Agronomy is a branch of agriculture which deals with sustainable production of food, feed, fuel and fiber crops by putting into practice biologically viable and economically attractive approaches encompassing persistently evolving production technology package and agricultural soil management, restoration and preservation. Agronomists hold critical role in boosting underutilized grasses cultivation on large scale by developing environmental friendly technology packages. Following are some of the vital roles that Agronomy and Agronomists can perform to make cultivation of underutilized grasses economically viable under changing climatic scenarios.

7.1 Bridging awareness and knowledge gaps

There exists serious research and knowledge gaps regarding the growth habits and input requirements of underutilized grasses, which have served as major constraints to the strives for promoting cultivation and creating demand of products developed from underutilized grasses. For time being, efforts are needed for raising awareness among stakeholders and encouraging them to execute research on underutilized grasses in order to redress their neglect status. Another aspect that needs thorough attention is to conduct a detailed analysis on the evolving status of species from underused grass to a well utilized crop. It becomes even more pertinent to develop criteria of a peak promotion stage at which a specific grass will cease to be underutilized. Agronomists need to shoulder the responsibility for promoting grasses that are not only biologically viable but also economically attractive to local farmers, keeping in view their technological level and size of landholdings. In addition, such a promotion package must also encompass boosting local diversity of flora and impart sustainability to production systems without compromising established farming systems and promoting cultivation of underutilized grasses on marginal lands and degraded soils that cannot support other crops of economic significance.

7.2 Access and multiplication of seeds

Planting material constitutes one of the most critical factors in determining the success of any crop and the same is the case of underutilized grasses. Agronomists would be required to strive for securing the genetic resources for establishing a diversified genetic pool of different underutilized grasses, and thereafter, intensive research might be conducted for screening out high yielding, climate resilient, stress tolerant and resource efficient genotypes. It will follow mass seed production through well planned and target-oriented seed production programs in order to improve the access of growers to quality seed at an affordable cost. Agronomists and plant breeders are required to work in liaison to run commercially feasible seed production programs.

7.3 Conservation through use

It must be conceded that resources have always been insufficient and scarce for conserving underutilized crops and grasses at large scale. Thus, this situation and desire for process sustainability requisite integration of conservation and utilization simultaneously and this concept is famously known as conservation through use. However, collecting information pertaining to distribution patterns, utilization preferences, and evaluation of existing traditional and localized knowledge on underutilized grasses is prerequisite as this information can serve as foundation of future research programs for improving access of growers to planting materials.

7.4 Localized agronomy

Since the cultivation and utilization of most of the underutilized grasses are primarily localized, thus agronomic packages for the cultivation of underutilized grasses must be developed keeping in view locally available farming resources, growers' technical know-how level, farm mechanization status, community needs and market scenarios. Local mechanisms that support the deployment of useful diversity will need to be strengthened. There is a dire need to develop integrated chains and networks that cohesively link Agronomists to farmers and end-users of products developed from underutilized grasses. Moreover, Agronomists need to work in liaison with agri-economists for assessing potential revenue generation from the cultivation of underutilized grasses and product development.

