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Review Paper

NUTRITIONAL AND REMEDIAL POTENTIAL OF AN UNDERUTILIZED FOOD LEGUME HORSEGRAM (*Macrotyloma uniflorum)*: A REVIEW

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ABSTRACT

Underutilized legumes are important group of crops which has special significance in subsistence farming and nutritional security of resource poor masses in developing countries. Among underutilized legumes, horsegram (*Macrotyloma uniflorum),* family *Fabaceae* is one of the minor or lesser known neglected legume mainly cultivated in Asian and African countries as a dual purpose crop. It is a climate resilient legume which is well known for its drought hardiness and embraces favourable agronomic features suitable for cultivation on dry lands under poor fertility condition. It is comparable to other commonly consumed pulses in its nutritional value and serves as a cheap source of nutrition for unprivileged rural communities residing in inaccessible areas. Horsegram has excellent therapeutic properties and traditionally used to cure kidney stones, asthma, bronchitis, leucoderma, urinary discharges, heart diseases, piles etc. Besides, it also possess anti-diabetic, anti-ulcer activity and also helps in dietary management of obesity due to the presence of beneficial bioactive compounds. In the present review nutritional composition, antinutritional factors, medicinal properties and its possibilities to be exploited as functional/ medicinal food for health benefits are summarised.

Keywords: Antinutritional factors, *Macrotyloma uniflorum*, medicinal properties, nutraceutical and nutritional composition

INTRODUCTION

Food legumes are second most important group of crops after cereals which have been a vital ingredient of balanced human diet since millennia (Bhadana *et al*., 2013) and recognised as second most valuable plant source for human and animal nutrition (Bhatt and Karim, 2009) . In the developing countries, primarily a handful of conventional legumes dominating the production and market chains and playing crucial role in eradicating protein malnutrition still, some of the underutilized indigenous legumes like, horsegram [*Macrotyloma uniflorum* (L.) Verdc] has great significance in the nutritional security of rural, tribal and underprivileged masses (Tontisirin, 2014). Horsegram is one of the highly nutritious vegetable pulse crop with ethno-medicinal values in India, which is commonly known as *Kulattha* (Sanskrit), *Kurti-kalai* (Bengali), *Kollu* (Tamil), *Ullavallu* (Telgu), *Muthira* (Malyalam), *Gahot* (Kumaon and Garhwal) and etymologically, *Gahot* means "which destroys stone in initial stage" (Pati and Bhattacharjee, 2013; Pande, 1999). Underutilized legumes make a significant contribution to the diet of the rural households particularly, during drought, famine and dry season (Magbagbeola *et al*., 2010) besides, in many cases these are the life-savers for millions of resource poor people in the regions where ensuring food and nutritional security is one of the significant problems, particularly in traditional subsistence farming systems (Haq, 2002). Presently, attention towards underutilized legumes is increasing for finding new alternate protein sources to meet the ever increasing demand for vegetable protein (Pugalenthi *et al*., 2005). This neglected and under-valorised crop has great untapped potential to support smallholder rural farming communities by providing income, food and nutritional security as well as sustaining the genetic resources needed to address present and future environmental challenges (Kahane *et al*., 2013).

Horsegram belongs to family *Fabaceae* is a potential grain legume having excellent nutritional and remedial properties with better climate resilience to adapt harsh environmental conditions (Kumar, 2006). It is one of the most important unexploited food legume being grown in almost all over the world including temperate and sub-tropical regions encompassing the countries in East and Northeast Africa, Asian countries particularly, India, China, Philippines, Bhutan, Pakistan, Sri Lanka and Queensland in Australia (Durga, 2012; Krishna, 2010). Horsegram is cultivated as a low grade pulse crop in southern Asia, mainly from India to Myanmar and also grown as a forage and green manure in many tropical countries especially, in Australia and South-East Asia (Brink, 2006).

Horsegram is a short day, twining, succulent, annual climbing herb which has trifoliate leaves, white coloured flowers, long linear pubescent pods with curved beak, flattened small seeds with light red, brown, grey, black or mottled testa (Singh, 1991) with photo and

thermo sensitive nature (Kumar, 2006). It is mostly grown as catch crop especially under late summer (*Kharif*) or with the rains after a prolonged drought condition (Prakash *et al*., 2002).

