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Scope of Horse Gram and Bambara Groundnut as Source of Food and Feed Legume: A Review

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ABSTRACT

Underutilized legumes are nutritionally important group of crops with immense medicinal values and contribute significantly as a resource of profit to the poor farmers. Horse gram (*Macrotyloma uniflorum*) and Bambara groundnut (*Vigna subterranean*) are two such underutilized legumes largely grown in India and other South Asian countries contribute significantly to the diet of poor people during adverse climatic condition particularly to them who cannot afford to grow pulses that require balanced nutrition. They are fit for diversification, green manuring and may be used as cover crops and also thrive well under stressful dry environment. Changing lifestyle and climate variability bring enough scope for their cultivation and profitability. Horse gram is medicinally superior to other traditionally consumed pulses and can fight against *Bacillus subtilis*, *Staphylococcus aureus*, *Escherichia coli* and *Pseudomonas aeruginosa*. Besides its use as fodder crop, it cures urinary stones, gastritis, excessive post-partum bleeding, rheumatism, coronary heart disease, diabetes, *etc*. Bambara groundnut has distinctive drought adaptations and is suitable under semi-arid climate. Extract of Bambara groundnut is used as weaning food in African countries. The present review focuses on origin, morphology, genetic diversity, traditional uses, nutritional and medicinal importance, potential as food and fodder crop and constraints to higher productivity of both horse gram and Bambara groundnut.

Key words: Bambara groundnut, Fodder, Horse gram, Medicinal, Nutritional, Underutilized legumes.

The rapid population growth, frequent climate change and depletion of resources are among the most challenges being faced by the plant scientists in the last few decades and therefore, there is extreme need to explore the natural resources further to mitigate the increasing demand of food. The recent history on food habit indicates that people are losing diversity from their dishes due to over-dependency on very few and highly modified field crops. There is no doubt that the principal field crops such as rice, maize and wheat with high productivity have prevented millions of deaths from hunger. Climate change is coming up as the worst threat to many secondary yet severe problems (Prasath *et al*. 2021). The mono cultivation of crops in higher density has broken up the interrelationship of plant-microbe-soil interaction, resulting from the complete dependency of crops on humans for all growth and survival requirement. Consequently, the present crop genetic diversity is not wide enough to combat the multiple biotic and abiotic stresses posed by climate change.

One of the ways to mitigate these issues might be introduction, genetic improvement and utilization of underutilized crops. They are often a significant component of the culture and nutrition of people worldwide and have been a rich source of various nutrients and medicines in the past. However, industrialization and increased standard of living as well as purchasing power have changed people's lifestyles and food habits. Once considered essential for their nutritional and medicinal richness, the crops are now not a part of urban food habits and are limited only to rural and tribal food habits. The term underutilized is synonymously used for "orphan," "new crop," "minor," undervalued" and "neglected" for crops fallen to disguise yet potential. The potential of underutilized crops to the national economy has neither been explored nor been paid due attention towards their cultivation. The Global Facilitation Unit for underutilized species (GFU) also defines them as "those species with a potential, not fully exploited, to contribute to food security and poverty alleviation...' and that tend to have the following standard features: a strong link to cultural heritage; poorly documented and researched; adapted to specific agro-ecological niches; weak or non-existent seed supply systems; traditional uses and produced with little or no external inputs". These crops lack adequate research and are not recognized as significant crops.

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The underutilized legume crops are of immense medicinal value in treating the day to day ailments and meeting the nutritional requirements which other conventional legume crops may fail to provide. Moreover, the amount of land available for fodder production has been diminishing and consequently the livestock is put to a huge hardship due to lack of total feed and fodder. A net shortfall of 35.6% green fodder, 10.95% dry crop residues and 44% concentrate feed ingredients exists in the country right now (Kumar *et al*., 2019). The development of high-quality fodder is especially crucial to cattle because feed accounts for 60-70 per cent of the cost of milk production (Kumar *et al*., 2020). This is where the role of underutilized legumes is important to support lack of quality fodder particularly, where other fodder crops may fail to sustain. The reason behind many potential crops to remain underutilized despite their numerous benefits and only selective crops to be actively encouraged in research as well as production might date back to colonial era when global colonizing powers had introduced few crops in new areas as cash crops which gradually replaced local legume crops. The traditional subsistence farming systems rely on underutilized legume crops to ease their hunger during droughts and famine (Anitha *et al*. 2006). In addition, these underutilized legume crops provide greater genetic miscellany and improve food security. Sustainable agricultural models identify these high valued but currently underutilized legume crops as critical component.

