ISSN 0973-354X
eISSN 2582-4899

JOURNAL OF HORTICULTURAL SCIENCES

Volume 16 June 2021 Issue 1

Society for Promotion of Horticulture
ICAR - Indian Institute of Horticultural Research, Bengaluru - 560 089

JOURNAL OF HORTICULTURAL SCIENCES

(Founded in 2005 by the Society for Promotion of Horticulture, Bengaluru, India)

Email : chiefeditor.jhs@gmail.com Webpage : https://jhs.iihr.res.in/index.php/jhs

SOCIETY FOR PROMOTION OF HORTICULTURE (REGD.)

Email : sphiihr2005@gmail.com Website : sph.iihr.res.in

This Journal is abstracted in CABI, Current Contents, AGRIS, Indian Science Abstracts, Scopus, DOAJ and Redalyc. It is a participant of AmeliCA.

Request for membership subscriptions along with cheque/DD drawn in favour of **Society for Promotion of Horticulture, Bengaluru** may be sent to General Secretary, Society for Promotion of Horticulture, Indian Institute of Horticultural Research, Hessaraghatta Lake Post, Bengaluru - 560 089, India. All members except student members and subscribers get all publications of SPH free of cost. Any correspondence other than editorial may be addressed to General Secretary, Society for Promotion of Horticulture, Indian Institute of Horticultural Research, Hessaraghatta Lake Post, Bengaluru - 560 089, India.

Sponsorship for programmes related to promotion of horticulture is accepted.

For information please contact
General Secretary, SPH, IIHR,
Bengaluru - 560089, India.

Coverpage Courtesy :
Top : **Lavanya** *et al.*, P. 67
Bottom : **Waman** *et al.*, P. 74

SUBSCRIPTION RATES	
Patron	₹ 20,000
Life member	₹ 5,000
Annual Member	₹ 1,000 / US $ 100 (US $ 50 for SAARC countries)
Student Member	₹ 500
Student Life Memeber	₹ 3,000
Annual Subscription	₹ 1,500 / US $ 100 (US $ 60 for SAARC countries) (for institutions)
Enrolment Fee	₹ 200 / US $ 5 (Additional for all types of Membership)

NAAS rating of this journal is 5.08. JHS is now available online.
Authors have to submit manuscripts using the link : https://jhs.iihr.res.in/index.php/jhs

*Technical Assistance : **Dr. Sridhar Gutam, Thippeswamy S. and Pramida A.***

JOURNAL OF HORTICULTURAL SCIENCES

Volume 16 **Issue 1** **June 2021**

CONTENTS

Short Communications

In this issue…

The farmers involved in the production of horticultural produce have defied the challenges due to second wave of the ***COVID pandemic****. Especially, the information that India's horticulture production is expected to increase by 2.93 per cent to a record level of 329.86 million tonnes (MT) in 2020-21, according to the second advance estimate of horticulture production released by the Ministry of Agriculture is very much motivating. Though many hurdles are faced by the farmers due to the prevailing* ***Covid Pandemic*** *with respect to timely marketing, storage and other issues, the horticultural production has maintained the steady growth. Wish that in other countries also the horticulture production enhances to provide the nutritional security. Journal of Horticultural Sciences takes pride in sharing the recent research developments in different disciplines of Horticulture.*

Many native vegetable crops have nutraceutical values. One of them is Moringa or commonly called as drumstick. ***Jattan et al.*** *have reviewed the traditional values, requirement for crop cultivation, crop improvement, value addition, nutraceutical and pharmaceutical values with respect to this crop.*

Many under-utilized fruit crops are brought to cultivation again with scientific interventions. One such crop is mountain sweet corn (Flacourtia montana). The fruits have high potential for processing into jam, jelly, wine, etc. and this plant has good medicinal value. ***Tripathi et al.*** *evaluated and characterized the mountain sweet corn accessions from Western Ghats and identified a suitable line with higher yield, regular bearing nature and less thorniness.* ***Ravishankar et al.*** *isolated and characterized the microsatellite markers from the under-utilized tree species Garcinia indica. In their study, 3725 microsatellites were identified and primers were designed for 1374 microsatellites. The SSR developed will be useful in studying genetic diversity, mapping and fingerprinting of Garcinia indica and related species.*

Among the leafy vegetables, Amaranthus ranks first in production. ***Agadi et al.*** *estimated the nature and extent of genetic variability among twenty Amaranthus genotypes. They found that Arka Arunima, Chikmagalur local, IC-551486, IC-551494 and IC-551466 recorded high foliage yield per plot and could be utilized in further breeding programme.****Challam et al.*** *studied the morpho-physiological parameters associated with resistance to iron deficiency induced chlorosis in potato and their effect on yield attributed. They found that genotype CP-3443) was found tolerant to Fe deficiency induced chlorosis.* ***Ayub et al.*** *evaluated responses of different okra (Abelmoschus esculentus) cultivars to water deficit conditions in Pakistan. They concluded that drought caused significant variation on physical and biochemical attributes of okra whereas the cultivar 'Sabz Pari' showed resistance towards the water stress.*

Gamma ray is an effective mutagen which creates useful variability in crops where the natural variation is very meagre and creation of variability by conventional methods is cumbersome. ***Lavanya et al.*** *studied the induced variability in cluster bean due to gamma irradiation and found that the traits like*

plant height, pod length, pod width, pulp to seed ratio showed sufficient variability. ***Sankaran et al. also*** *employed the gamma irradiation to generate variability in pummelo. They found that 60 Gy gamma dose can effectively be used for raising the mutant populations to identify a desirable mutation in pummelo*

Soil microbiome plays important role in crop production. There is need to pay attention on the nutrition management practices. They should encourage the soil microbe population that will indirectly help the plant health. ***Al-Mosour and Kalaivanan*** *have demonstrated that integrated nutrient management can maximize soil microbial community dynamics which is considered as driving force behind regulating soil processes that support sustainable sweet basil cultivation.*

While attempting to evaluate the spectral manipulations on cultivation of cut foliage crops, ***Nair et al.*** *found that coloured shade nets did not influence vase life of the cut foliage in Philodendron and observed that cultivation of Philodendron 'Xanadu' under white shade resulted in maximum cut foliage yield and quality.*

Mango ginger is an underutilized rhizomatous species that has been valued in the tropical Asian countries as a source of vegetable, spice, salad, medicine and essential oil. Huge quantity of seed rhizomes is required to promote this crop in larger area. ***Waman et al.*** *developed an in vitro protocol for the multiplication of mango ginger.*

Jamun seed is a rich source of polyphenolic compounds with antioxidant potential and alpha - glucosidase inhibitory activity. ***Arivalagan et al.*** *have optimized the methodology for the extraction of such polyphenols from jamun seeds. This will be of much in nutraceutical industry. Similarly,* ***González et al.*** *studied the post-harvest quality and quantification of betalains, phenolic compounds and antioxidant activity in fruits of three cultivars of prickly pear in Mexico. They observed that there was high correlation between antioxidant activity and phenolic compounds. The methodologies developed by them will be useful tool for the quantification of bioactive compounds fruit tissues.*

Post-harvest disease management is an important aspect in delivering the harvested produce safely to the end-user. ***Bhandari et al.*** *have recorded that application of essential oils with wax improved shelf life of sweet oranges in Nepal and this treatment enhanced juice retention, firmness, titratable acidity, vitamin C and disease reduction.*

S. Sriram
Editor in Chief

J. Hortl. Sci.
Vol. 16(1) : 1-13, 2021

Review

Moringa (*Moringa oleifera* L.) : An underutilized and traditionally valued tree holding remarkable potential

Minakshi Jattan[1], Kumari N.[2], Raj Kumar[3]*, Kumar A.[3], Rani B.[2], Phogat D.S.[1], Kumar S.[1] and Kumar P.[4]

[1]Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar, India
[2]Department of Biochemistry, CCS Haryana Agricultural University, Hisar, India
[3]ICAR-Centre for Soil Salinity Research Institute, Karnal, India
[4]Department of Plant Pathology, Punjab Agricultural University, Ludhiana, India
*Corresponding author email: rajhorticulture@gmail.com

ABSTRACT

Moringa (*Moringa oleifera* L.) commonly known as "drumstick tree" belongs to the family *Moringaceae*. It is now grown worldwide but its native region is India. It is a fast-growing tree that responds to low inputs and has high regeneration potential after cutting. Its nutritional value and capacity to grow economically in different soils and environmental conditions makes it a wonder tree. It is highly nutritious and each part is being utilized in various forms. It is widely cultivated for its young pods, flowers and leaves for use as traditional herbal medicine and vegetable. It is also used by indigenous people in the tropics and sub-tropics as a source of remedies. The leaves are also used as a source of fodder in many countries of the world as it can sustain green fodder availability round the year without extra efforts. Various parts of this tree are good source of ascorbic acid, calcium, iron, protein and antioxidant compounds. Hence, its remarkable properties help to fight nutritional deficiency, human diseases and improve performance of livestock.