Figure 1. a. Field view of crop b. Mature Plant, c. Pods, d. Different seed colours of horsegram

It matures in 4 to 6 months (Singh, 1991) and yield varies based on genotype and management such as, at 60 kg /ha phosphorus (P_2O_5) level, 25% improvement in seed yield was recorded compared to control and a positive impact on seed yield with the increase in plant densities from 2.66 lakh/ ha to 4.44 lakh/ ha (Keshava *et al*., 2007). Similarly, horsegram sown during first fortnight of August and September yielded significantly higher grain yield with less disease incidence compared to sown during first fortnight of October (Ganesha, 2001). Seed yield of horsegram usually varies from 0.13 - 1.2 tonnes/ha in India to 1.1-2.2 tonnes/ha in Australia whereas, green forage yield varies from 5-14 tonnes/ha in India and 4.4 tonnes/ha in Australia (Haq, 2011). It is also grown as a cover crop for soil and water conservation in semi-arid regions as well as found useful for improving soil fertility and integrated fertility management in dry land agriculture (Reddy *et al*., 2008). This underexploited grain legume has great significance in sustainable agriculture (Anitha *et al*., 2006) as well as dry land agriculture in tropics and subtropics (Kadam and Salunkhe, 1985; Jinka *et al*., 2009). Horsegram germinates reasonably well in drought-prone areas with very poor soils (where other crops invariably fail to grow) due to Dehydrins (MuDHN1, MuDHN2 and MuDHN3) which appeared to be the principle stress-responsive genes in various abiotic stresses (Ramya *et al*., 2013) besides, it is relatively tolerant to low to moderate salinity levels with pH up to 8 (Mehra and Upadhyaya, 2013) and heavy metal stresses compared to other pulse crops grown in semi-arid regions (Reddy *et al*., 2008). However, it is sensitive to water logging (Smartt, 1990) and completely intolerant of frost (Jones, 1969). Drought tolerance capacity of horsegram is attributed in parts to various pathways like antioxidant and osmolyte biosynthesis, making it sturdy enough to withstand long periods of drought with minimum management (Bhardwaj *et al*., 2013). It also exhibits amazing defence against attack by pests/pathogens and the possible source of the indomitable pest resistance may be due to a dual-function protein that exhibits both lectin and lipoxygenase like functions (Roopashree *et al*., 2006). The crude extracts of horsegram plant possess compounds with antimicrobial properties with a broad-spectrum of activity against both gram-positive and gram-negative bacteria and fungi (Kawsar *et al*., 2008).

Horsegram is an excellent crop for intercropping with various cereals like sorghum, pearl millet, finger millet, maize and little millet (Krishna, 2010). Intercropping maize with improved varieties of horsegram reduced labour cost since less weeding required in the intercrop as the horsegram smothered weeds and in most cases intercropping did not have a yield-reducing impact on their maize crop or on the availability of fodder (Witcombe *et al*., 2008). In many parts of India, horsegram is traditionally grown as mixed crop, in Karnataka, *Panch Dhani* is a common practice in which seeds of horsegram, Indian bean, cow pea, niger and castor are mixed and grown to combat drought (Kumar, 2006). Similarly, it is a component crop in traditional mixed cropping "*Barah Anaaja*" practiced from centuries in Uttarakhand hills of India in which seeds of twelve food grains are mixed and grown (Zhardhari, 2001). Mixed cropping of finger millet with horsegram found more profitable as compared to millet mono crop (Prasad *et al*., 2010). Better growth and development of lower crop canopy and pods in horsegram + finger millet intercropping system due to improved light penetration (1.3% in sole horsegram to 6.9% in horsegram + finger millet) as well as higher net

return and benefit: cost ratio reported under horsegram + finger millet (1:1) followed by horsegram + maize (2:1) under hilly agro-ecosystem of India (Kumar *et al*., 2010). Besides, intercropping allows lower inputs through reduced fertilizer and pesticide requirements, thus minimizing environmental impacts of agriculture (Lithourgidis *et al*., 2011). Horsegram is an ideal crop for a number of double/sequence/rotation combinations in different climatic and geographic zones with annuals, perennials, grasses *etc*. therefore, proved vital component in cropping system (Kumar, 2006).

Origin, habitat and climatic requirement: It is native to the old world tropics (Nene, 2006) and indigenous to India (Vavilov, 1951; Smartt, 1985). Archaeological investigations have revealed the use of horsegram as food especially in India as origin around 2000 BC (Mehra, 2000; Prakash *et al*., 2010). Horsegram belongs to the genus *Macrotyloma* contains 25 species indigenous to Africa and Asia (Lackey, 1981). Presence of wild or naturalized horsegram is recorded in Africa (Central, East and Southern Africa) and India (Verdcourt, 1982; Brink, 2006). The primary centre of origin and use of horsegram as a cultivated plant is in the plains and hills of low altitude extending southwards in the Western Ghats in South West India (Arora and Chandel, 1972). During Neolithic period through counter migration of human beings its cultivation was diffused to northern and western part of Indian subcontinent (Mehra, 2000; Fuller *et al*., 2004). It is generally grown under sub-humid to semi-arid climate with annual rainfall 300-600 mm (Krishna, 2010) and with less than 30 cm rainfall as dry land crop up to an elevation of 1800 m from mean sea level (Haq, 2011).Optimum temperature range for its growth is 25^0 to 32^0C and can tolerate temperature up to 40^0C but the growth rate declining markedly below 20^0C (Krishna, 2010; Mehra and Upadhyaya, 2013).