Scope of underutilized legumes

Looking at the greater prospect, based on genetic diversity, sturdy nature, traditional use as well as their potential role in human and livestock nutrition, present review has been focused on two underutilized legume crops, *viz*., horse gram (*Macrotyloma uniform*) and Bambara groundnut (*Vigna subterranean*) (Fig 1).

Origin, morphology and genetic diversity

Horse gram

Based on various pre-historic cultivation evidences, Horse gram is native to tropical southern Asia and has been found in archaeological sites in India, since 2500 BC. It was probably first domesticated in India. The name “horse gram” might have been coined due to its use as fodder for the horses for extra stamina. The crop is now placed in genus *Macrotyloma* by Verdecourt in 1982 and known as *Macrotyloma uniflorum* (Fabaceae) but it was formerly known as “*Dolichos biflorus* Linn,”.

While Horse gram (*M. uniflorum*) is widely distributed in Asia, Africa and Australia, its close relatives, *i.e*., *M. ciliatum* are common in Asia and Africa, *M. axillare* in Australia and other species under genus *Macrotyloma* are sparsely distributed in Africa (Dikshit *et al*. 2013). It is a self-pollinated annual herb; bears trifoliate leaves of 2.5-5.0 cm, produces light yellow flowers and can attain a height of 30-35 cm. The crop duration is 120-150 days. Each pod contains five to seven seeds of 3-6 mm length with light red to brown or mottled colour. Apart from a few organizations like GRIN (Germplasm Resources Information Network), KARI (Kenya Agricultural Research Institute) and Australian Tropical Crops and Forage Genetic Resources Centre, global efforts to conserve germplasm of horse gram are very much lacking and the crop remains ignored by the researchers as well. Recently, a collaborative project between the Indian Agricultural Research Institute and the United States Department of Agriculture, germplasm conservation of horse gram started in 1970s and they are being maintained by NBPGR (National Bureau for Plant Genetic Resources). The project identified several specific traits of interest, such as

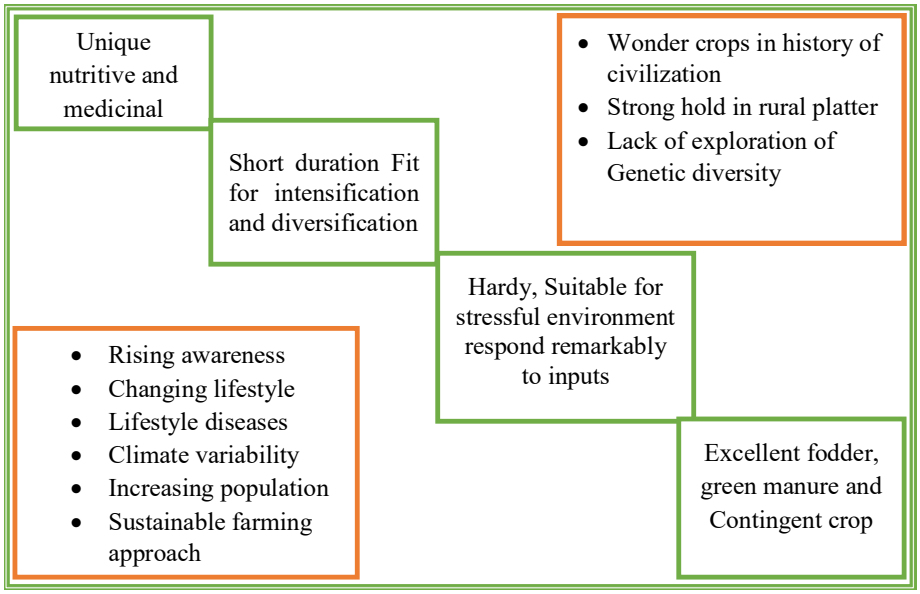

Fig 1: Scope of underutilized legumes.

