Chapter

Bottle Gourd Landraces and Its Potential Contribution to Food Security

Nkanyiso J. Sithole, Khayelihle Ncama, Lembe S. Magwaza, Nozipho M. Motsa and Jacob Mashilo

Abstract

Issues surrounding water scarcity and malnutrition in the rural household of sub-Saharan Africa continue to be a problem and pose threat to food security. In such cases, traditional and underutilized crops have been proposed because of their likely suitability in these marginal areas of crop production characterized by abiotic (drought and heat) and biotic environmental stresses (pest and diseases). Bottle gourd is one such crop with multipurpose use and a huge potential to contribute to food security. The crop is grown for its leaves, fruits, and seeds from landraces providing important nutrition for both humans and livestock. A lot has been documented about its medical properties. The crop exhibits wide genetic variation for qualitative and quantitative traits, which can be used for cultivar development. The objective of this review was to provide information on why bottle gourd is an important food security crop in sub-Saharan Africa. The first section of the paper presents water scarcity, food production, and climate change. This is followed by the section on the neglected underutilized crops species. Then the section of drought tolerance of the crop is presented, and lastly, the section on potential contribution of the crop to food security is presented.

Keywords: calabash, water scarcity, neglected crops, leafy vegetables

1. Introduction

The population of the world is expected to reach 9.1 billion by 2050, and the larger percentage of this growth is expected to come from the low-income countries such as those in sub-Saharan Africa [1]. Consequently, this will result in more water competition in these countries, which are already frequently affected by drought stress and food insecurities. In South Africa, the rainfall is uneven throughout the country and often unpredictable and erratic. The country as a result has been characterized as the "water scarce country" with less than 500 mm of rainfall received per annum as compared with the world average of 836 mm [2]. The predicted effects of climate change in sub-Saharan Africa and the country will make the situation worse due to the predicted increase and intensity and frequency of drought stress [3]. Therefore,

this is extremely worrying when looked within the context this will have in agricultural production and the vulnerability of the poor rural household and the poor urban, because the incident of crop failure will likely rise resulting in food insecurities within these communities [4]. This suggests that there is a need to continuously increase crop production and productivity by developing drought tolerant genotypes that are adapted to grow under varying and unpredictable conditions and under water scarcity conditions. This has resulted in the renewed efforts to consider the "landraces" as possible crops, which can safely guard food security in these marginal areas characterized by abiotic (drought and heat stress) and biotic (pest and diseases) environmental stress [5].

A review [6] on nutritional status of South Africans has revealed that under- (underweight, thinness, and stunting) and over-nutrition (obesity and overweight) and diet-related non-communicable diseases [7, 8] coexisted within the same communities and often on the same household. This phenomenon is known as the triple burden of malnutrition [9]. This has been exacerbated by the Covid-19 pandemic in 2020 and 2021 in South Africa where the government has provided R350 grants for the poorest affected people. Reportedly, the world hunger rose further in 2021 following a sharp upturn in 2020 during the Covid-19 pandemic making worse the existing inequalities, which have contributed to setbacks toward achievement of Zero Hunger Target by 2030 [10].

The increase in production and intake of traditional leafy vegetables was identified as the potential solution for addressing the problem associated with poor food security and nutritional imbalances in the rural communities [11, 12]. In contrast to urban and semi-urban communities, people in rural areas have access to land, which they can use to cultivate crops, thus contributing to their food security. However, this is usually hampered by a lack of adequate resources in these areas. Information, expertise, and low capital to buy agricultural inputs such as seeds, fertilizers, herbicides, and insecticides, as well as infrastructure needed to produce these crops, are often limiting in these areas. Under such circumstances, it has been suggested that traditional crop species can play a vital role in ensuring food security under such low input systems because of their likely suitability to these areas [13–15]. However, most traditional crops remain underutilized despite reports that they may be better suited to low input systems. This could be due to lack of clear policy instruments encouraging cultivation of these crops, lack of research interest from agricultural scientists, and low yields due to poor agronomic practices. Therefore, to promote the use of traditional crop species, there is a need to conduct research that will contribute to the documentation of optimum agronomic practices of these crops. This would contribute significantly to food security through increasing productivity of these crops, thus promoting balanced diets. Bottle gourd (*Lagenaria siceraria* (Molina) Standley) is one such crop species, which has been under researched in South Africa.

