

**EVALUATION OF *Moringa oleifera* Lam. SEED
SOURCES FOR NUTRITIONAL VALUE AND MINERAL
CONTENT**

Thesis

**Submitted to the Punjab Agricultural University
in partial fulfillment of the requirements
for the degree of**

**MASTER OF SCIENCE
in
FORESTRY
(Minor Subject: Microbiology)**

By

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(L-2018-A-81-M)**

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LUDHIANA-141 004 (INDIA)**

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CERTIFICATE - I

This is to certify that the thesis entitled, “**Evaluation of *Moringa oleifera* Lam. seed sources for nutritional value and mineral content**” submitted in partial fulfilment of the requirements for the degree of **Master of Science**, in the subject of **Forestry** (Minor Subject: **Microbiology**) of the Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Karamdeep Singh (L-2018-A-81-M)** under my supervision and the thesis has not previously formed the basis for the award of any degree, diploma or other similar title.

The assistance and help received during the course of investigation have been fully acknowledged.

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CERTIFICATE - II

This is to certify that the thesis entitled "**EVALUATION OF *Moringa oleifera* Lam. SEED SOURCES FOR NUTRITIONAL VALUE AND MINERAL CONTENT**" submitted by **Karamdeep Singh (L-2018-A-81-M)** to the Punjab Agricultural University, Ludhiana, in the partial fulfillment of the requirements for the degree of M.Sc. in the subject of **Forestry** (Minor subject: **Microbiology**) has been approved by the Student's Advisory Committee along with External Examiner after an oral examination on the same.

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ABSTRACT

The study presents nutritional, fodder and mineral values of tender leaves, mature leaves and twigs collected during rainy season from fourteen seed sources of *Moringa oleifera*. Out of 14 genotypes/seed sources, 5 were national varieties, 5 seed sources from Punjab and rest 4 from different parts of India. Studies on dry matter, ash content, organic matter, nutritional traits *i.e.* crude protein, crude fats, crude fibres, total carbohydrates, total soluble sugars, nitrogen free extract and total energy value; fodder traits *i.e.* NDF, ADF, ADL, IVDMD, hemicellulose, cellulose, DMI, DDM, RFV and pH; anti-nutritional characters *i.e.* total phenols, flavonoides, tannin, saponin, nitrate and oxalate were carried out using standard protocols and procedures, while mineral elements were determined by ICP-MS. Significant differences were observed for all traits studied among seed sources. Mean maximum dry matter, crude protein and total energy was recorded in S13, S9 and S14 sources, respectively. However, maximum dry matter intake and digestibility was observed for PAU local source (S5). Seed source S14 (PAU local source) was observed best for nutritional value (based on energy value) under Punjab conditions. In general, S9 seed source was found to be best for the fodder traits (based on RFV) and S5 had fewer amounts of anti-nutrients (based on nitrate content). The pH of leaves ranged from 5.11 to 6.59. Tender leaves were observed best for ash content, total carbohydrates, NFE, NDF, ADF, ADL, DMI, DDM, RFV and nitrates; mature leaves for crude protein, crude fats, crude fibre, total energy value, IVDMD and pH; and twigs for dry matter, TSS, hemicellulose, cellulose, phenols, flavonoids, tannins, saponins and oxalates. For mineral elements, mature leaves are better for N, P, K, Ca, Mg, S, Fe, Na, B, Mn and Ni except Cu and Zn. Tender leaves possess the less amount of heavy metals like Pb, Cd and Cr. Over all, PAU local source (S14) found better for major nutrients like K, Ca, Fe, Na and Mg. All traits were strongly genetically controlled as environmental coefficient of variation was very low. Dry matter showed positive correlation with OM, CP, fats and fibre, while negative with carbohydrates, TSS and NEF, however, negative with CP in twigs. Crude protein was negatively correlated with total carbohydrates, TSS and NFE.