7.5 Future agronomic strives needed

The underutilized grasses have the potential to provide livelihoods to thousands of farmers globally provided access to planting material and quality is ensured along with investing in infrastructure development for product development through creating the market demand of products (food, feed, fuel, fiber, medicinal, spices, aromatic, beverages, esthetic etc.) developed from underutilized grasses. The underutilized grasses are threatened biological assets having the potential to contribute significantly in poverty alleviation strives, while Agronomists hold the key to unlocking this unutilized treasure. Intensive and systematic liaison among Agronomists and policy makers for developing cost-effective production technology package under specified set of agro-environmental condition and soil productivity status through appropriate resource allocation is the need of the time. Agronomists by developing biologically viable farming approaches can convert underutilized grasses into high value commodities for meeting community's real needs. Agronomists need to develop criteria regarding (a) the minimum technical know-how of growers required for successful cultivation of underutilized grass species, (b) compiling information that is easy to understand and repeat in different regions of the world for seed multiplication methods and real-time assessment of grasses regeneration capacity and (c) fundamental knowledge compilation on different types of insect-pests, diseases, and site-specific cultivation related hindrances. In addition, fundamental changes are needed in reporting the agricultural statistics at regional, national as well as international levels. It might be suggested that agricultural statistics year book that is compiled and published by the Food and Agriculture Organization (FAO) must be broadened in scope by adding underutilized crops and grasses. Besides compilation, wider and easy access to this information must be made available to researchers, extension workers, industry and other stakeholders. At local and regional levels, site-specific studies to optimize production technology package of underutilized crops must be supported for ensuring their publication in order to make results available to wider audience.

8. Crop protection role in promoting underutilized grasses

Crop protection constitutes one of the most vital branches of agricultural science which keeps on devising biologically viable ways and cost-effective means for controlling various types of diseases, insect-pests in order to prevent significant damage by keeping harmful organisms below threshold levels. To prevent a severe disease outbreak comprises maintaining a healthy and vigorously growing crop. Each individual plant in the field requires optimum water and fertilizer quantity, as well as an aerated, well-drained soil but lacking any of these factors, the crop may become stressed ultimately more susceptible to disease. A study revealed that microbial diseases are responsible for the ultimate crop losses up to 16%, out of these 16% microbial losses almost 70–80% were due to fungal pathogens. It is estimated that more than 100,000 plant diseases can be caused by 8000 reported fungal species. As far as the underutilized grasses needs to be maintained by characterization and research on its agronomic factors, still there is a dire need to explore the pathogens causing mild to severe diseases ultimately suffering a huge loss in its production and quality traits. A few of the major crops may responsible for nutrition as well as food security that ultimately leads to keep the agriculture system vulnerable to various biotic and abiotic stresses due to the lack of genetic diversity in these crops. As far as diseases are concerned, there may be fungal and viral diseases that may be challenging to adopt in the underutilized grasses [15–18].

Besides numerous diseases, a few need more attention as to be more severe in the grasses which must be investigated to find out biologically viable solution for keeping these below the threshold level. Rust caused by the species of genus Puccinia and is obligate plant pathogen. This genus contains more than 4000 species based on their hosts. Considering lemongrass as an example of underutilized grasses the rust caused by *Puccinia nakanishikii* Dietel more sever in warmer and more humid areas. It produces light brown pustules on both the lower and upper surfaces of leaves. The spores dispersal through wind may spread the disease on larger scale. Unfortunately, there is still the lacking research on the management strategies of this disease on lemongrass and is a dire need to address this issue to overcome the pathogen potential. Furthermore, *Helminthosporium cymbopogi* another fungal pathogen causing a sever disease of grasses including lemongrass known as leaf spot. Similarly leaves curling and browning caused by brown tip disease is due to the low water content in the leaves. Foliage blight is another fungal disease caused by *Curvularia andropogonis* (Zimm.) infecting mostly grasses led to the considerable yield losses. The common management practice to control these fungal diseases is application of 1% Bordeaux mixture or 0.3% Zineb three times with an interval of fifteen days. Similarly, 0.2–0.3% Mancozeb can be an alternative fungicide application thrice in the season with 15 days interval [19–23].

Similarly blast is another important fungal disease on grasses especially on millet caused by *Pyricularia grisea* lead to sever grain losses 56–80% while upto 35% losses were reported in 1000-grain mass. Millet is vulnerable to this pathogen from seedling till its grain formation. Commonly the symptoms are spindle shaped lesions of different sized, generally the spots appear initially with yellowish margins and gray centers. The lesions later on turned to whitish gray and also olive gray growth of fungus may appear on the lesions. Seed treatments with Tricyclazole may be effective to overcome the primary seed born inoculum. Later on, fungicide application on ear appearance and after 10 days interval should give better results. It has been reported that biological control agent 0.6% *Pseudomonaas fluorescens* used as seed treatment following two later spays of the same bio-agent may constitute a good alternative to chemical fungicides for underutilized grasses [24–26].