yellow mosaic resistance of *M. axillare* and also the potential of *M. axillare, M. daltonii* and *M. africanum* as valuable leguminous forage crop (Kumar, 2006). Research initiatives such as ICAR's Coordinated All India Network project on arid legumes have identified other essential characteristics like plant architecture, indeterminate growth habits, asynchronous maturity, photoperiod sensitivity, thermo sensitivity, low harvest index, *etc*., that can be utilized in advanced breeding techniques. However, much emphasis for genetic improvement and identification of useful wild species are pretty slothful with compared to other leguminous crops.

Bambara groundnut

More than 500 closely related herbarium species of Bambara groundnut have been identified from savannah belt (an extended area from the Atlantic Ocean to the Red Sea) of sub-Saharan Africa and thus this area is considered probable origin of this crop (Pasquet, 2004). The known distribution of Bambara groundnut extends from West to southern Africa *via* Central Africa (Hepper FN, 1963). Bambara groundnut (*V. subterrania*), like cowpea (*V. unguiculata*), is the primary grain legume species of Africa (Hasan *et al*. 2021). Domestication of Bambara groundnut dates back to ten thousand years when other major crops also were domesticated. The name (Bambara groundnut) might have been derived from the name of a tribe named Bambara whose members still live mainly in Mali. During the initial domestication, major characteristics focused were larger leaves, seeds and flower. However, unlike any other domesticated legume, two very distinctive characters were included: longer leaf petiole and shorter stem internode. Later on, selective breeding has resulted in thicker shell wall of pods for more protection from humidity and unintended early germination. Bambara groundnut has an impressive record of international collaboration to preserve the germplasm and scientists from several countries of Europe joined hands with the growers and traders of Africa in this regard.

It is a deep rooted plant that helps to withstand water stress. The papilionaceous flowers borne on raceme. Like groundnut, pods of Bambara groundnut develop under the ground or just above the ground. The crop is highly thermo- and photoperiod sensitive but it can tolerate acidic and poor soils. The leaves and the seeds of the crop have several ethnobotanical uses like treatment of abscesses and infected wounds. Based on internode length, there are three distinct types, *i.e*., bunch, semi-bunch and spreading. Modern cultivation practices have given more edge to the erect bunch type that facilitates higher plant density and response toward inputs. However, in spite of a lower plant population per unit area the capability of spreading type to withstand aberrant climatic conditions, especially drought, may be harnessed as it can produce significant yield. Another way of characterization based on the number of seeds per pod emerged from the Cameroon area where one-seeded pod is classified as "Northern Group" and two or four seeded as "Southern group".

Traditional use of horse gram and bambara groundnut

Traditional use of horse gram

Culturally, horse gram is used for dal or rasam making but it is consumed whole as sprouted also. It is called kulattha, kolatha, kulthi, ulavalu, hurali, kollurmuthira, *etc*., in different regions of India. Besides pulse crop, it is grown as livestock fodder, green manure and medicinal crop. Previously, only tribal people used to consume sprouted seeds for excellent nutritional benefits. Due to risen health consciousness sprouts and dal have become common among the urban class people as well. Considering ethnomedicinal value, as mentioned in classical Indian texts like *Charak Samhita* and *Sushruta Samhita* the seeds of horse gram are traditionally used for medicine preparations to treat urinary stones ("gahot" meaning to destroy kidney stones) (Ravishankar and Vishnu Priya, 2012), abnormal menstrual cycles (Chirania and Sharma, 2021), piles, worms, obesity (Ingle *et al*. 2020), tooth calculus, extracts phlegm, common cold, throat infection, fever and is known to generate body heat suitable during winter days (Prasad and Singh, 2015). The seed extract is known to cure gastritis, excessive post-partum bleeding, rheumatism, coronary heart disease, diabetes, *etc*. (Kaundal *et al*. 2019).