Bottle gourd is a member of the *Cucurbitaceae* family together with pumpkins and watermelons [16]. The crop originates in Africa, and it exhibits a great diversity in nature, and this alone indicates wide environmental adaptation [17]. The leaves of the crop are consumed the same way as those of pumpkins, watermelons, and other popular cucurbits. They are usually consumed as a relish with maize staple. The seeds of the crop, on the other hand, are popular snacks in Africa and are reported to contain high levels of proteins as is the case with the seeds of its closest relative pumpkins [18]. The mature fruit can be used as a container to store water, food, and as a musical instrument [19]. In addition, in Asia, bottle gourd is used as a rootstock in winter production of watermelons and squashes to prevent root-borne pathogens such as

Fusarium oxysporum [20]. A lot has also been documented about its medicinal properties, especially in countries such as India and Pakistan. Bottle gourd has been reported to contain high levels of choline, which is a compound that is reported to heal mental disorders [21]. In India, it has been reported to cure stomach complications [19].

Given all these benefits, it is important to note that the potential of bottle gourd landraces as a possible food security crop has been overlooked by many researchers. These landraces have been preserved by the communities who have been utilizing them for over 100 years and form a possible germplasm resource. They may have adapted to ecological niches from which they have been preserved. This makes them an important food security crop for cultivation in marginal areas of crop production. However, owing to the popularity of exotic members of the *Cucurbitaceae* family (pumpkins, watermelon, butternut, and squashes), the popularity and cultivation of bottle gourd landraces have faced neglect. Therefore, is a need to conduct research on improvement of this crop and their potential to contribute to food security in marginal areas of crop production. Therefore, the objective of this chapter is to review the research conducted on bottle gourd landraces and highlight their potential contribution to food security.

2. Water scarcity, food production, and climate change

The climate of the sub-Saharan region is characterized as semi-arid to arid with most countries receiving the rainfall that is less than 500 mm per annum. Frequent occurrence of drought is common in most countries in the region. This in combination with climate change and variability has led to huge losses in local food production and has threatened food security [22]. This is important to note since larger part of the population in sub-Saharan Africa is still dependent of agriculture for subsistence. This is a vulnerable group with low income or no income at all, low adaptive capacity to climate change, and facing a great treat to food security [23, 24]. The predicted impact of climate change in sub-Saharan Africa is that of rising temperature, increased incidence of floods, increased occurrence of extreme events such as drought, and increased rainfall variability [25]. Already, some of these conditions are experienced in sub-Saharan Africa with the recent case of severe floods that have affected many communities in Durban, South Africa, in 2021.

In sub-Saharan Africa, most economies are still dependent on agriculture as the driver of rural and economic development, and it is argued that current agricultural activities within these communities are too mainstream and lack the necessary innovation to allow rural economic development [24]. Reportedly, 95% of the population in the region is still dependent on rainfed agriculture, and it is subsistence-based [26]. This, therefore, is a huge challenge when viewed with the context of impact this will have on agricultural production and vulnerability of the smallholder farmers [22]. Therefore, given these challenges, there is a need to embrace new paradigms or alternative approaches that promote context-specific, best bet agricultural technology that can perform under water scarcity, climate change and provide food and nutritional security for the rural household. Those solutions should be practical, sustainable, and resilient to the problems facing sub-Saharan Africa such as water scarcity, climate change, and food security. As a result, landraces or underutilized crop species such as bottle gourd have been promoted in South Africa to cope with water scarcity, climate change, and food security.