Nutritional composition: Grain legumes are an important source of nutrients and renowned as poor man's meat especially in developing countries (Hayat *et al*., 2014). Horsegram has been recognised as potential source of protein and other nutrients (Sreerama *et al*., 2012). It has high nutritional value (Table 1) equivalent to other commonly grown pulse crops in all aspects and also an excellent source of iron, molybdenum and calcium (Prasad *et al*., 2010; Tuteja, 2008; Bhokre, 2012). Horsegram seed contains carbohydrate (57.2%), protein (22%), dietary fibre (5.3%), fat (0.50%), calcium (287mg), phosphorous (311mg), iron (6.77mg) and calories (321 Kcal) (Gopalan *et al*., 1999) as well as vitamins like thiamine (0.4mg), riboflavin (0.2mg) and niacin (1.5mg) per 100g of dry matter (Bolbhat and Dhumal, 2012). However, several factors like the genotype, soil, fertilizer application, cultural practices, weather and climatic factors, postharvest handling and storage can directly or indirectly affect the nutritional quality (Hornick, 1992). Horsegram seed is low in fat and is excellent sources of protein, dietary fibre, a variety of micronutrients and phytochemicals (Sreerama *et al*., 2012) still it has remained an underutilized food legume, consumed only by the farming communities of inaccessible areas and low-income groups (Aiyer, 1990).

Carbohydrate: Carbohydrate content ranges from 50-60% in commonly consumed pulses (Bains and Brar, 2005). Carbohydrate includes starch, monosaccharides, oligosaccharides and other polysaccharides (Ekanayake *et al*., 2000). In the legume seeds, starch is the major source of available carbohydrate and most abundant (22–45%) along with oligosaccharides (1.8-18%) and dietary fibre (4.3-25%) (Hoover and Zhou, 2003; Ofuya and Akhidue, 2005). In whole and dehulled horsegram seeds, carbohydrate content ranged from 51.9-60.9% and 56.8-66.4% respectively (Sudha *et al*., 1995). Carbohydrate of raw horsegram seeds comprises 36±1.17g starch per 100g dry matter in which approximately 85% digestible, 14.47% resistant and 3.38% resistant starch associated to insoluble dietary fibres (Bravo *et al*., 1999). Horsegram has high non-digestible carbohydrate content which cause lower glucose release into the blood stream with potential beneficial effects in the dietary management of diabetes and this resistant starch is regarded as a prebiotic among the new generation of dietary fibres (Samanta *et al*., 2011). Horsegram seed contains 6.38% total soluble sugars (Bravo *et al*., 1999) of which 55–65% constitute flatulence-producing raffinose family oligosaccharides (RFO), stachyose and verbascose (Machaiah and Pednekar, 2002) and processing such as soaking, cooking and sprouting may bring about changes in the levels of oligosaccharides.

Crude protein: Horsegram is one of the cheapest sources of protein for both human beings and animals (Katiyar, 1984). On an average, horsegram seed contains 22–24% protein, which is comparable to commonly consumed pulses like chickpea, pigeonpea, greengram and blackgram however, due to varietal difference large variability observed in protein content ranging from 18.5–31.16% (Begum *et al*., 1977; Murthy, 1980). The dehulled horsegram seeds exhibit higher protein content (18.4–25.5%) than the whole (17.9–25.3%) (Sudha *et al*., 1995). A wild species of horsegram (*Macrotyloma sar-garhwalensis*) contains 38.37±1.03% crude protein. The true seed protein (34.88%) content of this wild horsegram reported about two times higher than the other commonly grown horsegram lines (Yadav *et al*., 2004). Horsegram protein comprises higher lysine content than pigeonpea and chickpea making it a good complement to a cereal based diet (Venkatesha, 1999; Prasad *et al*., 2010) whereas methionine is the major limiting amino acid and threonine and tryptophan are the other minor limiting amino acids (Khader and Venkat Rao, 1986).

Table 1. Nutritional composition of horsegram [*Macrotyloma uniflorum* (Lam.) Verdc.]