Among nematode disease cereal cyst nematodes among one of the oldest genus named Heterodera are the more important that may infect small cereal grain crops like oat, barley, wheat, rye, and triticale. Cereal cyst nematodes complex widely distributed on family Poaceae includes several species. Among these species oldest reported specie was *Heterodera avenae* followed by *H. latipons*, then H. *hordecalis* in North Europe, furthermore H. filipjevi in eastern Europe, up till now 11 species of genus *Heterodera* has been reported. Among these 11 species three of them i.e. *H. avenae*, *H. latipons*, and *H. filipjevi* considered economically important on cereals globally [25–28].

Generally, the best management practice to normalize the effect of cereal cyst nematode may include crop rotation with a non-host crop. The eggs of cyst may become dormant inside the cyst for many years but have a very narrow host range, therefore rotation led to the best cultural practice. Furthermore, clean fallows, sanitation of fields, weed control, sowing time to escape egg hatching and trap cropping should be effective. Use of resistant varieties and chemical nematicides directly minimize the population density of nematode. Studies revealed that the use of nematophagous fungi should be an alternative of chemical control as to target the cyst nematodes with the use of these biological control agents.

9. Food sciences contribution in boosting underutilized grasses products

Food science belongs to basic as well as applied sciences of food and its scope significantly overlaps with agricultural science along with nutritional science leading through different vital scientific aspects pertaining to food processing and food safety along with persistent development of economically feasible technologies for food processing. Regarding underutilized grasses, food sciences can potentially play a vital role through product development and creating market demand for food products developed from underutilized grasses like lemon grass. There is an increasing pressure on agriculture to produce greater yields of feed, food and biofuel from limited land resources for the estimated population of nine billion people on the globe by 2050 [1–3]. So it is proposed that production from agricultural sources has to be increased to manage an estimated 40% increase in the world's population. About 90% of this progress is likely to result from improved cropping and high crop yields, while the remaining has to be produced from land resources presently not utilized for farming. The diversification of crops from the poaceae family having nutritional value can also cope with the problem of food insecurity. The diversification into other grass crops could lead to sustainable agriculture by enhancing economic, ecological, nutritional and social conditions.

9.1 Underutilized grasses for sustainable food production and nutritional security

In comparison to the staple grasses, neglected or undervalued grasses are of immense importance in the food industry for developing valuable products. Food

Science and technology has a wide range of applications for utilizing different undervalued grasses for the production of edible sugars and glucose from non-used rice and wheat residues which are usually wasted or burnt, and has been recently introduced for the successful production of food grade sugars. Similarly, Green Grass juice from underutilized barley and wheat is another essentially therapeutic food product with functional food ingredients. Green juice from grasses contains chlorophyll which is considered as green blood as it is a substitute of hemoglobin. So, the utilization of these grasses for juice production in the juice industry can achieve a wide range of objectives, including maintaining consumer's health. The active ingredients in these juices also hold functional properties of immense importance for the juice processing industry. However, their contributions should be studied in order to enhance the precision. Cereal grass juices must be encouraged as a functional beverage in diet-based therapies against different lifestyle-related disorders [29–31].