3. Neglected underutilized indigenous crop species

In context of the above discussion, neglected and underutilized crop species have been recommended to mitigate some of these challenges. According to a report [27], neglected and underutilized crop species can be defined as those crops that have become indigenized over many years (more than 100 years) cultivation and natural and farmers selection within South Africa, thus they have become "landraces." On the other hand, landraces have been defined as the local variety of a plant species that evolved largely through selection by farmers in an unstructured way and which has become adapted to ecologies where it grows and survives [28]. These crops are sometimes called forgotten crops, neglected crops, orphans crops, underutilized crops, etc., as there is no consensus on what these crops should be referred to [22]. In the context of this document, landraces and neglected and underutilized crop species will be used interchangeable and have the same meaning. These crops currently have low level of use that is limited to subsistence farmers, have previously under-researched, and have not been previously classified and the major crops [29]. These crops previously, played an important role in ensuring household food security through providing alternative food source when the main crop has failed [29]. These crops also provided food source during times in-between subsequent harvest. Neglected crops species are cultivated from landraces using unimproved landrace varieties mostly by subsistence farmers. They are believed to be adapted to a range of ecological niches, both biotic, pest, and diseases and abiotic drought and heat stress. Therefore, there is a need to conduct more research on these crops and identify the desired traits as the initial stage of crop improvement. Therefore, these crops serve as an important germplasm for future crop improvements [22].

Promotion of few crops such as maize, wheat, soybeans in the mainstream agriculture has occurred at the expense of neglected indigenous crop species. Generally, these crops have been ignored in crop improvement programs by agronomist and plant breeders, and thus, they have earned the term "underutilized" [5]. There is currently little information describing their performance and responses to biotic and abiotic environmental conditions. The promotion of these crops will depend mainly to the availability of information about their growth and development, and bottle gourd is one such crop.

Bottle gourds exhibit large phenotypic variation, and this alone indicates wide genetic variation within the species. It is widely cultivated in sub-Saharan Africa for multiple uses by smallholder farmers [30, 31]. The crop is cultivated for its fruits, leaves, and seeds, and this can be consumed by both humans and livestock. The wide genetic variation within the crop provides the opportunity for selection and ideotype breeding [30]. There are no commercial varieties available of the crop in the region because of the lack of crop improvement programs dedicated into the crop. The crop is therefore classified as neglected underutilized crop species because its cultivation is mostly done by smallholder farmers using landraces under low input system with no improved seed varieties.

4. Drought tolerance of bottle gourd landraces

Larger percentage of the area in sub-Saharan Africa is characterized as arid to semi-arid. This therefore necessitate more studies on crop response to drought stress if the objective is to promote the neglected underutilized crop species. Drought

or water stress in one of the single important environmental factors limiting crop production in the region. Drought can be defined as an extended period (months or years) where a region experiences a deficiency in water supply whether surface or underground water [32]. The plant mechanism to cope with stress is based on the choice of response it adopts in responding to developing water stress [22]. The responses of plants to water stress are complex [33]. The plant may tolerate, avoid, or escape drought stress [34], and the paragraph below sought to explain these mechanisms.

Drought avoidance is associated with reduction in water loss while enhancing or maintaining the uptake by the roots [22]. Drought escape on the other hand is associated with timing of key phenological stages. Crops can escape drought by having short growing season, and this allows them to complete their life cycle before water stress becomes terminal, and flowering time is an important trait related to drought escape [35]. While drought avoidance involves the responses of crop such as the regulation of stomata and the enhanced water capture, proliferation, and extensive root system [36]. Root thickness, root length, and root depth are some of the characteristics associated with enhanced water capture during drought stress [37]. Plant morphological changes such as number of leaves, plant height, leaf area, and leaf area index are reduced during drought stress, thereby assisting the plant to lose less water (or avoid drought) during water limiting conditions [38]. However, these mechanisms do not occur in isolation as drought avoidance can be associated with reduced leaf number and reduced season period, which is a trait of drought escape [34]. Finally, drought tolerance, which has been defined as the capacity of the plant to maintain metabolic activities under water scarcity or drought stress [34]. This is different from drought escape in that it does not show signs or evidence of yield reduction [34]. Drought tolerance is characterized by antioxidant defense system (i.e., reactive oxygen species and reactive nitrogen species) and osmotic adjustment (i.e., proline) [39]. Therefore, the understanding of all these mechanisms involved in water stress is important for strategic breeding of bottle gourd landraces and the release of improved varieties of the crop.

Bottle gourd in sub-Saharan Africa is grown by smallholder farmers from landraces. These landraces are believed to be adapted to stressful conditions of arid and semi-arid characterized by water stress and salinity. The recent studies conducted in South Africa on the response of the crop to water stress have shown some level of tolerance to these conditions [40–42] as compared to other cucurbits crops. As a result, it is suggested [31] that strategic crosses between drought-tolerant landrace accessions may enhance the level of drought tolerance and development of well-adapted hybrid varieties. This coupled with the understanding of the physiological mechanisms to drought tolerance can assist in effective screening and identification of the novel genes in the crop for breeding purposes. The accumulation of secondary metabolites such as cucubitacins during drought stress has been observed in the crop [40, 41] and can be associated with drought tolerance in bottle gourd landraces. In contrast, the concrete evidence that suggests their role in conferring drought tolerance is limited in cucurbit crops including bottle gourd landraces. Cucurbitacins E and I have been found to increase in response to water deficit [42], and the authors suggested that this may be the potential physiological marker of selection and identification of the crop for drought tolerance breeding. Thus, full understanding of the function of cucurbitacins during water deficit may assist in identification of the novel genes that confer drought tolerance [31].

5. Economic and medicinal uses

In South Africa, about 30 years ago, the crop was planted for the pipe making industry [43]. The necks of the fruits were bent in such a way that they grow to form bowls of pipes, and when the fruits were dry and ripe, the necks sawn off, cleaned, and exported to pipe markets overseas [43]. In Malaysia, rural farmers have been reported to increase their income due to planting and selling bottle gourd leaves and fruits [44]. A lot has been reported on medical properties of the crop. Bottle gourd has been shown to contain triterepenoide cucurbitanics B, D, G, and H, two sterols (fucosterol and campesterol), aerpene, byonolic acid, flavone-C glycosides, and lagenin [19]. The extract from the seed was found to contain antibiotic properties, and the fruit juice is helpful in constipation, premature graying hair, urinary disorder, and insomnia. To date, the crop has been found to contain high levels of choline [19, 21]. Choline serves as a precursor of the neurotransmitter acetylecholine, which in turn is important for retaining and enhancing memory. Further, a report [19] indicated that bottle gourd juice helped to regulate blood pressure in hypertensive patients because of its high potassium content, reducing weight quickly because of its high diet fiber and low fat and cholesterol content. Furthermore, the crop has been reported to lower blood cholesterol. In addition, the antihyper lipidemic effects (anti-lipids effect) of four different extracts have been explored [45]: chloroform, petroleum ether, alcoholic and aqueous extract from bottle gourd. They found that both chloroform and alcoholic extract had a significant effect on lowering total cholesterol, triglycerides, and low-density lipoprotein along with increase in high density lipoprotein as compared to others. Their results also suggested marked antihyperlipidemic and hypolipidemic effects of the extract.

6. Potential contribution to food security

In most parts of the world and in South Africa, bottle gourd is grown mainly as a vegetable for human consumption. Leaves of the crop are consumed the same way as those of popular cucurbits (watermelon, pumpkin, and squashes) and other popular leafy vegetables (spinach, Amaranthus spp., spider flower, chines cabbage, etc.). The young fruit of the crop is a popular vegetable in many parts of the world [46]. According to others [17], the leaves of the crop can also be added fresh and mixed with maize porridge in southern Africa, and they can also be dried and stored for later use in the off season. The seeds of the crop have been reported to contain high levels of oil that is comparable to those of sunflower and grape oil [47]. Other reports [48] indicated that bottle gourd was rich in protein, oil, and energy. Apart from these nutritional uses, bottle gourd has been used for decades in Asia as a root stock for watermelon to promote the root system under stressful conditions of water deficit and salinity [49], low temperature [50], as well as root-borne pathogens (Han et al., 2004 use numbers to cite references). In South Africa and the neighboring countries (Botswana and Zimbabwe), the oil is extracted from the seed and used as an alternative for vegetable oil [51]. According to other reports [17], the defatted cake can be used as a protein supplement in rural communities. *L. siceraria* seeds have been reported to contain about 45% oil and 35% proteins. [46] argued that the potential for bottle gourd as a food security crop lay on the use of its seed kernel in food and livestock industry. Given such benefits of the crop, it is a wonder that in South Africa, the benefits of the crop have not yet been fully exploited. The country is still faced