Traditional use of bambara groundnut

Bambara groundnut also known as Bambara pea or Bambara nut in Africa is an underutilized legume but it is the third most consumed legume, trailed by groundnut and cowpea in the African continent. In the past, there was a general acuity about Bambara groundnut in Zimbabwe that "it grows on poor land and is consumed by the poor people or by women", which was one of the reasons for its limited market share. However, awareness about the benefit of the crop has led to increased consumption and consequently wide cultivation leading to more market share.

Traditionally, the raw Bambara groundnut is processed in several ways, such as roasting, sprouting and fermentation before being consumed. The most common processing step is cleaning the seeds thoroughly, soaking in lukewarm water for twenty-four hours, sprouting for seventy-two hours inside a wet jute bag, drying at 60°C and finally milling. The fermented Bambara groundnut has also been reported where boiled seeds are tightly wrapped in plantain leaves and allowed to ferment for four days and then they are dried and milled.

Bambara groundnut is also used in place of cowpea while preparing *Akara*, a deep-fried snack prepared with dehulled legume paste or in *Okpa,* which is a steamed food product. The flour along with pepper, salt, oil and onion is used to prepare *Akpekpa,* a steamed snack of gel consistency that is widely popular in Nigeria. *Tubani,* a flour-based snack of steamed Bambara groundnut is quite popular in Ghana. The proximate composition analysis indicates raw

Bambara groundnut flour contains about 51-71% carbohydrate, 18-24% crude protein, 4-12% ether extract (oil), 3-12% crude fibre and 3-12% ash (Mayes *et al*. 2019). Murevanhema and Jideani (2015) have pointed out that Bambara groundnut can also produce plant-based milk like soybean, which is sometimes used as weaning food in several African countries.

Bambara groundnut has also been extensively used as traditional medicine in African continent. The white grains are sometimes boiled with the meat of guinea fowl for the treatment of diarrhoea, while flour is used to treat skin rashes (Akpalu, 2015).

Nutritional and medicinal importance

In recent times, legumes have been gaining much attention globally due to increased awareness of the consumers regarding the multitude of nutritional and health benefits like curing several ailments since ages as mentioned in ancient scripts. In addition, the global vegan movement also acts as a driving force for increased demand for vegetable protein, making legumes as the crop of this millennium. However, to meet this demand, the first and foremost step is to evaluate the nutritional profile of different utilized and underutilized legumes then detect and remove anti-quality factors and biofortification.

Horse gram

Looking at the nutritional and therapeutic benefits, there is an increasing trend of research on underutilized legumes to combat climate change and at the same time to alleviate malnutrition and to lower the risk of numerous diseases among the people of underdeveloped countries during the present days. Horse gram contains exceptionally high dietary fibre, with various mineral nutrients and bioactive phytochemicals. The seeds contain substantial amount of protein, carbohydrate and essential amino acids, low fat and high Fe, Mo, P, pro-vitamin Beta-carotene, B1 (thiamine), B2 (riboflavin), B3 (niacin), Vitamin C (ascorbic acid) (Fig 2). Protein content in horse gram varies from 18.5 to 28.5 percent, of which albumin-globulin accounts for 3/4th of the total protein. Its lysine (550 mg/g) content is higher than that of pigeon pea (480 mg/g) and black gram (400 mg/g) (Prasad and Singh, 2015). However, methionine and tryptophan limit amino acids (Thirumaran and Kanchana 2000). Carbohydrates constiutute 50-70 per cent of total dry matter in seeds, of which 43 per cent is resistant starch. Fermentation of resistant starch in the large intestine after bypassing the small intestine produces butyrate that prevents malignant tumor cells, colorectal cancer (Scheppach *et al*. 1995), moderate blood pressure, reduce constipation and reduce cholesterol.