S. No.	Nutritional composition			References
1.	**Carbohydrate**	57.2%		Gopalan *et al*.,1999
		51.9%-60.9% (Whole) and 56.8%-66.4% (Dehulled)		Sudha *et al*., 1995
		66.6±2.1%		Sreerama *et al*., 2012
	(i)	**Starch**	36± 1.17g/100g [Digestible (85%), Resistant (14.47%) and Resistant starch associated with dietary fibres (3.38%)]	Bravo *et al*., 1999
	(ii)	**TSS**	6.38%	Bravo *et al*., 1999
			Oligosaccharides 26.8 mg/g [Raffinose (7.1± 0.0), Stachyose (15.6± 0.4) and Verbascose (4.1± 0.0)]	Sreerama *et al*., 2012
	(iii)	**Dietary fibre**	16.3% [Insoluble (14.9± 0.4%) ,Soluble (1.4%±0.0%) and Resistant starch (2.2±0.2)%]	Sreerama *et al*., 2012
2.	**Protein**	22%		Gopalan *et al*.,1999
		17.9%-25.3% (Whole) and 18.4%-25.5% (Dehulled)		Sudha *et al*., 1995
		23%		Venkatesha RT, 1999
		22.5 ±1.0%		Sreerama *et al*., 2012
3.	**Fat**	0.50%		Gopalan *et al*.,1999
		0.70-2.06% (Whole) and 0.81-2.11% (Dehulled)		Sudha *et al*., 1995
		0.6-2.6%		Sreerama *et al*., 2010
		1.4± 0.0 %		Sreerama *et al*., 2012
	(i)	**Saturated Fatty Acids**	27.5% [Palmitic (21.97%), Arachidic (2.85%), Stearic (2.32%) and Myristic (0.36%)]	Mishra H and Pathan S, 2011
	(ii)	**Unsaturated Fatty Acids**	72.49% [Linoleic (42.78%), Oleic (16.15%) and Linolenic acid (13.56%)]	Mishra H and Pathan S, 2011
4.	**Moisture**	11.39%		Gopala *et al* .,1997
		11.55% (Whole) and 9.73%(Dehulled)		Sudha *et al*., 1995
		6.8 ± 2.0%		Sreerama *et al*., 2012
5.	**Ash**	3.0%–3.8% (Whole) and 2.7–3.4 %(Dehulled)		Sudha *et al*., 1995
		4.50% (in leaves)		Mandle *et al*., 2012
		2.7± 0.0%		Sreerama *et al*., 2012
	(i)	**Macro minerals**		
			Ca [238mg/100g (Whole) and 223 mg/100g (Dehulled)]	Sudha *et al*., 1995
			Ca (244–312 mg/100g)	Khatun *et al*., 2013
			Ca (287mg/100g)	Gopalan *et al*.,1999
			P (311mg/100g)	Gopalan *et al*.,1999
			Fe (5.89–7.44 mg / 100 g)	Khatun *et al*., 2013
			Fe (6.77mg/100g)	Gopalan *et al*.,1999
			K (13.06 - 14.61 mg/g) **, Ca** (1.20 - 3.13 mg/g), **P (** 3.83 - 4.43 mg/g), **Mg (** 1.64 - 1.73 mg/g) **and S** (1.85 - 2.46 mg/g)	Morris *et al*., 2011
	(ii)	**Micro minerals**		
			Cu (10.28 - 13.16 µg/g), **Fe (** 68.25 - 92.95 µg/g), **Mn (** 31.26 - 59.85 µg/g), **Ni** (1.04 - 1.33 µg/g), **Zn** (29.24 - 38.13 µg/g)	Morris *et al*., 2011
6.	**Vitamins**		**Thiamine** (0.4mg/100g), **Riboflavin** (0.2mg/100g) and **Niacin** (1.5mg/100g)	Bolbhat and Dhumal, 2012

Dietary fibre: Adequate dietary fibre is essential for proper functioning of the gut and has also been related to risk reduction for a number of chronic diseases including heart disease, certain cancers and diabetes. Fibre includes pectin, gum, mucilage, cellulose, hemicelluloses and lignin (Khogare, 2012). In most grain legumes consumed as pulses by humans, the fibre content ranges from 8.0–27·5%, with soluble fibre in the range 3·3–13·8 % (Guillon and Champ, 2002). Horsegram seed contains 28.8% total dietary fibres, mainly insoluble dietary fibre (IDF) 27.82% and soluble dietary fibre (SDF) 1.13% with IDF**:** SDF 24.6 (Khatoon and Prakash, 2004) whereas,

horsegram flour contains 16.3% total dietary fibre (14.9% insoluble and 1.4% soluble and 2.2% resistant starch) (Sreerama *et al*., 2012). Horsegram seeds contains more insoluble dietary fibre (Kawale *et al*., 2005) required for normal lower intestinal function in humans (Anderson *et al*., 1994). Crude fibre is only one-seventh to one-half of total dietary fibre (Trowell,1976) and the high content of dietary fibre in horsegram flours might be helpful in terms of maintaining positive effects on intestine and colon physiology, besides other homoeostatic and therapeutic functions in human nutrition (Sreerama *et al*., 2012). Pulse derived fibre have been shown to alter energy expenditure, substrate trafficking and fat oxidation as well as visceral adipose deposition (Ramen *et al*., 2013).