with the problem of malnutrition. In recent years, obesity has increasingly become problematic in both rural and urban communities. High incident of stunted, underweight children, and increasing infant mortality due to marasmus and Kwashiorkor have been reported [17]. The use of bottle gourd seeds or defatted cake could help in mitigating protein deficiencies in rural communities. Oil extracted from bottle gourd is reported to be rich in sterolic compounds and fatty acids [47]. Thus, the use of bottle gourd seeds could contribute significantly in providing much needed amino acids in the diets of vulnerable communities. Nutritionists have argued that inclusion of leafy vegetables in diets could increase dietary diversity, nutrient availability, and absorption contributing to the reduction of malnutrition [52]. A report [19] indicated that the crop to form excellent diet that is rich in iron, vitamins, and minerals. In addition, the seeds and fruit of the crop can also be used to supplement livestock feeds in rural communities where grazing land is also becoming a problem. Observations in Zimbabwe have shown that leaves, seeds, and fruits are being used to supplement livestock feeds [53]. It has also been reported [17] that bottle gourd also contained sodium, potassium, essential elements, and trace minerals. They concluded that the crop could be useful to hypertensive patients since it contained high levels of potassium and sodium. Global population and that of South Africa continue to increase rapidly. This necessitates the production of more food to meet the growing demand by the increasing population. To achieve this, it is necessary for the country to look at the diversity that exists in traditional crops. Another problem that the country and the world face is that of climate change. It is important therefore to also look for diverse crops that can withstand high temperatures and possible outbreak of diseases in order to ensure food security, especially in the marginal areas of crop production. This makes bottle gourd attractive for a range of uses.

7. Conclusions

Bottle gourd landrace is an underutilized crop with a huge potential to contribute to food security. This crop has been growing in marginal areas of crop production characterized by water stress and salinity for hundreds of years, and thus, it is believed to be adapted to these conditions. The crop can strive well in the field with minimal agricultural inputs such as water and fertilizer and the use of herbicides and pesticides. The crop contains beneficial nutrients and medicinal properties that are beneficial to humans. The crop seeds have also been used in livestock supplements where the seed served as the protein source. Therefore, with the countries in sub-Saharan Africa faced with the problem of malnutrition, it is important to investigate the diversity of crops that are suited in these areas characterized by drought stress while at the same time providing enough nutrition to safeguard food security.

Conflict of interest

The authors declare no conflict of interest.

Author details

Nkanyiso J. Sithole[1*], Khayelihle Ncama[2], Lembe S. Magwaza[3,4*], Nozipho M. Motsa[5] and Jacob Mashilo[6]

1 Faculty of Natural and Agricultural Sciences, Department of Crop Sciences, North-West University, Mmabatho, South Africa

2 Faculty of Natural and Agricultural Sciences, Food Security and Safety Niche Area, North-West University, Mmabatho, South Africa

3 Discipline of Crop Science, School of Agricultural, Earth and Environmental Sciences, University of KwaZulu-Natal, Pietermaritzburg, South Africa

4 Horticultural Science, School of Agricultural, Earth and Environmental Sciences, University of KwaZulu-Natal, Pietermaritzburg, South Africa

5 Faculty of Science and Agriculture, Department of Agriculture, University of Zululand, Empangeni, South Africa

6 Limpopo Department of Agriculture and Rural Development, Towoomba Research Centre, Agriculture Regulatory and Technology Development, Crop Science Directorate, Bela-Bela, South Africa

*Address all correspondence to: nkanyisoj@gmail.com; justice.sithole@nwu.ac.za and magwazal@ukzn.ac.za

References

[1] United Nations. Department of Economics and Social Affairs, Population Division. World Population Prospects: The 2008 Revision. New York: United Nations Publications; 2009

[2] Department of Water Affairs and Forestry (DWAF). National Water Resource Strategy: Report. 1st ed. Pretoria, South Africa: Department of Water Affairs and Forestry (DWAF); 2002