Keywords: Antioxidants, Fodder, Livestock, Malnutrition, Moringa, Nutrients and Pharmaceutical

INTRODUCTION

Moringa (*Moringa oleifera* L.) also known as ben oil tree, benzolive tree, drumstick tree or horseradish tree is the most versatile and comes under the category of underutilized perennial plant species. All parts of this plant *i.e.* leaves, roots, flowers, pods and seeds have remarkable range of properties due to the presence of essential nutrients like vitamins, minerals, phytochemicals etc. Therefore, this plant can serve as a highly nutritious food with medicinal properties for human beings as well as fodder for livestock (Nouman *et al.,* 2014 and Masih *et al.,* 2019). Essential nutrients present in *Moringa oleifera* such as vitamins, minerals, fatty acids and amino acids are helpful in activating enzymes, hormones and osmotic adjustment in the body. Hence, enhance growth, body functions and maintenance of life processes (Anjorin *et al.,* 2010). Also, a wide range of antioxidants available in leaves, make it a valuable source of natural antioxidants, nutraceuticals and functional components (Anwar *et al.,* 2007). Therefore, *Moringa oleifera* can serve as an effective remedy for malnutrition particularly in the developing countries of the world.

In the present scenario when the cultivatable area for fodder production is decreasing day by day due to the cultivation of cash crops; *Moringa oleifera* can serve as an important source of quality fodder. This plant can be used as livestock fodder, as a supplement to enhance the dry matter intake (DMI) and digestibility of fodder in livestock. It is helpful in weight gain and enhances milk production in livestock. Fodder quality can be improved by mixing *Moringa oleifera* leaves with other fodder crops which contributes towards better livestock performance. Hence, *Moringa oleifera* can be used as nutritional supplement for livestock due to its nutritional value and good biomass production (Sanchez *et al.,* 2006).

Due to several medicinal and therapeutic properties of *Moringa oleifera* traditionally, it has been used to treat problems such as anemia, anxiety, asthma, bronchitis, skin infections in different cultures of the world. It also possesses anti-diabetic, anti-hypertensive, anti-inflammatory, anti-spasmodic and anti-tumor activities (Sharma *et al.,* 2012). Therefore, various bioactive compounds isolated from *Moringa oleifera* are utilized in medicinal field at large scale (Abalaka *et al.,* 2009). *Moringa oleifera* being rich in phytochemicals and nutrients as compared to vegetables; helps to enhance immunity. Hence, its consumption should be encouraged to strengthen immunity and cope up with malnutrition.

The biochemical composition of different parts of *Moringa oleifera* varies from location to location (Anjorin *et al.,* 2010). These variations in biochemical composition may be due to cultivation methods, environment and genetic background (Brisibe *et al.,* 2009). There is very scanty scientific information on the potential of this species to alleviate nutritional problems. There is lack of *Moringa oleifera* varieties due to less information available on genetic improvement programs for this tree (Padulosi *et al.,* 2013). Therefore, to solve the malnutrition problems such as protein deficiency in the population of developing countries of the world; further studies are needed on breeding and genetic improvement of this species. This information will be helpful in utilizing the full potential of this nutrient rich and incredible tree in various arenas of life.

ORIGIN AND DISTRIBUTION

Moringa is a member of the family Moringaceae which is comprised of thirteen species from various geographical locations (Shahzad *et al.,* 2013). It is commercially cultivated in parts of Africa and India. Four species *i.e. Moringa drouhardii* (Madagascar), *M. ovalifolia* (Namibia and southwest Angola), *M. hilderandtii* (Madagascar) and *M. stenopetala* (Kenya and Ethiopia) are characterized by bloated water-storing trunks. Three species *i.e. M. peregrine, M. oleifera* and *M. concanesis* are known for their slender trees with juvenile stage being tuberous. The remaining six species (*M. arborea, M. borziana, M. longituba, M. pygmaea, M. rivae* and *M. peregrina*) are tuberous in nature. *M. oleifera* is chiefly cultivated species of *Moringa* genus. It is a softwood deciduous tree. It is indigenous to the Himalayan foothills. It is widely cultivated in tropical regions of South Asia from northern Pakistan to northern Bengal state in India and northeastern Bangladesh, Nepal, Afganistan, Sri Lanka, West Asia, the Caribbean and sub-Saharan Africa, Latin America and reported in Florida and the Pacific Islands (Sachan *et al.,* 2010).

TREE MORPHOLOGY

Moringa oleifera tree bears spreading, open crown of drooping and fragile branches. The compound tripinnate leaves alternately bear leaflets in opposite pairs and leaf length ranges from 45-90 cm. The leaflets are dark green with red tinged midveins, entire margins and rounded at apex (Rollof *et al.,* 2009). The soft stem wood is light weight and bark is whitish-grey, thick and corky. The deep tap root system and spreading tuberous lateral roots provide support to the tree. It may flower twice in a year or round the year. The flowers have pleasant smell and these are produced in 10-25 cm long loose axillary panicles. The flowers are white or ceamy-white in colour, zygomorphic and pentamerous (Sachan *et al.,* 2010). Calyx contains five sepals which are green, lobed and tubular. Corolla comprises five narrowly spathelate, veined and creamy-white petals. Androecium is comprised of five fertile yellow stamens with alternating five smaller sterile stamens (staminodes). Gynoecium is represented by a single, stalked superior ovary with slender style. Ovary is one celled with double rows of ovules (10-25). Moringa fruit is called as pod and looks like drumstick. Pods are large (10-60 cm long) and turn brown at maturity. The seeds are rounded, one cm in diameter, dark brown to black in color with three papery wings.

TRADITIONAL VALUE

Each part of *Moringa oleifera* tree has immense potential **(Fig 1)**. It was documented in Indian Vedic literature nearly 5000 years ago (Patwardhan, 2003). In the tropical and sub-tropical regions, Moringa is highly valued by local people because of its pharmaceutical value and consumed as infusions and decoctions. This tree has served as a remedy to cure more than 300 diseases and can be regarded as a panacea. The roots have a pungent odour resembling with horseradish tree (*Armoracia rusticana*). It is used as a flavoring agent and in cardiac & circulatory problems (Mishra *et al.,* 2011). Root-bark is used as antiviral, anti-inflammatory, analgesic. The leaves are

Fig. 1: Moringa (*Moringa olefera* L.) at different growth and development stages: (A) seed, (B) direct seeded sapling in field, (C) nursery raised sapling, (D) harvesting stage for fodder, (E) flowering stage, (F) fruiting stage

used as a remedial source for the treatment of various ailments like influenza, malaria, typhoid, arthritis, inflammations, skin problems, hypertension and diabetes. The flowers are generally consumed as cooked vegetable or salad. Stem-bark and flowers are hypoglycemic. Pods are antipyretic and anthelmintic. Seeds have 30-40% oil and it is called as Ben oil which is resistant to rancidity and used in cooking (Yu *et al.,* 2005). It is also used for the treatment of hysteria, scurvy, prostate problems and bladder troubles (Fahey, 2005). Indian Ayurveda claims that Moringa oil possesses antitumor, antiepileptic, anti-inflammatory, antiulcer, antibacterial, antifungal properties and it is utilized for the treatment of different ailments in the indigenous system of medicine.