Another wonderful candidate from Poaceae family is lemon grass. Lemongrass is primarily cultivated and grown for its essential oil (EO) that has multiple medicinal (anticancer, analgesic and antimicrobial) and cosmetic uses. It is also utilized in the form of herbal tea (green tea) as it contains a variety of vitamins and minerals which are essential for health. Lemongrass derivatives in aqueous or dried extract form can be used for the preparation of acceptable mixed beverages. This valuable product could be developed to improve the antioxidant activity, nutritional aspects, and health benefits. Usually, grains from grasses are utilized but grasses are ignored as a waste. Barley grass powder has a huge potential of utilization as a functional food ingredient in food preparations. Barley grass is rich in vitamins and minerals and can be developed as a powdered supplement to treat many chronic diseases. Also, food industries can utilize the barley powder for fortification purposes. Infect some effective strategies of food scientists are required that can guide futuristic research on production of functional foods from barley grass for prevention and treatment of chronic diseases [32].

Recently, Denmark's National Food Institute contributed towards the novel application of grass protein as a food for human consumption. As it will be a cheaper and valuable source of protein to cope with the issues of food insecurity and alternatively protein deficiency malnutrition around the globe [33]. Interestingly, grass protein powder is a profitable and sustainable concept for serving humanity on the earth. Researchers claimed that grass protein has similar amino acid profile to that of egg, soya and whey proteins. For grass proteins ryegrass is an ideal candidate as it contains the right amino acids composition that can be turned out as a good protein source for human consumption. It is of prime interest that protein powder from rye grass can be utilized in a wide range of food products. As a novel food item grass protein powder must be approved by the European Food Safety Authority to ensure the powder is safe for human consumption. Researchers and food technologists are ambitious to develop grass protein as a food ingredient as it will be of great contribution towards an economical, approachable and sustainable solution to solve Food insecurity issues.

10. Plant breeding and molecular approaches for underutilized grasses promotion

Plant breeding is a set of scientifically driven procedures and techniques for developing new genotypes through process called crop improvement, cultivar development and seed improvement. It assists to create multi-generations of genetically diverse populations generally through human triggered selection for creating the adapted plants having new combinations of desirable traits. There is an urgent need of developing the grass species having potential to yield higher under rapidly changing climate scenarios. This can be achieved by imparting traits of tolerance against abiotic and biotic stresses in order to fulfill the rising demands of food for rapidly growing populations. In the mid era of twentieth century, conventional breeding methods of plants had resulted in the historical green revolution since very high yielding crop varieties were produced by breeders. However, now under the scenario of climate change, conventional methods of breeding plant species are not sufficient. Molecular tools and techniques have evolved for developing plant-species with enhanced nutritional value through direct transfer of desirable genes controlling the demanded traits. Genetically engineered or modified crops, conventionally named the genetically-modified-crops (GMOs) can effectively supplement the conventional methods for producing improved quality plants for food and feed. Crop-species can be developed by genetic engineering for enhanced yield, nutritional qualities as well as the enhanced resistance to different environmental stresses. Breeding strategies for improved forage species is different from major crops since it requires a long-duration and demands the integrated use of the other disciplines such as; genetics, breeding, biotechnology, agronomy, entomology, physiology, pathology and animal-nutrition [34].

Breeding programs for underutilized grass species require complete knowledge of species-genetic-relationship, chromosomal composition, polyploidy and the, degree of existing gene-recombination or genetic variation for further selection and hybridization. Hence, the overall strategy differs among the species. However, a remarkable progress in the areas of modern molecular gene engineering tools has opened new horizons. Molecular approaches using biotechnological tools to produce improved forage crop varieties were started in the late-eighties. Such biotechnological tools include: Molecular techniques to observe the genetic composition, foreign or distant-gene insertion directly into the targeted plant-genome, and micro propagation from single cells in vitro. Various other such techniques such as embryo rescue, haploid plant production and creation of new variations aid in different steps involved conventional breeding methods consequently minimizing time required for conventional breeding methods. Additionally, the plants bred through such techniques do not conflict with the interests of the individuals who oppose the genetically -modified -organisms. For production of hybrids of Lolium-Festuca, the embryo-rescue technique has been exploited efficiently. There are several classic techniques of molecular breeding viz.; restriction-fragment-length polymorphism (RFLP), random amplified polymorphic DNA (RAPD), amplified- fragment-length polymorphism (AFLP), and isozymes which are frequently exploited for characterization of germplasm, quality trait loci (QTL) identification, detection of hybrids, cultivar identification, gene tagging, and genetic mapping. The molecular characterization of the genetic structure of forage crops as well as weeds is equally important. Since, if the gene identified from one plant species or living-organism contains the similarity in its sequence offers ease in its transfer into the target species through gene transformation [35].