[3] Hassan R. Climate change and African agriculture. Policy No. 28. Based on Durand (2006), "assessing the impact of climate change on crop water use in South Africa". In: CEEPA Discussion Paper No. 28, CEEPA. South Africa: University of Pretoria; 2006

[4] Sisulu S, Scaramella C. Food for Thought: A Climate for Ending Hunger. Skyways, February 2012. Kyalami, South Africa: Panorama publications; 2012. pp. 31-33

[5] Mabhaudhi T. Drought Tolerance and Water-Use of Selected South African Landraces of Taro (*Colocasia esculenta* L. Schott) and Bambara Groundnut (*Vigna subterranea* L. Verdc). PhD thesis. Pietermaritzburg, South Africa: Crop Science, University of KwaZulu-Natal; 2012

[6] Oelofse A, van Averbeke W. Nutritional value and water use of African leafy vegetables for improved livelihoods. Water Research Commission Report No TT 535/12. 2012:294-302

[7] Govender L, Pillay K, Siwela M, Modi A, Mabhaudhi T. Food and nutrition insecurity in selected rural communities of KwaZulu-Natal, South Africa-linking human nutrition and agriculture. International Journal of Environmental Research and Public Health. 2016;**2016**(14):17. DOI: 10.3390/ijerph14010017

[8] Dakora FD, Belane AK. Evaluation of protein and micronutrient levels in edible cowpea (*Vigna Unguiculata L.* Walp.) leaves and seeds. Frontiers in Sustainable Food System. 2019;**3**:70. DOI: 10.3389/fsufs.2019.00070

[9] Modjadji P, Madiba S. The double burden of malnutrition in a rural health and demographic surveillance system site in South Africa: A study of primary schoolchildren and their mothers. BMC Public Health. 2019;**19**:1087. DOI: 10.1186/s12889-019-7412-y

[10] FAO, IFAD, UNICEF, WFP, WHO. The state of food security and nutrition in the world 2022. In: Repurposing Food and Agricultural Policies to Make Healthy Diets more Affordable. Rome: FAO; 2002. DOI: 10.4060/cc0639en

[11] Schippers RR. African Indigenous Vegetables. An Overview of the Cultivated Species 2002—Revised Version on CD-ROM. Aylesford, UK: Natural Resources International Limited; 2002

[12] Laker MC. Introduction to the special edition of water SA on indigenous crops, water and human nutrition. Water SA. 2002;**33**:317-326

[13] Modi M, Modi AT, Hendriks S. Potential role of wild vegetables in household food security: A preliminary case study in KwaZulu-Natal, South Africa. African Journal of Food Agriculture Nutrition and Development. 2006;**6**:1-13

[14] Schonfeldt HC, Pretorius B. The nutrient content of five traditional south

African dark vegetables-a preliminary study. Journal of Food Composition and Analysis. 2011;**24**:1141-1146

[15] Odhav B, Beekrum S, Akula U, Baijnath H. Preliminary assessment of nutritional value of traditional leafy vegetables in KwaZulu-Natal, South Africa. Journal of Food Composition and Analysis. 2007;**20**:430-435

[16] Decker-Walter DS, Wilkins-Ellert M, Chung S, Staub JE. Discovery and genetic assessment of wild bottle gourd [*Lagenaria siceraria* (Mol.) Standley; Cucurbitaceae] from Zimbabwe. Economic Botany. 2004;**58**:501-508

[17] Chimonyo VGP, Modi AT. Seed performance of selected bottle gourd (*Lagenaria siceraria* (Molina) Standl.). American journal of. Experimental Agriculture. 2013;**3**:740-766

[18] van Wyk BE, Gericke N. People's Plants: A Guide to Useful Plants of Southern Africa. Pretoria, South Africa: Briza Publications; 2001. p. 325

[19] Milind P, Satbir K. Is bottle gourd a natural guard? International Research Journal of Pharmacy. 2011;**6**:13-17

[20] Han JS, Mok IG, Park HG, Kim CK. Efficient plant regeneration from the cotyledon explants of bottle gourd (Lagenaria siceraria Standl.). Plant Cell Reports. 2004;**23**:291-296. DOI: 10.1007/s00299-004-0846-3