GROWTH CONDITIONS AND PLANTATION

Moringa oleifera grows very fast and it can adapt to variable ecosystems and farming systems with a temperature range of 25-35 ^{0}C. It is tolerant to drought and can be grown in sandy or loamy soils. The soils which are waterlogged or poorly drained are not suitable because it may cause rotting. The soil with a slightly acidic to slightly alkaline pH is suitable for it. An annual rainfall of 250-3000 mm is essential for its proper growth. During germination phase, it can withstand up to 3 dS m^{-1} electrical conductivity (EC). However, its resistance to salinity increases during later stages of growth. The antioxidant system of *Moringa oleifera* is responsible to tolerate moderate salinity with a mild effect on its mineral composition (Nouman *et al.,* 2012). Therefore, it can be grown in diverse environments *i.e.* hot, humid and dry with well drained soils. Although this plant can grow in versatile environments, yet the nutrient content and strength of the plant is ensured by the soil condition. Soil fertility, application of different doses and combinations of fertilizers; cause variations in nutrient composition of plant/plant parts (Dania *et al.,* 2014).

Moringa plantation can be done from seeds, cuttings or nursery saplings. However, direct cultivation through seeds is utilized when seed is sufficient in quantity. This method has high seed germination rate and takes 5-12 days for germination (Leone *et al.,* 2015). It can be grown to full-sized trees to get leaves, flowers, pods and seeds as economic parts. It can also be grown as a bush and intensively planted to get leaves as the economic part (Fig. 2). The best sowing

is the beginning of the rainy season. It ensures enough water to the growing tree during its first growing season to become well-established. After that, much water is not required. Planting method depends on available space and which economic part is to be utilized. For good seed production, 2-3 seeds per hole are planted 2-3 cm deep with 2-5 meter spacing between trees depending of the annual or perennial types. For good leaf production, dense planting should be done *i.e.*, 30 cm x 10 cm spacing. When the trees reach about 1.5 m tall, prune them down to 15 cm. The pruned rows grow back with a greater number of branches and leaves. It gives a continuous supply of leaves. Plantation can be done from cuttings having diameter 4-5 cm and length 100 cm; by digging a hole, adding manure and mounding the soil (Peter, 1978). The sprouting takes variable time depending on various factors like genotype, length of cuttings and growth conditions. However, plants grown from cuttings are sensitive to winds and drought due to lack of strong root system. It can also be cultivated through nursery raised saplings. The saplings are grown in plastic bags having sandy or loamy soils. Saplings have tender roots and hence transplanted carefully when attain the height of about 30 cm.

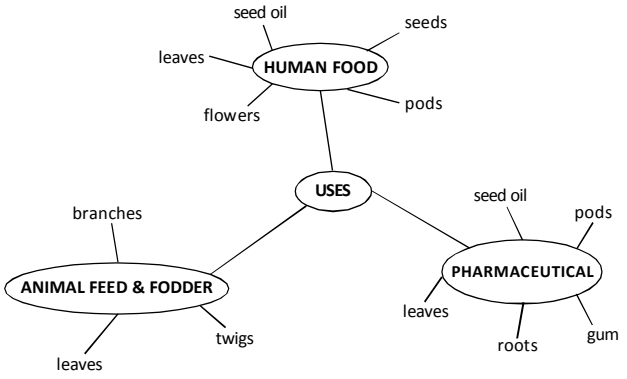

Fig. 2: Potential utilities of different parts of Moringa (*Moringa oleifera* L.)

AGRONOMIC MANAGEMENT

Field preparation for cultivation is done by adding farmyard manure (10 MT/ha) and chemical fertilizers. The application of chemical fertilizers depends on the soil condition. Generally, *Moringa oleifera* cultivation for fodder purpose needs 150 kg nitrogen, 60 kg phosphorus, 40 kg potash, 30 kg sulphur and 10 kg zinc sulphate for one hectare. Nitrogen is given in split doses; 30 kg at the time of filed preparation and later equal split doses *i.e.* after 45 days of sowing and after subsequent cuttings. Cultivation for the pod or seed purpose requires 20 kg farmyard manure per pit at the time of sowing and then application of chemical fertilizers *i.e.*, 100 g each of urea, super phosphate and muriate of potash per plant for getting higher yield (Kader and Shanmugavelu, 1982). The application of 7.5 kg farmyard manure and 0.37 kg ammonium sulfate per tree can increase yield up to three folds (Morton, 1991). For proper weed control weeding should be done at regular intervals whenever required. Irrigation requirement in Moringa depends on the rainfall. First irrigation should be given just after sowing. During early stages of development, irrigations should be managed properly for the establishment of plant. Then in later stages it should be given as per need. For the management of insect pests like hairy caterpillar; bio-pesticide like neem seed kernel extract (5 % solution) should be sprayed on the crop during infestation.

POST HARVEST MANAGEMENT AND VALUE ADDITION

Moringa plant parts can be used directly as a fresh harvest or these can be processed and value added through various methods for utilization in diverse forms. Leaves and flowers are generally shade dried and ground to a fine powder for utilization as tea or food additive. Moringa leaf dry matter in the form of powder or pellets is also utilized as a value-added product for livestock. The roots from young plants are dried after removing root bark and powdered for use as a hot seasoning base. In many countries, the use of Moringa as a food fortificant is increasing rapidly. Different parts of this tree are used in making soups (Babayeju *et al.*, 2014), weaning foods (Arise *et al.,* 2014), herbal biscuits (Alam *et al.,* 2014), bread (Chinma *et al.,* 2014), cake (Kolawole *et al.,* 2013) and yoghurt (Hekmat *et al.,* 2015). Hence, different parts of the tree put value to diversity of food items by enhancing their nutritional potential. Also, the Ben oil obtained from seeds after cold pressing or solvent extraction has been used in skin preparations and ointments since Egyptian times. The oil is used in making cosmetic products and perfumes. The oil cake is a byproduct of oil extraction and useful as an organic fertilizer. In this way, processing and value addition of Moringa leads to increase in its value and it can serve as a good source of income for small land holding farmers.

NUTRITIONAL POTENTIAL OF MORINGA

Moringa oleifera is used to fight malnutrition among infants and nursing mothers especially promising in the tropics because it can provide leaves as a source of food and fodder even in dry period when other sources are typically scanty (Folkard and Sutherland, 1996). Moringa has enormous potential as it is helpful in improving human health, weight gain and milk production in livestock.

As a food sensere care

There should be sustainability and stability in quality food supply for raising any stable community. Cereals, pulses, vegetables, fruits, meat and milk are the sources of food which fulfill our nutritional requirements. However, many of these food items are not affordable by a large population, especially those living below the poverty line. In developing countries, the diet is devoid of proteins, vitamins and minerals. Therefore, for these people; plants that are particularly nutritious represent a valuable option to fulfill such needs. *Moringa oleifera* has the potential to fulfill many of such needs Due to the multitudes of properties which are harbored by this tree species. Moringa leaves have plentiful of nutritional components. The leaves can be taken fresh, cooked or in the form of dry powder. The dry powder retains its nutritional value for many months without refrigeration. The leaves and pods are generally used in common food items. Moringa leaves are rich in vitamin A, C and E (Hekmat *et al.,* 2015). Dry leaves contain ten times more vitamin A than carrot and seven times more vitamin C than orange. Minerals i.e., iron (25 times than spinach), potassium (15 times than bananas) and calcium (17 times than milk) are also in abundance in dry powder of Moringa (Rockwood *et al.,* 2013). Moringa leaves also contain large amount of magnesium, manganese, copper, zinc and iron (Hekmat *et al.,* 2015).