Although, characterization of available germplasm is crucial particularly under the changing climates scenario, the gene-tagging and genetic-mapping in forage species is much lagging behind. For traits which are under the control of a single gene, gene tagging is essential, but in the case of forages most of the desirable agronomic traits are under the control of many genes and are thus very difficult to tag. Gene identification for the genes controlling apomixes in grass-breeding is a key to produce hybrid seed of underutilized grass species. Cloning and functional identification of these genes can be patented by breeder and can also be used for fixing heterosis in various species and offers time saving for hybrid seed production each year. Famous example is the Napier x Bajra hybrid, which was produced by the cross between *Pennisetum glaucum* and *Pennisetum purpureum*.

Recent progresses in the areas of genomics complemented with high-throughput and precision phenotyping facilitate the identification of genes controlling economic agronomic traits. The detection of these genes can be combined with genome editing techniques for the speedy development of climate change resilient plant species. Currently, genome editing is applied in major food crops and this technique has the potential for rapid improvement of underutilized crop plants, specially, targeting the current and future challenges of climate change. The success of genomics in improving a given plant species is also influenced by the nature of the trait under study. For example, traits intensely affected by the environment and genotypic and the environmental interaction are more challenging to study and modify [36]. Another approach could be intercropping underutilized grasses with staple cereals and legumes as this approach has the potential to boost soil fertility, total yield, and economic turnouts along with numerous other ecological benefits such as improvement in soil microbial population [37–40].

Transgenic technology allows the transfer of foreign genes from unrelated species and thus offers enormous scope to improve underutilized grass species. The development of more detailed gene maps of different species, using genomics and allied molecular tools will help in the identification of genes or gene sequences that might be associated with responses to changing climate stress. Although the biosafety and health hazards linked with GM crops have been questioned, a number of crop species have already been genetically-engineered and carefully tested and possess no obvious risk. Integrated use of modern biotechnology, with conventional agricultural in a sustainable way, can lead to achieving the ultimate goal of achieving food security for current and future populations. Transgenic approaches have been employed to improve these species in the following aspects: significant improvement of dry matter digestibility in the case of tall fescue, alfalfa, and perennial ryegrass. By efficient integration of novel germplasm into practical breeding programs, transgenic cultivars offer the potential to play a potential role in fulfilling the growing demand for animal products as well as renewable fuels in the coming years.

11. Pertinence of participatory approach and agri-sciences integration

A participatory approach integrating different disciplines including Agronomy, crop protection, plant breeding molecular genetics and food sciences to promote the cultivation and market demand of products developed from underutilized grasses is the need of time. It becomes even more important as studies on underutilized grasses have remained neglected historically and constitute one of the biggest challenges in crop genetic resource history. The destiny changing phenomenon of the green revolution holds witness to the fact that inter-disciplinary and trans-disciplinary approaches integrated in a coherent way to boost underutilized grass production is one of the most feasible, doable and viable options. It must be recognized that underutilized grass species will never command the same prime undertaking as a major crops which requisites a different but integrated approach for their viable promotion. Such an approach must link all stakeholders and research activities pertaining to local grass agro-botanical and pathological information collection, research trials, product development, nutritional assessment of developed products for safety and taste, product utilization policy and marketing as well as commercialisation plans. A chain of researchers from Agronomy, crop protection, plant breeding and food sciences can conduct interconnected research for boosting cultivation of underutilized grasses and develop products keeping in view the needs and demands of local, regional, national and international markets.