In addition to nutrients, content of certain non-nutritive bioactive compounds like phenolics, flavonoids, lectins and tannins play vital role in disease prevention and other metabolic and physiological effects (Gupta and Abu-Ghannam, 2012). Allergy to horse gram bioactive compounds have not been reported so far unless eaten in raw form. Nutraceuticals are food or part of food that help in the prevention, protection and/or treatment of coronary heart disease, diabetes, obesity and have other health benefits resulting from biochemical and cellular interactions. The horse gram seeds can fight against *Bacillus subtilis*, *Staphylococcus aureus*, *Escherichia coli* and *Pseudomonas aeruginosa* (Gupta *et al*. 2005). Pterocarpans Dolichin A and B, pyro glutaminyl glutamine isolated from horse gram have free radical scavenging activity (antioxidant property). The known anti-nutritional factors like phenols, tannins, phytic acids, saponins and oligosaccharides are studied to have potential antioxidative properties and are antidiabetic (Lalitha *et al*. 2020), anticarcinogenic (Muricken and Gowda, 2011), prevent kidney and intestinal disorders, hypocholesterolemia (Aditya *et al*. 2019), *etc*. Though phytic acids are hard to cook, they reduce digestibility and reduce the bioavailability of micronutrients, it is potentially known for anticarcinogenic property as it reduces abnormal cell proliferation and atherosclerotic lesions. Horse gram is rich in phenolic acid (3.5 mg gallic acid equivalent/g). Quercetin, kaempferol and myricetin, as well as vanillic, hydroxybenzoic and ferulic acids, that are the main phenolic compounds in horse gram seeds (Sreerama *et al*. 2010a). Phenolics help dilate blood vessels, apoptosis, enzyme activation, *etc*. They have anti-inflammatory, antiallergic, antiviral properties. Oligosacc harides are fermented anaerobically by *clostridia sps*. in the large intestine, it produces a mixture of carbon dioxide, hydrogen, methane, hydrogen sulphide and ammonia (Dilis and Trichopoulou, 2009). However, they promote the growth of beneficial microflora in the colon, which feed on oligosaccharides and act as prebiotics important for human health. BBIs, a group of Bowman-Birk type protease inhibitors found in horse gram seeds, is known to inhibit serene protease and help in suppressing carcinogenesis. Therefore, horse gram can be justified as a functional food offering health benefits beyond nutrition. Fig 2 shows the nutrient composition of horse gram.

Bambara groundnut

The seed is regarded as balanced food because it contains about 10% iron, 3.24% ash, 22.2% crude protein, 6.6% fat, 7.5% potassium, 4.4% cellulose and 63.56% carbohydrates. A comparable fatty acid composition for seeds with cream and dark red seed coats has been reported. However, the level of palmitic and linoleic acids in Bambara groundnut was higher than those in groundnut (Ferrao *et al*. 1987). In addition, the seeds of Bambara groundnut contain 63% carbohydrate, 19% protein and 6.5% oil (Linnemann, 1987). From studies on proximate composition and particular functional properties of 4 cultivars of Bambara groundnut Onimawo *et al*. (1998) reported 17.5-21.1% crude protein, 7.3-8.5% crude fat, 4-5% total ash 1.8-2.0% crude fibre. However, carbohydrate and moisture content for the different cultivars were 53.0-60.8% and 7.5-12.3%, respectively. The functional property determinations indicated that the bulk density ranged between 0.65 and 0.75 g/ml, water binding