Moringa leaves are rich in protein and this is cited in various studies (Thurber and Fahey, 2009). The studies also reveal that average crude protein in animal milk is much less in comparison to fresh and dry moringa leaves (Stelwagen, 2003; Chandan, 2006). Moringa leaves possess higher amino acids content than those recommended by Food and Agriculture Organization (Mendieta-Araica et al., 2011). Moringa seed meal contains large number of amino acids, except for valine, lysine, and threonine (Oliveira *et al.,* 1999). Moringa dry leaves and fresh pods contain higher contents of arginine, valine and leucine. However, some amino acids (serine, glutamate, aspartate, proline, glycine and alanine) have not been identified in dry leaves and fresh pods (Fuglie, 2000).

The phytonutrients (carotenoids, tocopherols and ascorbic acid) have also been reported in Moringa leaves which help in free radical scavenging (Dan Malam *et al.,* 2001; Saini *et al.,* 2014a; Saini *et al.,* 2014b). Moringa flowers and pods also contain appreciable amounts of carotenoids. Therefore, moringa is the best food supplement for children and infants to combat malnutrition.

The whole seeds of moringa can be eaten as such, roasted or used in powdered form. Moringa seeds have sweet to bitter taste and are consumed mostly after frying (Makkar and Becker, 1996). Moringa seed oil (Ben oil) is used for cooking and salad dressing. Ben oil in seeds is about 30-40% which is rich in unsaturated fatty acids (82%) (Ferrao and Mendez, 1970). The fatty acids present in oil are; linolenic acid, linoleic acid, oleic acid, palmitic, stearic, and behenic acid. The seeds also contain fibre, minerals, proteins, vitamins and amino acids (Kasolo *et al.*, 2010).

As animal feed and fodder

Various tree species are utilized as a fodder for livestock or supplement low quality fodder especially in the dry period (Otsyina and Dzowela, 1995). *M. oleifera* has the potential to supplement low-quality livestock fodders thereby increasing dry matter intake (DMI) and digestibility. It serves as the best example of quality fodder for increasing milk and meat production along with its environment friendly nature and low input requirements. The green fodder as well as dry matter (DM) production depends on the fertilizer, genetic make-up, season and ecological conditions (Palada *et al.,* 2007). Macronutrients which are present in abundance in Moringa play important roles like tissue building, physiological, metabolic, and biochemical processes in livestock. Magnesium (Mg) and Potassium (K) are important for lactating animals. The lactating cows require 0.17–0.20% Mg in dry matter (NRC, 1996). Magnesium (Mg) deficiency during lactating period results in low blood Mg which causes low milk yield. Similarly, beef cows require 0.70% K in dry matter. Besides essential nutrients and multivitamins, Moringa leaves also possess crude protein (21.8%), acid

detergent fibre (22.8%), and neutral detergent fibre (30.8%). The crude fat (412.0 g kg^{-1}), carbohydrates (211.2 g kg^{-1}) and ash (44.3 g kg^{-1}) have also been reported in Moringa leaves (Oliveira *et al.,* 1999). All these compounds are important in increasing livestock production. Hence, Moringa leaves which are rich source of these nutrients; fulfill the nutritional requirements of livestock in the best possible way.

Different plant parts (leaves, twigs or branches etc.) of this tree have variable concentration of nutrients. Hence, the fodder mixtures containing different proportions of Moringa plant parts provide an array of nutrition. For example, mixing of Moringa leaves with soft twigs in fodder provides lower CP and higher NDF contents, whereas mixing Moringa leaves with seed cake in fodder provides higher CP contents (Murro *et al.,* 2003 and Fujihara *et al.,* 2005). Depending upon the nutritional requirement of an animal; specific combination of Moringa plant parts can be given to the animal so that it can utilize the fodder in a best way. As for an example, moringa leaves with twigs having low crude protein can be given to dry cows, requiring low nutrient fodders.

Animals like cattle, goat, sheep, rabbits as well as pigs easily eat green leaves and stems of Moringa (Mulugeta and Fekadu, 2014). It increases the animal weight gain and protein intake (Aharwal, 2018). Positive effects of different parts of Moringa have been reported in the form of increased milk yield in cows, growth rate in sheep and feeding behavior in goat. Livestock feed supplemented with Moringa leaves can increase up to 32% of daily weight gain in livestock. Mixing of fresh Moringa leaves (15 to 17 kg) in daily feed of livestock can boost milk production by 43%. The milk production can be increased further with the supplementation of dry matter feed *i.e.*, 58 and 65% increase by 2 kg and 3 kg dry matter feed, respectively (Foidl *et al.,* 2001). Moringa diet has the highest efficiency of protein & nitrogen utilization and nutrient digestibility (Sultana *et al.,* 2015). Moringa Leaf Meal (MLM) can also be included in poultry and fish meal. The MLM in poultry feed can be particularly used by the small farm holders as natural and healthy feed substitute to synthetic feed supplements (Hermogenes *et al.,* 2014). Moringa leaves which are rich in protein help in improving the microbial protein synthesis in rumen of animals. Hence, it is a suitable alternate of soybean and rapeseed meal and can be given to ruminants (Soliva *et al.,* 2005).

Anti-nutritional factors

Besides nutritional factors, antinutritional factors are also reported in many food and fodder trees and these exert negative effect on human and animal health by interfering with various physiological processes. Therefore, such trees are not selected as priority for food and fodder. Some trees belonging to genus *Acacia*, *Albizia*, *Sesbania* are utilized for fodder purpose and these possess antinutritional factors (Kumar, 1992). However, *Moringa oleifera* represents unique property of being rich in minerals and lower in antinutritional factors. Moringa leaves possess tannins that range from 13-20 g $kg^{-1}$of dry leaves and it is very less in comparison to *Sesbania sesban*, *Acacia angustissima*, and *Acacia cyanophylla* leaves (31, 66 and 38 g kg^{-1}, respectively). The concentration of phytates is also low in Moringa and it ranges from 25-31 g $kg^{-1}$of the dry leaves (Ahn *et al.,* 1989; Makkar and Becker, 1996; Salem *et al.,* 1999). Lectins, trypsin, and amylase inhibitors have not been reported in Moringa leaves (Ferreira *et al.,* 2008). The glucosinolates and isothiocyanates have been reported in Moringa leaves and roots (Bennett *et al.,* 2003; Newton *et al.,* 2010). However, their concentration depends upon the soil type, climatic conditions, cultivar and its growth stage. Moringa leaves possess saponins, which impart a bitter taste. Saponins and isothiocyanates do not always have harmful effects and hence can be consumed by both livestock and human beings (Foidl *et al.,* 2001; Price, 2000). Other antinutritional factors found in many fodder trees are oxalates. However, oxalates reported in Moringa leaves are mainly insoluble oxalates and hence do not cause harmful effect (Radek and Savage, 2008). Hence, *Moringa oleifera* is having better nutritional composition than other leafy vegetables or fodders and can be utilized for food as well as fodder purpose.