Fat: The fat content of horsegram ranges from 0.6–2.6 % (Sreerama *et al*., 2010). Dehulled horsegram seeds exhibit higher crude fat content (0.81–2.11%) than the whole (0.70–2.06%) seeds (Sudha *et al*., 1995). Horsegram seeds are a good source of essential fatty acids and contains 27.5% saturated fatty acids (21.97% palmitic, 2.85% arachidic, 2.32% stearic acid and 0.36% myristic), 72.49% unsaturated fatty acids (42.78% linoleic, 16.15% oleic and 13.56% linolenic acid) and among unsaturated fatty acids linoleic acid is useful for the treatment of diabetes and cardiovascular diseases (Mishra and Pathan 2011). In an optimum balance, the essential fatty acids linoleic acid with α-linolenic acid may slow the onset of Parkinson's and Alzheimer's diseases and these fatty acids are important for healthy cell membrane formation and functional development of the brain and nervous system, therefore, increase intake of legumes can be beneficial to human health (Morris *et al*., 2013; Ryan *et al*., 2007). Further, horsegram lipids have anti-ulcer activity due to presence of phytosterol esters (Berger *et al*., 2004) which imparts protective and healing effect on acute gastric ulceration produced by alcohol (Jayraj *et al*., 2000).

Moisture and ash content: The moisture content in horsegram seeds is about 11.39 per cent (Gopala Krishna *et al*., 1997). However, moisture content in seeds depends on the stage and time of harvesting of the crop as it is generally on higher side (18-25%) at the time of harvesting and 9-12% is the optimum range for safe storage in pulses (Mohan *et al*., 2011). In whole and dehulled horsegram seeds, moisture content is found 11.55% and 9.73%, whereas ash content ranges from 3.0%–3.8% and 2.7–3.4 %, respectively (Sudha *et al*., 1995). Higher ash content is indicative of high mineral content. Horsegram is also used as leafy vegetable and its leaves contain relatively very high content (4.50%) of minerals as compared to other common vegetables (1.5–2.4%) (Mandle *et al*., 2012). In horsegram accessions, mean concentrations of macro minerals (Ca, K, Mg, P, and S) ranges from 1.3–14 mg and micro minerals (Cu, Fe, Mn, Ni, and Zn) ranges from 1.0–95.0 µg per gram dry weight (Morris *et al*., 2013). It is a fairly rich source of calcium which is 238mg in whole seed and 223 mg in dehulled seed per 100g seed (Sudha *et al*., 1995). In raw horsegram, the calcium and iron content ranges from 244–312 mg and 5.89–7.44 mg per 100 g of seed, respectively with in-vitro bio-accessibility of 22.50–38.50 mg of calcium and 0.26–0.85 mg of iron per 100 g of seeds (Khatun *et al*., 2013). Germination, cooking and roasting significantly increased the *in-vitro* bio-accessibility of calcium and iron (Khatun *et al*., 2013).

Antinutritional factors: Pulses contain several antinutritional factors that reduce the bioavailability of nutrients (Jain *et al*., 2009). Horsegram flour contains trypsin inhibitor activity (9246±18 TIU/g), phytic acid (10.2±0.4mg/g), polyphenols (14.3±0.4mgGA/g) and oligosaccharides (26.8mg/g) (Sreerama *et al*., 2012). The utilization of horsegram as human food is restricted due to presence of high level of enzyme inhibitors, haemagglutinin activities, oligosaccharides, tannins, polyphenols and phytic acid compared to the other legumes which can be reduced below their mischief potential through processing (Dhumal and Bolbhat, 2012; Sharma, 2011). Conventional processing methods such as dehusking, germination, cooking, and roasting have been shown to produce beneficial effects by decreasing the content of undesirable components which results in enhanced acceptability and nutritional quality in addition to optimal utilization of horsegram as human food (Kadam and Salunkhe, 1985). As far as the presence of antinutritional factors are concerned, some of the commonly considered antinutritional compounds like phytic acid, phenols, tannins are now being considered as potential antioxidants having health promoting effects. The phytic acid has now been shown to possess rich antioxidant, anticarcinogenic and hypoglycaemic activities, therefore, depending upon consumer preferences retaining or elimination of these compounds could be facilitated (Bhatt and Karim, 2009).