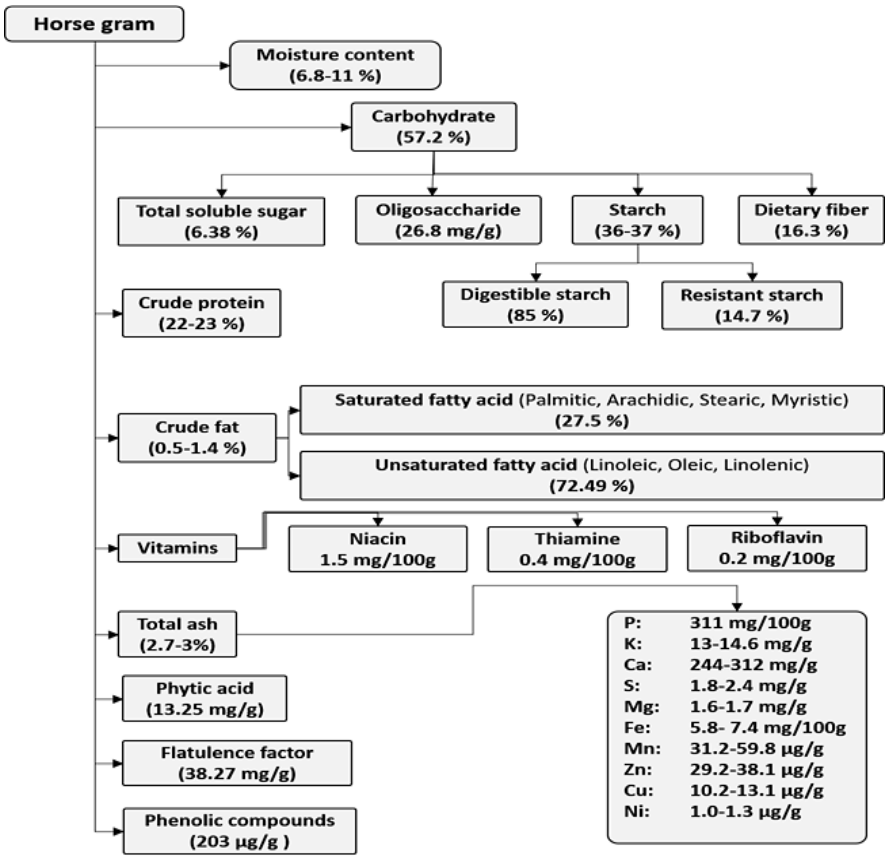

Fig 2: Nutritional composition of horse gram. (Sources: Bolbhat and Dhumal, 2012; Bravo *et al.* 1999; Gopala *et al.*1997; Gopalan *et al.* 1999; Khatun*et al.* 2013; Mishra and Pathan, 2011; Morris *et al.* 2011; Sreerama *et al.* 2010b; Sreerama *et al.* 2012).

capacity 2.1-2.9 g/2 g sample, oil binding capacity 0.9-1.6 g/2 g sample, emulsifying activity 55.1-60.0% and emulsifying stability 10-12%.

Potential as food and fodder crop

In addition to nutritional security to the livestock, forage legumes contribute to sustainable crop production. Such contributions are crucial for the nutritional security of mankind as they are integral components for the increased availability of animal protein and product which has higher biological value than plant proteins. A comparable quantity of legume forage and cereal forages/grasses at similar crop growth stages reveal that the former provides higher nutrition than the later, resulting improved animal performance (Kumar *et al*. 2020).

Horse gram

Problems of food security and malnutrition due to yield stagnation might be addressed by diversification of cropping systems through deliberate inclusion of non-conventional or underutilized crops particularly in the areas where other crops fail to grow. This hardy legume can thrive under stressful situations like drought, high temperature, salinity, heavy metals and biotic stress (Aditya *et al*. 2019). Due to short duration, it fits well into the existing cropping system as an intercrop and mixed crop. Crop intensification with legume crops improves soil fertility, reduces fertilizer and pesticide requirement and alleviates adverse environmental effects. It can thrive well under both physiological and physical drought condition. It survives on marginal lands with low available nitrogen, organic matter and also on coastal sandy soil. However, it cannot tolerate soil acidity, water logging and frost. The anti-nutritional factors such as phytic acid, oligosaccharides, trypsin inhibitors, *etc*., are reduced by soaking and cooking.