There is a very critical role of international organizations such as FAO for the sharing of findings acquired in region with equal benefits to other regions in terms of grasses cultivation and product development. The participatory approaches formulated collectively through larger brainstorming among stakeholders and implemented under localized conditions occupies the strategic position for making the best utilization of existing resources and promoting synergism across different regions. Underutilized grasses also constitute a class of grasses that are ignored socially and therefore, generalized masses and farmers are bound to attract towards multi-disciplinary research teams instead of working in isolation. The inter-disciplinary and multi-disciplinary researchers put a halt to the persistent decline in genetic erosion of grasses. Even extension workers can perform strategic role by collecting information regarding underutilized grasses from farmers of far-flung areas and thereafter Agronomists and Food Technologist can work cohesively to reveal the true potential of underutilized grasses through the production of quality products having rich perspectives in localized and regional markets.

Additionally, Agronomist need to work in loop with crop protection researchers to analyze the constraint factors related to insect-pest and diseases incidence, leading to the development of a technology package enabling grasses to cope with biotic and abiotic stresses effectively under a changing climate. The participatory approach involving Agronomists with Breeders may contribute to enhancing the see and germplasm selection, production, multiplication, supply, processing, product development and commercialisation. Furthermore, inclusive strategies hold the perspectives to develop rapid marketing demand for products from underutilized grasses through intensive cooperation with the private sector. The participatory approaches must attempt to explore options to grasses conservation and use simultaneously in order to secure a resource base for boosting underutilized grass cultivation and production. The approaches may differ, depending on whether the crop is seed propagated or clonally propagated, annual or perennial, outbreeding or self-pollinated. It is worth mentioning that a participatory approach must encompass information on the smallest size of ex situ collection that may ensure genetic diversity along with the ways and techniques to economically maintain the genetic diversity. Moreover, it is also vital to determine the extent of diversity that must be included in the production systems along with developing monitoring criteria in order to make the successful cultivation of underutilized grasses on a wider scale.

Besides agronomic packages, technologies entailing molecular genetics and GIS might play their role in developing the conservation techniques and utilization strategies for underutilized crops. As implied in the case of inter-disciplinary and trans-disciplinary approaches, it is also needed to initiate sustainable linkages among researchers, research and development organizations, farmers and consumers. It is always unlikely that researchers belonging to a specific discipline have all the expertise, while any single organization can also ill-afford to support research work on a large scale for boosting underutilized grass production and product development. Ultimately, it must be recognized that underutilized grasses present unique a set of problems and potential opportunities under varying socio-economic conditions, and thus participatory approaches can improve conservation and utilization of underutilized grasses under changing climate scenarios.

12. Conclusions

The commercial-oriented farming systems encompassing the cultivation of major grasses have caused a serious decline in the intra and interspecific diversity of crops. In addition, the decline of grasses biodiversity has led to higher vulnerability among growers and end-users while the changing climate has made it mandatory to promote underutilized grasses (Feather lovegrass, job's tears, bermuda grass, Japanese sweet flag, pycreus grass, hairy crabgrass, signalgrass, switchgrass, miscanthus, giant reed, reed canary grass, lemon grass, Chinese silvergrass, big bluestem, wild sugarcane etc.) diversity in order to ensure food security and economic viability of modern farming systems. The panacea lies in a participatory approach entailing integration of agronomic practices with crop protection, food sciences and plant breeding in order to develop sustainable technology packages for ensuring economic production of food, beverage and medicinal products from underutilized grasses. Moreover, creating market demand for novel products of underutilized grasses coupled with sustainable supplies of raw material along with processing, packaging and branding facilities hold key in booting cultivation and utilization of underutilized grasses under changing climate. Last but not least, United Nation's envisaged sustainable goals of zero hunger and poverty alleviation might also be addressed by boosting cultivation and utilization of underutilized grasses.

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