PHARMACEUTICAL POTENTIAL OF MORINGA

The various parts of *Moringa oleifera* possess antioxidative, anti-inflammatory, antitumor, antiulcer, antibacterial and antifungal properties. Many bioactive

compounds like glycosides, malonates and flavonoids have been isolated from *Moringa oleifera* (Bennett *et al.,* 2003; Miean and Mohamed, 2001). Isothiocyanates isolated from Moringa leaves possess the capability to fight against human tumor cells. The reason behind this activity may be its capability to induce reactive oxygen species in cancerous cells which is target specific (Tiloke *et al.*, 2013; Jung, 2014; Leelawat and Leelawat, 2014). Many of the plant glycosides can be used in treatment of cancer or chronic diseases (Chumark *et al.,* 2008; Ghasi *et al.,* 2000; Murakami *et al.*, 1998). Lipid peroxidation plays an important part in artherogenesis, thrombosis and cancer development. The flavonoids isolated from Moringa leaves could modulate this process of lipid peroxidation and hence can combat with these diseases. The flavonoids also help in scavenging of free radicals and inhibition of oxidative and hydrolytic enzymes which are involved in several chronic diseases (Rodrigo *et al.,* 2011; Siddhuraju and Becker, 2003). Quercetin, which is a powerful antioxidant, also helps in lowering blood pressure (Larson *et al.,* 2012). Moringa leaf powder also helps in reducing blood sugar levels due to the presence of isothiocyanates (Kushwaha *et al.,* 2014; Waterman *et al.,* 2015).

Moringa leaf, pod and seeds also possess anti-inflammatory properties (Cheenpracha *et al.,* 2010). However, these results are based on lab and animal studies and confirmation on human beings further needs to be verified. Pods are helpful in treating eye disorders, diarrhea, joint pain, liver and spleen problems. The immature pods are used against intestinal worms (Kasolo *et al.*, 2010). Moringa seeds help in treating many diseases like epilepsy, arthritis, viral diseases etc (Kasolo *et al.*, 2010 and Sutalangka *et al.*, 2013) . The flowers of Moringa can cure arthritis, cold, urinary and heart problems (Fuglie, 2005). The gum is used as an antiseptic (Rajangam *et al.,* 2001). The fresh root is used in case of intermittent fever. It can also be applied externally as a paste to treat inflammation, palsy, dropsy and animal bites. The root infusion helps in treating asthma and ascites. Root bark acts as an anti-ulcer, anti-inflammatory and cardiac stimulatory agent (Mishra *et al.,* 2011 and Fahey, 2005).

CROP IMPROVEMENT

Moringa oleifera is a cross-pollinated tree species having diploid chromosome number equal to 28. Therefore, high heterogeneity in morphological, physiological and quantitative traits is anticipated. This tree presents diversity of forms *i.e.,* annual to perennial types, deciduous to evergreen, semi-spreading to upright. Also, some trees flower in two seasons and others flower throughout the year (Raja *et al.*, 2013). Hence, the variability present in various characters can be a source for genetic improvement. However, lack of elite cultivars adapted to local environment and use of open pollinated seed for crop cultivation may be important factors that limit its productivity. Moreover, the number of germplasm accessions and active germplasm banks are incipient across the world. Despite India, some other research centres like AVDRC (Taiwan), Rural development initiative (Zambia) and Moringa Philippines foundation (Philippines); are also involved at the global level, in moringa improvement. Many ecotypes *viz.* Jaffna, Chavakacheri murungai, Chemmurungai, Kadumurungai and Kodikkal murungai have been reported in India (Kumar *et al.,* 2014). Despite huge variability in *Moringa oleifera* no institution has database for cultivated or natural germplasm accessions. There is great inconsistency between the inherent genetic variability in this species and reflected in available germplasm. Hence, priority must be focused on the fixation of poor variability in available germplasm in germplasm banks because it may hinder with the progress of crop improvement programs.

Any crop improvement program depends on the available genetic diversity. There is much less information available on genetic diversity of genus *Moringa*. Some of the studies show a wide genetic diversity present in Moringa (Ramachandran *et al.,* 1980; Shahzad *et al.,* 2013; Suthanthirapandian *et al.,* 1989). These studies also emphasize on the great potential for genetic improvement of this species to enhance the use of this under-utilized tree. There is one downside also i.e., some antinutritional factors in Moringa can reduce the absorption of minerals and protein (Richter *et al.,* 2003; Teixeira *et al.,* 2014). Hence, different strategies should be explored to harness the available genetic diversity. The true understanding of genetic diversity can be gained by the characterization of both cultivated and natural accessions present all over the world. Various

breeding programs, including plant introduction, evaluation, selection, hybridization and use of biotechnological methods have been employed for the development of varieties with dwarf stature, high biomass production, high seed yield and oil content, better quality, resistance to pest and diseases.

Introduction

The variety, Jaffna is presumed to have been introduced from Sri Lanka. It is cultivated in Southern India. Chavakacheri murungai is also an introduced variety from Sri Lanka.

Selection (Mass and Pure line)

The selection of plants starts with open pollination. The plants are selected based on production potential and tested under various conditions and sites. Then, it is followed by controlled pollination. The variety, PKM 1, has been developed through pure line selection. It is annual type and best suited for tropical plains.

Hybridization and selection

It involves hybridization between diverse genotypes followed by selection. The variety, PKM 2 is derived from a cross involving MP31 and MP28 as parents. It is annual type and gives 48% more yield over PKM1. It is suitable for cultivation in tropical plains of India.

Mutation breeding

It is also an important breeding method for creation of variability or novel traits. However, this method is not much utilized in Moringa.

Molecular breeding

Work on Moringa crop improvement based on biotechnology or molecular breeding is very limited and it is just at budding stage. It is obvious from the nucleotide database (NCBI) which possess very less sequence information (DNA and RNA). Recently, due importance has been given to micro propagation (Kantharajah and Dodd, 1991) and use of molecular markers for characterization of germplasm for crop improvement. Use of molecular markers can enhance the genetic improvement as it helps in identifying diverse genotypes. These diverse genotypes can be utilized in hybridization programs to produce recombinants with wide variability.

Biotechnological studies in Moringa started with the use of dominant markers. The amplified fragment length polymorphism (AFLP) marker technique was used to study diversity in natural populations from India and introduced populations in Malawi and Kenya (Muluvi *et al.*, 1999). In this study it was noticed that the population differentiation was significant and genotypes separated according to geographical origin. Further, randomly amplified polymorphic DNA (RAPD) marker technique was used by different researchers to study diversity among cultivated and non-cultivated population of Moringa (Mgendi *et al.,* 2010; Abubakar *et al.,* 2011; Da Silva *et al.,* 2012; Saini *et al.,* 2013 and Rufai *et al.,* 2013). In all these studies an appreciable level of genetic diversity was reported in natural populations with respect to cultivated ones. Hence, less genetic diversity in cultivated accessions indicates that there is an utmost requirement to widen the genetic base for crop improvement programs. Later, with the advent of co-dominant markers like simple sequence repeats (SSRs), the molecular genetic diversity studies got improved. Moringa accessions collected from different countries (Pakistan, India, Tanzania, Senegal, Mozambique, Zimbabwe, Florida, Mexico, Haiti and Belize) have been evaluated earlier and it has been reported that there was high genetic diversity in wild Pakistan accessions, as compared with other accessions (Shahzad *et al.,* 2013). Both morphological and molecular markers (SSRs) have been used for characterization of 300 genotypes of Moringa collected from different locations of India and large diversity have been observed (Ganesan *et al.,* 2014). Both these markers have been used later to screen 34 genotypes of Moringa collected from different regions of Tamil Nadu (Natarajan and Joshi, 2015). It has resulted in identification of superior genotypes which can be utilized in hybridization program to improve oil yield. In this way, morphological markers along with molecular markers can prove an authentic tool to enhance and strengthen breeding programs of Moringa.

CONCLUSIONS AND FUTURE PERSPECTIVES

Moringa oleifera has several strengths and potential utilities. The usage and merits of Moringa as food, livestock fodder and pharmaceutical have been documented widely. Although Moringa plant has

enormous potential, however it has some challenges. Many aspects of this tree e.g., the most successful utilization in agricultural practices, harmful effects of antinutritional factors on human beings and livestock, are still unanswered. Some antinutritional factors reported in this species may limit its utility in form of food and fodder. Therefore, more attention and research are warranted in this direction i.e., how it should be used in diets. Aside from this, agronomic practices requirements for high fodder biomass production have not yet been studied. Therefore, more emphasis should be given to these arenas of research on Moringa to highlight this underutilized tree in a better way.