It grows on residual soil moisture and is an excellent green manure crop. Horse gram is a common *piara* crop in upland rice when soil moisture is limited. It is intercropped well with oilseeds, grasses and trees, with a 2:1 ratio of Niger and horse gram and horse gram between two rows of sorghum and groundnut. In double or sequence, winter horse gram follows upland rice, maize, sorghum in Odisha. The plant by-products such as residues, straw, pods, *etc*., are nutrient-dense and are preferred by livestock. In dryland areas, they serve as important forage crop during the lean period. The forage crop is ready for harvest in 6 weeks with a productivity of 50-140 q/ha. Seed meal is promising in animals' growth, development and maintenance (Aditya *et al*. 2019). It is an outstanding green manure and cover crop, helps in soil water conservation and integrated nutrient management, significantly contributing towards sustainable agriculture.

Bambara groundnut

Bambara groundnut also an underutilized crop might play significant role in sustaining the impoverished rural populations by increasing their available food and protein basket. Where groundnut and other traditional legumes failed to survive under dry spell conditions, this crop is known to produce relatively acceptable yields. Thus in the face of the lack of detailed comparisons of performance between legume species under drought conditions, Bambara groundnut having distinctive drought adaptation, necessitates research for further improvement. The minimum rainfall requirement of the crop was estimated to be 300 mm. However, during harvest, excessive rainfall results in drastic yield losses. Production is most suitable in regions with temperatures between 19°C and 30°C. Temperatures above 30°C result in heat stress. In India, this crop grows well under the western part of the country in a semi-arid climate. Therefore, the *Kharif* season where sowing is done in early July is preferable. The high yielding genotypes, *i.e*. DODR-TZ, S.B. 4-2 and S19-3, with a 117-133 days maturity period, could be suitable in other parts of India. The short duration genotypes AS-17 and S19-3 could be grown in Rajasthan, Maharashtra and Gujarat, where the growing period is short.

Constraints to higher productivity

The two crops under study are often grown neglected on hungry and thirsty soils and these crops are second in priority to the farmers. Abiotic constraints such as severe drought, water logging, heat stress, frost, hail storm, saline and alkaline soils, low pH, micronutrient deficiencies, *etc*. and biotic stresses like lack of suitable *Rhizobium* strain for biological nitrogen fixation, lack of biofertilizers and other insect pest and disease attack in certain agro-ecological niches often limit the adoption and productivity (Kumar, 2006). Physiologically flower drop, photosynthetic assimilation, harvest index are limiting. Shattering in Horse gram and other postharvest losses due to lack of storage conditions and processing facilities adds to it. In case of Bambara groundnut however, lack of improved variety is major constraint in India. It suffers from a lack of proper harvesting implement also. Lack of awareness and access to improved technologies, improved and certified seeds and proper varieties for a given soil and agro climate, mechanization, transport and marketing is the reason behind declining acreage (Aditya *et al*. 2019). Long duration cultivars suffer from terminal moisture stress and do not fit into the existing cropping system. Productivity of Bambara groundnut is mostly affected by several factors, *e.g*., biotic stresses like diseases caused by fungi, bacteria and viruses, insect pests and nematodes and abiotic stress, *e.g*., drought, extreme temperatures and extreme poor soil fertility and socio-economic factors.

CONCLUSION

A comprehensive review on nutritional, medicinal, food and fodder value of both horse gram and Bambara ground nut reveals that the former is a nutrient and anti-nutrient rich legume crop with nutritional value comparable but medicinal value superior to many other pulse crops. It has high amount of antioxidants, fibre, phytic acid and other bioactive components. The latter however, is a less popular pulse crop limited to African and some Asian countries with age old traditional usages. Both the crops are fit for diversification and suitable as fodder for enhancing livestock productivity. However, commercial cultivation of both the crops has still not gained enough momentum mainly due to lack of better and productive genotype and therefore, sufficient research work need to be taken up to evolve profitable varieties through exploitation of tolerance to biotic and abiotic stresses of both the crops.

Conflict of interset: None.

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