Protease inhibitors: Horsegram invariably contain inhibitors of proteases that cause decreased digestibility of dietary proteins by formation of irreversible trypsin enzyme and trypsin inhibitor complex in the intestine. The horsegram protease inhibitors resembles other Bowman-Birk protease inhibitors and characterized by low molecular weight, high disulfide content with low content of aromatic amino acids which can bind and inhibit trypsin and chymotrypsin either independently or simultaneously (Singh and Rao, 2002; Ramasarma *et al*., 1994). In horsegram flour, trypsin inhibitor activity is significantly higher (9246 TIU/g) as compare to chickpea (6452 TIU/g) and cowpea (6981 TIU/g) flour (Sreerama *et al*., 2012). High level of trypsin inhibitor activity (950 x 10^3 TIU/g seed) in ungerminated horsegram seeds reduced by 16% in 72 h germinated seeds (Subbulakshmi

et al., 1976). Germination induces changes in the Bowman-Birk type proteinase inhibitors of horsegram at both qualitative and quantitative levels (Gowda and Sreerama, 1998) and facilitates protein hydrolysis for utilization in germination process. Trypsin inhibitor is thermolabile and its inhibitory activity can be reduced considerably by thermal treatment (Liener, 1994).

Total free phenolics and tannins: Phenolic compounds and tannins are important phytochemicals, synthesized by plants for protection against predators and also under various stress conditions, plants accumulate phenolic compounds in their metabolism (Thenmozhi *et al*., 2012). These compounds are highly appreciated for their quality to add flavour, taste and appearance to the product (Pugalenthi *et al*., 2005) as well as impart health benefits for humans (Alonso and Arellano, 2005). Phenolic compounds are known to interact with proteins forming complexes which in turn, decrease the solubility of proteins and make protein complexes less susceptible to proteolytic attack (Reddy *et al*., 1985). Tannins are structurally more complex and wide spread phenolic compounds that contribute astringency and bitterness to plants as well as has the property to precipitate proteins (Chirinos *et al*., 2008; Furlan *et al*., 2010). Horsegram seeds are rich in tannins and polyphenols compared to the other legumes (Kadam and Salunkhe, 1985) and contains relatively high levels of total free phenolics (1.670g/100g) (Sundaram *et al*., 2013) and tannins (763.7-895.9mg/100g) (Sudha *et al*., 1995). Black seeds contain relatively high levels of total phenolics and tannins than the brown seeds (Siddhuraju and Manian, 2007). The extracts of horsegram plant examined as potential sources of phenolic compounds and out of eight phenolic acids, most abundant were *p*-coumaric acid (8.95 mg) and *p*-hydroxy benzoic acid (7.81 mg) per 100 g of dry sample (Kawsar *et al*., 2008). Phenolics and tannins are water soluble which are concentrated to seed coat. Soaking and cooking process cause leaching of tannins and beneficial impact on nutritional value and marked reduction in tannin content (215.3–361.9 mg/100g) by dehulling as compared to whole seeds (763.7–895.9mg/100g) of horsegram (Sudha *et al*., 1995). Phenolics have attracted the attention of food and health scientists in recent times due to antioxidant properties and their uses in health care (Alonso and Arellano, 2005). There is ample proof of health benefits as anti-inflammatory, cicatrizant and anti-HIV functions of tannins together with their role in protection against environmental stresses (drought, UV-B radiation and atmospheric pollution), microbial pathogens, harmful insects and other herbivores in plants (Furlan *et al*., 2010).

Haemagglutinins: Haemagglutinins are cell agglutinating sugar specific proteins, widely distributed in leguminous plants and sometimes referred as phytoagglutinins or lectins (Srilakshmi, 2003; Kumar and Gopalrao, 1986). Excess consumption of lectins can cause severe intestinal damage, nutrient deficiencies and they can bind to erythrocytes simultaneously with immune factors, causing hemagglutination and anemia (Laura, 1991). However, oral administration of low doses can have many beneficial effects on digestive efficiency, the immune system and the body's endocrine system with beneficial consequences for general metabolism (Zhang *et al*., 2008). In horsegram, *D. biflorus* agglutinin (DBA) is an important dietary lectin, identified as an allergen (Siddanakoppalu *et al*., 2006) and retarded growth observed in rats fed on this lectin (Manage *et al*., 1972). Horsegram seeds are rich in lectins and DBA differentially expresses in seeds, stems, leaves and roots (Beran *et al*., 2007). Horsegram seed lectin has 'A' blood group specificity which can distinguish between A1 and A2 blood groups therefore, commonly used in blood banks in blood group testing (Hamid and Masood, 2009; Shah,2014). Preliminary soaking prior to autoclaving or cooking is required for complete elimination of the toxicity of lectins (Jain *et al*., 2009).