REFERENCES

Abalaka, M. E., Olonitola, O. S., Onaolapo, J. A. and Inabo, H. I. 2009. Evaluation of acute toxicity of *Momordica charantia* extract, using wistar rats to determine safety levels and usefulness of the plant in ethnochemotherapy. *Int. J. App. Sci.*, **3**: 1-6.

Abubakar, B. Y., Wusirika, R., Muazu, S., Khan, A. U. and Adamu, A. K. 2011. Detection of variability using RAPD markers in some accessions of *Moringa oleifera* lam. in northern Nigeria. *Int. J. Botany*, **7**:237-242.

Aharwal, B., Roy, B., Lakhani, G. P., Baghel, R. P. S., Saini, K. P. S. and Yadav, A. 2018. Effect of *Moringa oleifera* Leaf Meal on Feed Intake and Growth Performance of Murrah Buffalo Calves. *Int J Curr Microbiol Appl Sci.,* **7**: 1960-1973.

Ahn, J. H., Robertson, B. M., Elliott, R., Gutteridge, R. C. and Ford, C. W. 1989. Quality assessment of tropical browse legumes: Tannin content and protein degradation. *Anim. Feed Sci. Technol.,* **27**: 147-156.

Alam, M., Alam, M., Hakim, M., Abdul Huq, A., Obidul Moktadir, S. and Golam. 2014. Development of fiber enriched herbal biscuits: a preliminary study on sensory evaluation and chemical composition. *Int. J. Nutr. Food Sci.,* **3**:246-250.

Anjorin, T. S., Ikokoh, P. and Okolo, S. 2010. Mineral composition of *Moringa oleifera* leaves, pods and seeds from two regions in Abuja, Nigeria. *Int. J. Agric. Biol.*, **12**: 431-434.

Anwar, F. S., Latif, M., Ashraf and Gilani, A. H. 2007. *Moringa oleifera*: A food plant with multiple medicinal uses. *Phytother. Res.,* **21**: 17-25.

Arise, A. K., Arise, R. O., Sanusi, M. O., Esan, O. T. and Oyeyinka, S. A. 2014. Effect of *Moringa oleifera* flower fortification on the nutritional quality and sensory properties of weaning food. *Croat. J. Food Sci. Technol.,* **6:** 65-71.

Babayeju, A., Gbadebo, C., Obalowu, M., Otunola, G., Nmom, I., Kayode, R., Toye, A. and Ojo, F. 2014. Comparison of organoleptic properties of egusi and eforiro soup blends produced with *Moringa* and spinach leaves. *Food Sci. and Qual. Manage.,* **28:** 15-18.

Bennett, R. N., Mellon, F. A., Foidl, N., Pratt, J. H., DuPont, M. S. and Perkins L. 2003. Profiling glucosinolates and phenolics in vegetative and reproductive tissues of the multi-purpose trees *Moringa oleifera* L. (Horseradish tree) and *Moringa stenopetala*. *J Agric Food Chem*, **51**: 3546-3553.

Brisibe, E. A., Umoren, U. E., Brisibe, F., Magalhaes, P. M., Ferreira, J. F. S., Luthria, D., Wu, X. and Prior, R. L. 2009. Nutritional characterization and antioxidant capacity of different tissues of *Artemisia annua* L. *Food Chem.*, **115**:1240-1246.

Chandan, R. C. 2006. History and consumption trends, In: *Manufacturing Yogurt and Fermented Milks*, edited by RC Chandan, (Blackwell Publishing, Ames, IA, USA), 3-15.

Cheenpracha, S., Park, E. J., Yoshida, W. Y., Barit, C., Wall, M., Pezzuto, J. M. and Chang, L. C. 2010. Potential anti-inflammatory phenolic glycosides from the medicinal plant *Moringa oleifera* fruits. *Bioorg. Med. Chem.,* **18:** 6598-6602.

Chinma, C., Abu, J. and Akoma, S. 2014. Effect of germinated tiger nut and *Moringa* flour blends on the quality of wheat-based bread. *J. Food Process. Preserv.,* **38:** 721-727.

Chumark, P., Khunawat, P., Sanvarinda, Y., Phornchirasilp, S., Morales, N. P., Phivthong-ngam, L., Ratanachamnong, P., Srisawat, S. and Pongrapeeporn, K. U. 2008. The in vitro and ex vivo antioxidant properties, hypolipidaemic and anti-atherosclerotic activities of water extract of *Moringa oleifera* Lam. Leaves. *J. Ethnopharmacol.,* **116**: 439-446.

Da Silva, A. V. C., Dos Santos, A. R. F., Ledo, A. D. S., Feitosa, R. B., Almeida, C. S., Da Silva, G. M. and Rangel, M. S. A. 2012. Moringa genetic diversity from germplasm bank using RAPD markers. *Trop. Subtrop. Agroecosystems*, **15**: 31-39.

Dan Malam, H., Abubakar, Z. and Katsayal, U. 2001. Pharmacognosostic studies on the leaves of *Moringa Oleifera*. *Niger J. Nat. Prod. Med*., **5**: 45-49.

Dania, S. O., Akpansubi, P. and Eghagara, O. O. 2014. Comparative Effects of different fertilizer sources on the growth and nutrient content of moringa (*Moringa oleifera*) seedling in a greenhouse trial. *Adv Agric.*, **5**: 67-72.

Fahey, J.W. 2005. *Moringa oleifera*: A review of the medicinal evidence for its nutritional, therapeutic, and prophylactic properties, Part 1. *Trees Life J*, **1**: 5.

Ferrao, A. M. B. C. and Mendez, F. J. E. 1970. Acidos gordos em oleo de Moringueiro (*Moringa oleifera* Lam.). *Agronomia Angolana*, **8**: 3-16.

Ferreira, P. M. P., Davi, F. F., Jose, T. A. O. and Ana, F. U. C. 2008. *Moringa oleifera*: bioactive compounds and nutritional potential. *Annu. Rev. Nutr.*, **21**: 431-437.

Foidl, N., Harinder, P. S., Markar, P. and Becker, K. 2001. The potential of *Moringa oleifera* for agricultural and Industrial uses. In: *The miracle tree: The multiple attributes of moringa*, edited by LJ Fuglie, (Dakar Senegal: Church World Service), 45-76.

Folkard, G. and Sutherland, J. 1996. *Moringa oleifera*: a tree and a litany of potential. *Agrofor. today*, **8**:5-8.

Fuglie, L. J. 2000. New uses of Moringa studied in Nicaragua. ECHO Development Notes-68.

Fuglie, L. J. 2005. The Moringa Tree: A local solution to malnutrition. *Church World Service in Senegal*, **5**:75.

Fujihara, T., Kakengi, A., Shem, M. and Sarwatt, S. 2005. Can *Moringa oleifera* be used as a protein supplement for ruminants? *Asian-Australas J Anim Sci*., **18**:42.

Ganesan, S. K., Singh, R., Debjani, R. C., Jyoti, B., Veena, G. and Avinash, S. 2014. Genetic diversity and population structure study of drumstick (*Moringa oleifera* Lam.) using morphological and SSR markers. *Ind Crops Prod*, **60**:316-325.

Ghasi, S., Nwobodo, E. and Ofili, J.O. 2000. Hypocholesterolemic effects of crude extract of leaf of *Moringa oleifera* Lam. In high-fat diet fed wistar rats. *J. Ethnopharmacol,* 69**:** 2-5.

Hekmat, S., Morgan, K., Soltani, M. and Gough, R. 2015. Sensory evaluation of locally-grown fruit purees and inulin fibre on probiotic yogurt in Mwanza, Tanzania and the microbial analysis of probiotic yogurt fortified with *Moringa oleifera. J Health Popul Nutr,* **33:** 60-67.