[21] Rahman ASH. Bottle gourd (Lagenaria siceraria): A vegetable for good health. Natural Product Radiance. 2003;**2**:249-254

[22] Chivenge P, Mabhaudhi T, Modi AT, Mafongoya P. The potential role of neglected and underutilised crop species as future crops under water scarce conditions in sub-Saharan Africa. International Journal of Environmental Research and Public Health. 2015;**12**:5685-5711. DOI: 10.3390/ijerph120605685

[23] Jones L, Carabine E, Roux JP, Tanner T. Promoting the Use of Climate Information to Achieve Long-Term Development Objectives in Sub-Saharan Africa: Results from the Future Climate for Africa Scoping Phase. Oxford, UK: Future Climate For Africa; 2015

[24] Mudau FN, Chimonyo VGP, Modi AT, Mabhaudhi T. Neglected and underutilised crops: A systematic review of their potential as food and herbal medicinal crops in South Africa. Frontiers in Pharmacology. 2022;**12**:809866. DOI: 10.3389/fphar.2021.809866

[25] International Panel on Climate Change (IPCC). Working Group 1 Fourth Assessment Report "The Physical Science Basis". 2017. Available online: http://www.ipcc-wg1.unibe.ch/publications/wg1-ar4/wg1-ar4.html. [Accessed: May 22, 2017]

[26] Singh P, Wani SP, Pathak P, Sahrawat KL, Singh AK. Increasing crop productivity and water use efficiency in rainfed agriculture. In: Integrated Watershed Management; Wani, SP, Rockstrom J, SaHrawat L, Eds.; London, UK: CRC Press; 2011; charpter 10, p. 315-348

[27] Schippers RR. Traditional vegetables in Africa. In: Proc. Int. Symp. On the Nutritional Value and Water Use of Indigenous Crops for Improved Livelihoods. (Available on CDROM). Pretoria, South Africa: Univ. Pretoria; 2006

[28] Nass LL, Parterniani E. Pre-breeding: A link between genetic resources and

maize breeding. Scientia Agricola. 2000;**57**:581-587

[29] Azam-Ali SN. Fitting underutilized crops within research-poor environments: Lessons and approaches. South African Journal of Plant and Soil. 2010;**27**:293-298

[30] Mashilo J, Shimelis H, Odindo A. Genetic diversity of bottle gourd (*Lagenaria siceraria* (Molina) Standl.) landraces of South Africa assessed by morphological traits and simple sequence repeat markers. South African Journal of Plant and Soil. 2015;**33**:113-124. DOI: 10.1080/02571862.2015.1090024

[31] Mkhize P, Mashilo J, Shimelis H. Progress on genetic improvement and analysis of bottle gourd [*Lagenaria siceraria* (Molina) Standl.] for agronomic traits, nutrient compositions, and stress tolerance: A review. Frontiers in Sustainable Food Systems. 2021;**5**:683635. DOI: 10.3389/fsufs.2021.683635

[32] Oval Myers J, John HY, Krishnamani MRS. Breeding soyabean for drought resistance. Plant Breeding. 1986;**4**:203-232

[33] Blum A. Drought resistance – It is really a complex trait? Functional Plant Biology. 2011;**38**:753-757

[34] Blum A. Drought resistance, water-use efficiency, and yield potential – Are they compatible, dissonant, or mutually exclusive? Australian Journal of Agricultural Research. 2005;**56**:1159-1168

[35] Araus J, Slafer GA, Reynolds MP, Royo C. Plant breeding and drought in C3 cereals: What should we breed for? Annals of Botany. 2002;**89**:925-940

[36] Kavar T, Maras M, Kidric M, Sustar-Vozlic J, Meglic V. Identification of genes involved in the response of leaves of Phaseolus vulgaris to drought stress. Molecular Breeding. 2007;**21**:81-87

[37] Turner NC, Wright GC, Siddique KHM. Adaptation of grain legumes (pulses) to water-limited environments. Advances in Agronomy. 2001;**71**:123-231