Phytic acid: Phytic acid (known as phytate when in salt form) acts as the primary phosphorus reservoir accounting for up to 85% of total phosphorus in cereals and legumes and has the ability to bind minerals, proteins and starch and forms complexes consequently lowers the bioavailability of minerals (zinc, iron, calcium, magnesium, manganese and copper) as well as inhibit enzymatic digestion of both proteins and starch (Pugalenthi *et al*., 2005). However, it exhibits beneficial health effects as it has a positive role as an antioxidant and in protection against a variety of cancer and coronary heart disease, diabetes mellitus and renal stones (Kumar *et al*., 2010). In horsegram seeds, phytate phosphorus (184±6.0mg/100g) accounted for 57% of the total phosphorus (320±8.5mg/100g) (Borade *et al*., 1984). The phytic acid content in horsegram flour (10.2±0.4mg/g) comparable to chickpea (12.1±0.5mg/g) and cowpea (14.0±0.7mg/g), black gram (11mg/g), lentil (12.5mg/g), red kidney bean (14.4mg/g) and white kidney bean (12.3mg/g) but higher than the levels reported for pigeon pea (2.2mg/g) (Sreerama *et al*., 2012). Simple processing like germination, cooking, roasting, soaking and fermentation cause significant reduction in phytic acid content in legumes (Khamgaonkar *et al*., 2013).

Remedial properties: Horsegram has long history as traditional medicine to cure many diseases, still it is neglected for its remedial potential. As per *Charak Samhita*, the seed of horsegram are useful for the cure of piles, hiccup, abdominal lump, bronchial asthma, in causing and regulating perspiration and in the *Sushruta Samhita* it is mentioned that the seed powder is useful in stopping excessive perspiration (Pati and Bhattacharjee, 2013). Traditional texts describes its use as traditional

medicine for curing kidney stones, asthma, bronchitis, leucoderma, urinary discharges, heart diseases and piles (Ghani,1998; Yadava and Vyas, 1994). It also has anthelmintic activity which can be used as dietary food for infants to eradicate worms (Philip *et al*., 2009). It supposed to have unique property of dissolving kidney stones, therefore, in many parts of the country it is given to prevent or cure urinary stones (Singla and Kumar, 1985). In seed extract of horsegram water soluble, heat stable, polar, non-tannin and non-protein crystallization inhibitors are reported and a marked decrease in anticalcifying activity observed with the post-harvest storage of seeds (Peshin and Singla, 1995). The extract of horsegram exerts a hypolipidaemic and hypoglycaemic actions (Senthil, 2009) and has also been found beneficial in urinary troubles, acid peptic disorder (gastritis), constipation, sun-burn, kidney stone, female diseases (leucorrhoea, menstrual troubles, bleeding during pregnancy, post partum excessive discharges), colic caused by wind, piles, rheumatism, hemorrhagic disease, intestinal worms *etc*.(Pati and Bhattacharjee, 2013). It is prescribed for persons suffering from jaundice, water retention, as part of a weight loss diet, iron deficiencies and also helpful for maintaining body temperature in the winter season (Ramesh *et al*., 2011). It is considered as *Garmi dal* and preferred during the winter months by rural communities (Khanal *et al*., 2009). Horsegram seed are rich source of dietary antioxidants (Siddhuraju and Manian, 2007) as well as has antidiabetic effect (Gupta *et al*., 2011). Extracts from horsegram seeds reported to have significant activity against *B. subtilis*, *S. aureus*, *E. coli*, and *P. aeruginosa* (Gupta *et al*., 2005). Horsegram used as medicine to treat hiccups, worms and in the treatment of bacterial and fungal infections (Kawsar *et al*., 2008; Chunekar and Pandey, 1998). It has functional ingredients against hypercholesterolemia and obesity (Kumar *et al*., 2013).