Hermogenes, M. P., Rina, Q. P., Christian, B. and Rudy, C. 2014. Utilization and evaluation of *Moringa oleifera* L. as poultry feeds. *APCBEE Procedia,* **8**: 343-347.

Jung, I. L. 2014**.** Soluble extract from *Moringa oleifera* leaves with a new anticancer activity**,** *PloS One*, **9**: 1-10.

Kader, M. M. and Shanmugavelu, K. G. 1982. Studies on the performance of annual drumstick (*Moringa pterygosperma* Gaertn.) at Coimbatore conditions. *South Indian Hortic.*, **30**:95-99.

Kantharajah, A. S. and Dodd, W. A. 1991. Rapid clonal propagation of *Moringa oleifera*. *South Indian Hortic.*, 39: 224-228.

Kasolo, J. N., Bimenya, G. S., Ojok, L., Ochieng, J. and Ogwal-okeng, J. W. 2010. Phytochemicals and uses of *Moringa oleifera* leaves in Ugandan rural communities. *J. Med. Plant Res.,* **4**: 753-757.

Kolawole, F., Balogun, M., Opaleke, D. and Amali, H. 2013. An evaluation of nutritional and sensory qualities of wheat- *Moringa* cake. *Agrosearch,* **13:** 87-94.

Kumar, A. R., Prabhu, M., Ponnuswami, V., Lakshmanan, V. and Nithyadevi, A. 2014. Scientific seed production techniques in moringa. *Agric. Rev.,* **35**: 69-73.

Kumar, R. 1992. Antinutritional factors. The potential risks of toxicity and the methods to alleviate them. In: *Legume Trees and Other Fodder Trees as Protein Source for Livestock*, edited by AW Speedy & PL Pugliese, (FAO, Rome), 1992, 145-160.

Kushwaha, S., Chawla, P. and Kochhar, A. 2014. Effect of supplementation of drumstick (*Moringa oleifera*) and amaranth (*Amaranthus tricolor*) leaves powder on antioxidant profile and oxidative status among postmenopausal women. *Food Sci. Technol.,* **51:** 3464-3469.

Larson, A. J., Symons, J. D. and Jalili, T. 2012. Therapeutic potential of quercetin to decrease blood pressure: review of efficacy and mechanisms. *Adv Nutr.*, **3**:39-46.

Leelawat, S. and Leelawat, K. 2014. *Moringa olefiera* extracts induce cholangio carcinoma cell apoptosis by induction of reactive oxygen species production. *Int. J. Pharmacogn. Phytochem. Res.*, 6: 183-189.

Leone, A., Spada, A., Battezzati, A., Schiraldi, A., Aristil, J. and Bertoli, S. 2015. Cultivation, genetic, ethnopharmacology, phytochemistry and pharmacology of *Moringa oleifera* leaves: An Overview. *Int. J. Mol. Sci.*, **16**: 12791-12835.

Makkar, H. P. S. and Becker, K. 1996. Nutrional value and antinutritional components of whole and ethanol extracted *Moringa oleifera* Leaves. *Anim. Feed Sci. Technol.*, **63**: 211-228.

Masih, L. A., Singh, S., Elamathi, S., Anandhi, P. and Abraham, T. 2019. Moringa: A multipurpose potential crop-A review. *Proc. Natl. Acad. Sci.,* **85**:589-601.

Mendieta-Araica, B., Sporndly, R., Sanchez, N. R. and Sporndly, E. 2011. Moringa (*Moringa oleifera*) leaf meal as a source of protein in locally produced concentrates for dairy cows fed low protein diets in tropical areas. *Livest. Sci.*, **137**:10-17.

Mgendi, M. G., Manoko, M. K. and Nyomora, A. M. 2010. Genetic diversity between cultivated and non-cultivated *Moringa oleifera* Lam. provenances assessed by RAPD markers. *J. Cell Mol. Biol.,* **8**: 95-102.

Miean, H. K. and Mohamed, S. 2001. Flavonoid (myricetin, quercetin, kaempferol, luteolin, and apigenin) content of edible topical plants. *J. Agric. Food Chem.*, **49**: 3106-3112.

Mishra, G., Singh, P., Verma, R., Kumar, S., Srivastav, S., Jha, K. K. and Khosa, R. L. 2011. Traditional uses, phytochemistry and pharmacological properties of *Moringa oleifera* plant: An overview. *Der Pharm. Lett.,* **3**:141-164.

Morton, J. F. 1991. The Horseradish Tree, *Moringa pterygosperma* (Moringaceae) - A Boon to Arid Lands? *Econ. Bot.*, **45**: 318-333.

Mulugeta, G. and Fekadu, A. 2014. Industrial and agricultural potentials of *Moringa, J. Nat. Sci. Res.,* **4**:14.

Muluvi, G. M., Sprent, J. I., Soranzo, N., Provan, J., Odee, D., Folkard, G., McNicol, J. W. and Powell, W. 1999. Amplified fragment length polymorphism (AFLP) analysis of genetic variation in *Moringa oleifera* Lam. *Mol. Ecol.*, **8**: 463-470.

Murakami, A., Kitazono, Y., Jiwajinda, S., Koshimizu, K., Ohigashi, H. and Naizimin, A. 1998. Thiocarbamate from the leaves of *M. oleifera*, holds a strict structural requirement for inhibition of tumor-promoter-induced Epstein-Barr virus activation. *Planta Medica*, 64 () 319-323.

Murro. J., Muhikambele, V. and Sarwatt, S. 2003. *Moringa oleifera* leaf meal can replace cottonseed cake in the concentrate mix fed with Rhodes grass (*Chloris gayana*) hay for growing sheep. *Livest. Res. Rural. Dev.*, **15**:11.

Natarajan, S. and Joshi, A. 2015. Characterization of Moringa (*Moringa oleifera* Lam.) genotypes for growth, pod and seed characters and seed oil using morphological and molecular markers. *Vegetos*, **28**:64-71.

Newton, K. A., Bennett, R. N., Curto, R. B. L., Rosa, E. A. S., Turc, V. L., Giuffrida, A., Curto, A. L., Crea, F. and Timpo, G. M. 2010. Profiling selected phytochemicals and nutrients in different tissues of the multipurpose tree *Moringa oleifera* L., grown in Ghana. *Food Chem.*, **122**: 1047-1064.

Nouman, W., Basra, S. M. A., Siddiqui, M. T., Yasmeen, A., Gull, T. and Alcayde, M. A. C. 2014. Potential of *Moringa oleifera* L. as livestock fodder crop: a review. *Turk J Agric For*, **38**:1-14.

Nouman, W., Siddiqui, M. T., Basra, S. M. A., Khan, R. A., Olson, M. E. ad Munir, H. 2012. Response of *Moringa oleifera* to saline conditions. *Int J Agric Biol*, **14**: 757-762.

NRC. 1996. Nutrient requirements of beef cattle. 7th Revised edition. National Research Council, (National Academy Press, Washington DC, USA).

Oliveira, J. T. A., Silvana, B. S., Ilka, M. V., Benildo, S. C. and Renato, A. M. 1999. Compositional and nutritional attributes of seeds from the multiple purpose tree *Moringa oleifera* Lam. *J. Sci. Food Agric.,* **79**: 815-820.

Otsyina, R. and Dzowela, B. 1995. Importance of Leucaena in Africa. In: *Leucaena psyllid: A Threat to Agroforestry in Africa*, edited by Ciesla WM & Nshubemuki L, (FAO, Rome).

Padulosi, S., Thompson, J. and Rudebjer, P. 2013. Fighting poverty, hunger and malnutrition with neglected and underutilized species (NUS): needs, challenges and the way forward, *Bioversity International*, Rome.

Palada, M. C., Chang, L. C., Yang, R. Y. and Engle, L. M. 2007. Introduction and varietal screening of drumstick tree (*Moringa* spp.) for horticultural traits and adaptation in Taiwan, *Acta Horticulturae*, **752**: 249-253.