[38] Mitchell J, Siamhan D, Wamala MH, Risimeri JB, Chinyamakobvu E, Henderson SA, et al. The use of seedling leaf death score for evaluation of drought resistance of rice. Field Crops Research. 1998;**55**:129-139

[39] Farooq M, Wahid A, Kobayashi N, Fujita D, Basra SMA. Plant drought stress: Effects, mechanisms and management. Agronomy for Sustainable Development. 2009;**29**:185-212

[40] Sithole NJ, Modi AT. Responses of selected bottle gourd [*Lagenaria siceraria* (Molina Standly)] landraces to water stress. Acta Agriculturae Scandinavica, Section B — Soil and Plant Science. 2015;**65**:350-356

[41] Mashilo J, Odindo AO, Shimelis HA, Tesfay SZ MP, Magwaza LS. Drought tolerance of selected bottle gourd [*Lagenaria siceraria* (Molina) Standl.] landraces assessed by leaf gas exchange and photosynthetic efficiency. Plant Physiology and Biochemistry. 2017;**120**:75-85

[42] Mashilo J, Odindo AO, Shimelis HA, Musenge P, Tesfay SZ, Magwaza LS. Photosynthetic response of bottle gourd [*Lagenaria siceraria* (Molina) Standl.] to drought stress: Relationship between cucurbitacins accumulation and drought tolerance. Scientia Horticulture. 2018;**231**:133-143

[43] Welman M. National Herbarium, Pretoria. South African National Biodiversity Institute (SANBI); 2005.

Also available on line: http://www.plantzafrica.com/plantklm/lagensic.htm. Accessed July 30, 2022

[44] Awasthi BD. Relevance of Market Information System to Environment Protection. Ministry of Agriculture and Co-operatives: Singhdurbar; 2012. pp. 46-54

[45] Ghule VB, Ghate MH, Saoji AM, Yeole PG. Hypolipidemic and antihyperlipidemic effect of Lagenaria siceraria (Mol.) fruit extracts. Indian Journal of Experimental Biology. 2006;**44**:905-909

[46] Prasad R, Prasad A. A note on the heritability and genetic advance in bottle gourd (*Lagenaria siceraria* (Mol.) Standl.). Indian Journal of Horticulture. 1979;**36**:446-448

[47] Axtell BL, Fairman RM. Minor Oil Crops: Edible oils Food and Agriculture Organization of the United Nations. 1992. Available: http://www.fao.org/docrep/X5043E/X5043E00.htm. [Accessed: September 10, 2022]

[48] Loukou AL, Lognay G, Barthelemy JP, Maesen P, Baudoin JP, Zoro BI. Effect of harvest time on seed oil and protein contents and compositions in the oleaginous gourd *Lagenaria siceraria* (Molina) Standl. Journal of Science Food and Agriculture. 2011;**91**:2073-2080

[49] Park M, Won H, Kim J, Han J, Ahn Y. Expression of H+ phosphatase from Arabidopis enhances resistance of drought stress in transgenic bottle gourd (*Lagenaria siceraria* Standl.). In: Sari, Somlaz, Aras, editors. Proceedings of Xth EUCARPIA Meeting on Genetics and Breeding of Cucurbitaceae. Antalya (Turkey): University of Cukurova, Ziraat Fakultesi; 2012

[50] Yetisir H, Sakar M, Serce S. Collection and morphological characterization of Lagenaria siceraria germplasm from the Mediterranean region of Turkey. Genetic Resource Crop Evolution. 2008;**55**:1257-1266

[51] Grubben GJH, Denton OA. Plant Resources of Tropical Africa 2. Vegetables. Wageningen, Netherlands: PROTA foundation, Wageningen, Netherlands/Backhuys Publishers, Leiden, Netherlands/CTA; 2004

[52] Maunder EMW, Meaker JL. The current potential contribution of home-grown vegetables to diets in South Africa. Water SA (Special Edition). 2007;**33**:401-406

[53] Chikwanha OC. Seasonal Changes in Body Condition Scores of Pigs and Chemical Composition of Pig Feed Resources in a Semi-Arid Smallholder Farming Area of Zimbabwe. MSc thesis,. Harare, Zimbabwe: Department of Animal Science, University of Zimbabwe; 2006