Potential of horsegram as functional food and feed: Horsegram has great potential both as food and feed suggested by experiences worldwide. Its nutritious composition, medicinal properties and indomitable pest resistance makes it a rich yet cheap source of food, fodder, fuel supplement and green manure (Bhardwaj *et al*., 2013). U.S. National Academy of Science has identified this legume as a potential food source for the future (NAS, 1979). The inception of nutraceutical concept and health consciousness among masses has increased the utilization of potential antioxidants from legumes including horsegram as it reduces the risk of intestinal diseases, diabetes, coronary heart disease, prevention of dental caries etc. due to presence of bioactive compounds (Prasad and Singh, 2014). The seeds, sprouts or whole meal of horsegram is used by large populations in rural areas (Kadam and Salunkhe, 1985). Raw horsegram seed is a rich source of antioxidant activities which are concentrated more in the seed coat of the seeds and consumption of food items prepared with unprocessed raw horsegram seeds may have more health benefits for hyperglycaemic individuals (Tiwari *et al*., 2013). Horsegram seed proteins exhibit free radical scavenging capacities which can be used as a food supplement, natural antioxidant and useful as therapeutics for health benefits of human (Petchiammal and Hopper, 2014). The seeds and sprouts of horsegram are excellent examples of 'functional food' as it has role in lowering the risk of various diseases and exerting health promoting effects in addition to its nutritive value (Ramesh *et al*., 2011). However, the metabolic changes during sprouting affect the bioavailability, palatability and digestibility of essential nutrients (Masood *et al*., 2014). In some parts of India, leaves of horsegram are also used as vegetable (Mandle *et al*., 2012) and leaves contain additional health enhancing traits such as anthocyanins which are potent antioxidants by acting as free radical scavengers and shown to be anti-inflammatory (Morris, 2008). Non-toxic extracts from aerial parts of horsegram justifying its ethnobotanical use (Kawsar *et al*., 2008). Horsegram is low cost pulse with high protein and acceptable cooking quality and has the potential to formulate products (Hiramath *et al*., 2001). In addition, horsegram flour has good functional properties with swelling capacity (1.43±0.01 ml), water solubility index (7.56±0.10 %), oil absorption capacity (80.76±0.03 %), water absorption capacity (142.14±0.10 g/100g) and swelling index (0.46±0.15%), hence can be used as functional foods for nutrition and food formulation (Marimuthul and Krishnamoorthi, 2013). Horsegram flour is rich in protein, calcium and dietary fibre, after simple processing like soaking and drying or roasting eliminates the antinutritional content hence suitably processed horsegram flour could be used in the preparation of various food products (Thirukkumar and Sindumathi, 2014). Horsegram flour found to have favourable functional properties like higher water absorption capacity (148.1±3.4mg/100g), emulsion activity (58.1±0.5%) and emulsion stability (52.0±1.6%) as compared to chickpea flour which suggest its scope to be exploited in the preparation and development of food products such as bakery products, soups and snacks as well as may be used to produce composite flours as partial substitutes of chickpea flour in snacks, confectionery and other traditional food products (Sreerama *et al*., 2012).

The whole seeds of horsegram are generally utilized as cattle feed and are usually given after boiling (Reddy *et al*., 2008; Kadam and Salunkhe, 1985). Non shattering pods has shown the potential of stand over dry season livestock feed in Northern Australia while in India as annual pulse and forage crop in areas receiving less than 875mm average annual rainfall (Blumenthal and Staplesz, 1993). Horsegram seed can also be utilized in

chick and grower ration without any deleterious effect as better feed efficiency observed in the diets of egg-type chicks and growers with 10% raw horsegram seeds without mortality (Ravindran and Bino Sundar, 2009). Sheep appeared to prosper best when fed hay containing 70% *M. uniflorum* than hay consisting of 70% *Stylosanthes hamata*, *Vigna unguiculata*, and *Crotalaria juncea* (Murthy and Prasad, 2005). Horsegram seed meal is non-toxic in nature, safe for edible use and has a better promise as a source of food supplement and likely to be satisfactory in supporting growth and maintenance in animal feeding (Sreelekshmi *et al*., 2011). It possess high nutritional value and remedial properties. Moreover, it has the potential for further utilization as nutraceutical, food and forage for malnourished and drought-prone areas of the world (Morris, 2008). There are great possibilities exist for horsegram to be explored further for various undiscovered phytochemicals, therapeutics usage as well as development of low cost functional and medicinal food.

Conclusion: Horsegram is an important food and feed crop traditionally grown in arid regions of the developing world and often considered as minor/ neglected/ underexploited/ poor man's pulse. Its innate climate resilience suggests its scope as a suitable alternative in the present climate change era. It is a treasure house of various therapeutic, bioactive compounds along with excellent nutritional quality makes it a wholesome food that should be added to diet on a regular basis. The health benefits of horse gram are being recognized in the western world recently, but have been known for its ability to prevent and cure various diseases by Indian "*Ayurvedic*" system since centuries. Furthermore, there are still great possibilities exist for this legume to be explored for its chemoprofile, pharmacology, biological evaluation, toxicological consequences, innate health-promoting aspects and many undiscovered phytochemicals as well as there is need to promote and support the initiatives that make the most use of this indigenous underutilized legume to address food and nutritional security issues.

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