Patwardhan, B. 2000. Ayurveda: the designer medicine. *Indian Drugs*, **37**: 213-227.

Peter, K.V. 1978. Drumstick-A rare Indian tree. *Indian Farmers Digest*, **11**: 12.

Price, M. L. 2000. The Moringa tree. ECHO Technical Note, http://www.echonet.org,.

Radek, M. and Savage, G. P. 2008. Oxalates in some Indian green leafy vegetables. *Int. J. Food Sci. Nutr.*, 59: 246-260.

Raja, S., Bagle, B. G. and More, T. A. 2013. Drumstick (*Moringa oleifera* Lam.) improvement for semiarid and arid ecosystem: Analysis of environmental stability for yield. *J. Plant Breed. Crop Sci.,* ***5***: 164-170.

Rajangam, J., Azahakia Manavalan, R. S., Thangaraj, T., Vijayakumar, A. and Muthukrishan, N. 2001. Status of production and utilisation of moringa in southern India. In: Proceedings of the 2001 Workshop on Developmental Potential for Moringa Products, Dar Es Salaam, Tanzania, October 20-November 2, 2001, 33-42.

Ramachandran, C., Peter, K. and Gopalakrishnan, P. 1980. Drumstick (*Moringa oleifera*)- a multipurpose Indian vegetable. *Econ. Bot.*, **34**: 276-283.

Richter, N., Siddhuraju, P. and Becker, K. 2003. Evaluation of nutritional quality of Moringa (*Moringa oleifera* Lam.) leaves as an alternative protein source for Nile tilapia. *Aquaculture,* **217:** 599-611.

Rockwood, J. L., Anderson, B. G., Casamatta, D. A. 2013. Potential uses of *Moringa oleifera* and an examination of antibiotic efficacy conferred by *M. oleifera* seed and leaf extracts using crude extraction techniques available to underserved indigenous populations. *Indian J Phytotherapy Res.,* **3**: 61-71.

Rodrigo, R., Gonzalez, J. and Paoletto, F. 2011. The role of oxidative stress in the pathophysiology of hypertension. *Hypertens. Res.,* **34:** 431-440.

Rollof, H., Lang, U. and Stimm, B. 2009. Enzyklopadie der Holzgewachse, Handbuchund Atlas der Dendrologie, **1**: 8.

Rufai, S., Hanafi, M. M., Rafii, M. Y., Ahmad, S., Arolu, I. W. and Ferdous, J. 2013. Genetic dissection of new genotypes of drumstick tree (*Moringa oleifera* Lam.) using random amplified polymorphic DNA marker. *Biomed Res. Int.*, 1-6.

Sachan, A., Meena, A. K., Kaur, R., Pal, B. and Singh, B. 2010. *Moringa oleifera*: A Review. *J Pharmacy Res.*, **3**:-842.

Saini, R., Prashanth, K. H., Shetty, N. and Giridhar, P. 2014a. Elicitors, SA and MJ enhance carotenoids and tocopherol biosynthesis and expression of antioxidant related genes in *Moringa oleifera* Lam. Leaves. *Acta Physiol. Plant.*, **36**: 2695-2704.

Saini, R., Shetty, N., Prakash, M. and Giridhar, P. 2014b. Effect of dehydration methods on retention of carotenoids, tocopherols, ascorbic acid and antioxidant activity in *Moringa oleifera* leaves and preparation of a RTE product. *J. Food Sci. Technol.*, **51**: 2176-2182.

Saini, R. K., Saad, K. R., Ravishankar, G. A., Giridhar, P. and Shetty, N. P. 2013. Genetic diversity of commercially grown *Moringa*

oleifera Lam. cultivars from India by RAPD, ISSR and cytochrome P450-based markers. *Plant Syst. Evol.,* **299**: 1205-1213.

Salem, H. B., Nefzaoui Salem, L. B. and Tisserand, J. L. 1999. Different means of administering polyethylene glycol to sheep: effect on the nutritive value of *Acacia cyanophylla* Lindl. Foliage. *Anim. Sci.,* **68**: 809-818.

Sanchez, N. R., Stig, L. and Inger, L. 2006. Biomass production and chemical composition of *Moringa oleifera* under different management regimes in Nicaragua. *Agrofor. Syst.*, **66**: 231-242.

Shahzad, U., Khan, M. A., Jaskani, M. J., Khan, I. A. and Korban, S. S. 2013. Genetic diversity and population structure of *Moringa oleifera*. *Conserv. Genet.,* **14**: 1161-1172.

Sharma, V., Paliwal, R., Janmeda, P. and Sharma, S. 2012. Chemopreventive efficacy of *Moringa oleifera* pods against 7, 12-dimethylbenz [a] anthracene induced hepatic carcinogenesis in mice. *Asian Pac J Cancer Prev*, **13**: 2563-2569.

Siddhuraju, P. and Becker, K. 2003. Antioxidant properties of various solvent extracts of total phenolic constituents from three different agroclimatic origins of drumstick tree (*Moringa oleifera* Lam.) leaves. *J. Agric. Food Chem.*, **51**: 2144-2155.

Soliva, C. R., Kreuzer, M., Foidl, N., Foidl, G., Machmuller, A. and Hess, H. D. 2005. Feeding value of whole and extracted *Moringa oleifera* leaves for ruminants and their effects on ruminal fermentation in vitro. *Anim. Feed Sci. Tech.,* **118**: 47-62.

Stelwagen, K. 2003. Milk secretion and biosynthesis/lactose, In: *Encyclopedia of Dairy Sciences*, edited by Roginski H, Fuquay JW& Fox PF, (Academic Press, New York), 1842-1847.

Sultana, N., Alimon, A. R., Huque, K. S., Baba, M. and Hossain, J. 2015. Evaluation of Moringa Foliage (*Moringa oleifera*) as Goat Feed. *Iran. J. Appl. Anim. Sci.,* **5**:865-871.

Sutalangka, C. J., Wattanathorn, S. and Muchimapura, W. 2013. Thukham-mee, *Moringa oleifera* mitigates memory impairment and neuro-degeneration in animal model of age-related dementia. *Oxid. Med. Cell Longev.*, 1-9.

Suthanthirapandian, I. R., Sambandamurthy, S. and Irulappan, I. 1989. Variations in seedling populations of annual moringa (*Moringa pterygosperma* Gaertn.). *South Indian Hortic.* **37**: 301-302.

Teixeira, E. M., Carvalho, M. R., Neves, V. A., Silva, M. A. and Arantes-Pereira, L. 2014. Chemical characteristics and fractionation of proteins from *Moringa oleifera Lam.* Leaves. *Food Chem.*, **15:** 147-151.

Thurber, M. D. and Fahey, J. W. 2009. Adoption of *Moringa oleifera* to combat under-nutrition viewed through the lens of the Diffusion of Innovations theory. *Ecol Food Nutr*, **48**: 212-225.

Tiloke, C., Phulukdaree, A. and Chuturgoon, A. A. 2013. The antiproliferative effect of *Moringa oleifera* crude aqueous leaf extract on cancerous human alveolar epithelial cells. *BMC Complement Altern. Med.*, **13**: 226-233.

Waterman, C., Rojas-Silva, P., Tumer, T. B., Kuhn, P., Richard, A. J., Wicks, S., Stephens, J. M., Wang, Z., Mynatt, R., Cefalu, W. and Raskin, I. 2015. Isothiocyanate-rich *Moringa oleifera* extract reduces weight gain, insulin resistance, and hepatic gluconeogenesis in mice. *Mol Nutr Food Res,* **59:** 1013-1024.

Yu, L., Parry, J. W. and Zhou, K. 2005. Oils from Herbs, Spices, and Fruit Seeds. In: *Bailey's Industrial Oil and Fat Products*, Sixth Edition (John Wiley and Sons, Inc).

(Received on 20.03.2021, Revised on 27.05.2021 and Accepted on 27.06.2021)