Key Words: *Moringa oleifera*, seed sources, genetic variability, nutritional values, fodder traits, antinutrients, mineral content.

Signature of Major Advisor

Signature of Student

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ਸਾਰ

ਅਧਿਐਨ ਵਿੱਚ ਪੰਜਾਬ ਦੇ ਮੇਰਿੰਗਾ ਓਲੀਫੇਰਾ ਦੇ ਚੌਦਾਂ ਬੀਜ ਸਰੋਤਾਂ ਤੋਂ ਬਰਸਾਤ ਦੇ ਮੌਸਮ ਵਿੱਚ ਇਕੱਠੇ ਕੀਤੇ ਕੋਮਲ ਪੱਤੇ, ਸਿਆਣੇ ਪੱਤੇ ਅਤੇ ਟਹਿਣੀਆਂ ਦੇ ਪੌਸ਼ਟਿਕ, ਚਾਰੇ ਅਤੇ ਖਣਿਜ ਮੁੱਲ ਪੇਸ਼ ਕੀਤੇ ਗਏ ਹਨ। 14 ਜੀਨੋਟਾਈਪਸ/ਬੀਜ ਸਰੋਤਾਂ ਵਿੱਚੋਂ, 5 ਰਾਸ਼ਟਰੀ ਕਿਸਮਾਂ, 5 ਬੀਜ ਪੰਜਾਬ ਤੋਂ ਅਤੇ ਬਾਕੀ 4 ਭਾਰਤ ਦੇ ਵੱਖ-ਵੱਖ ਹਿੱਸਿਆਂ ਤੋਂ ਸਨ। ਸੁੱਕੇ ਪਦਾਰਥ, ਸੁਆਹ ਦੀ ਸਮੱਗਰੀ, ਜੈਵਿਕ ਪਦਾਰਥ, ਪੇਸ਼ਣ ਸੰਬੰਧੀ ਗੁਣ ਅਰਥਾਤ ਕੱਚੇ ਪ੍ਰੋਟੀਨ, ਕੱਚੇ ਚਰਬੀ, ਕੱਚੇ ਤੰਤੂ, ਕੁੱਲ ਕਾਰਬੋਹਾਈਡਰੇਟ, ਕੁਲ ਘੁਲਣਸ਼ੀਲ ਸ਼ੱਕਰ, ਨਾਈਟ੍ਰੋਜਨ ਮੁਕਤ ਐਸਟਰੈਕਟ ਅਤੇ ਕੁੱਲ ਊਰਜਾ ਮੁੱਲ ਬਾਰੇ ਅਧਿਐਨ; ਚਾਰੇ ਦੇ ਗੁਣ ਜਿਵੇਂ ਕਿ ਐਨਡੀਐਫ, ਏਡੀਐਫ, ਏਡੀਐਲ, ਆਈਵੀਡੀਐਮਡੀ, ਹੇਮੀਸੈਲੂਲੋਜ਼, ਸੈਲੂਲੋਜ਼, ਡੀਐਮਆਈ, ਡੀਡੀਐਮ, ਆਰਐਫਵੀ ਅਤੇ ਪੀਐਚ; ਐਂਟੀ ਪੌਸ਼ਟਿਕ ਅੱਖਰ ਅਰਥਾਤ ਕੁੱਲ ਫੀਨੋਲ, ਫਲੇਵੋਨੋਇਡਜ਼, ਟੈਨਿਨ, ਸੈਪੋਨੀਨ, ਨਾਈਟ੍ਰੇਟ ਅਤੇ ਆਕਸਲੇਟ ਸਟੈਂਡਰਡ ਪ੍ਰੋਟੋਕੋਲ ਅਤੇ ਪ੍ਰਕਿਰਿਆਵਾਂ ਦੀ ਵਰਤੋਂ ਕਰਦਿਆਂ ਕੀਤੇ ਗਏ, ਜਦੋਂ ਕਿ ਖਣਿਜ ਤੱਤ ਆਈਸੀਪੀ-ਐਮਐਸ ਦੁਆਰਾ ਨਿਰਧਾਰਤ ਕੀਤੇ ਗਏ ਸਨ। ਬੀਜ ਸਰੋਤ ਵਿਚਕਾਰ ਅਧਿਐਨ ਕੀਤੇ ਸਾਰੇ ਗੁਣਾਂ ਲਈ ਮਹੱਤਵਪੂਰਨ ਅੰਤਰ ਵੇਖੇ ਗਏ। ਮਤਲਬ ਵੱਧ ਤੋਂ ਵੱਧ ਸੁੱਕੇ ਪਦਾਰਥ, ਕੱਚੇ ਪ੍ਰੋਟੀਨ ਅਤੇ ਕੁੱਲ ਊਰਜਾ ਕ੍ਰਮਵਾਰ ਐਸ 13, ਐਸ 9 ਅਤੇ ਐਸ 14 ਸਰੋਤਾਂ ਵਿੱਚ ਦਰਜ ਕੀਤੀ ਗਈ। ਪੀਏਯੂ ਸਥਾਨਕ ਸਰੋਤ (ਐਸ 5) ਲਈ ਵੱਧ ਤੋਂ ਵੱਧ ਖੁਸ਼ਕ ਪਦਾਰਥ ਦਾ ਸੇਵਨ ਅਤੇ ਪਾਚਕਤਾ ਵੇਖੀ ਗਈ। ਬੀਜ ਸਰੋਤ ਐਸ 14 (ਪੀਏਯੂ ਸਥਾਨਕ ਸਰੋਤ) ਨੂੰ ਪੰਜਾਬ ਦੀਆਂ ਸਥਿਤੀਆਂ ਅਧੀਨ ਪੌਸ਼ਟਿਕ ਮੁੱਲ (ਊਰਜਾ ਮੁੱਲ ਦੇ ਅਧਾਰਤ) ਲਈ ਸਭ ਤੋਂ ਵਧੀਆ ਮੰਨਿਆ ਗਿਆ ਹੈ। ਆਮ ਤੌਰ ਤੇ, S9 ਬੀਜ ਸਰੋਤ ਚਾਰੇ ਦੇ ਗੁਣਾਂ ਲਈ ਸਭ ਤੋਂ ਵਧੀਆ ਪਾਇਆ ਜਾਂਦਾ ਹੈ (ਆਰਐਫਵੀ ਦੇ ਅਧਾਰ ਤੇ) ਅਤੇ ਐਸ 5 ਵਿੱਚ ਐਂਟੀ-ਪੌਸ਼ਟਿਕ ਤੱਤਾਂ ਦੀ ਘੱਟ ਮਾਤਰਾ ਹੁੰਦੀ ਸੀ (ਨਾਈਟ੍ਰੇਟ ਸਮੱਗਰੀ ਦੇ ਅਧਾਰ ਤੇ)। ਪੱਤਿਆਂ ਦਾ ਪੀਐਚ 5.11 ਤੋਂ 6.59 ਤੱਕ ਸੀ। ਟੈਂਡਰ ਦੇ ਪੱਤੇ ਸੁਆਹ ਦੀ ਸਮੱਗਰੀ, ਕੁੱਲ ਕਾਰਬੋਹਾਈਡਰੇਟ, ਐਨਐਫਵੀ, ਐਨਡੀਐਫ, ਏਡੀਐਫ, ਏਡੀਐਲ, ਡੀਐਮਆਈ, ਡੀਡੀਐਮ, ਆਰਐਫਵੀ ਅਤੇ ਨਾਈਟ੍ਰੇਟਸ ਲਈ ਵਧੀਆ ਵੇਖੇ ਗਏ; ਕੱਚੇ ਪ੍ਰੋਟੀਨ, ਕੱਚੇ ਚਰਬੀ, ਕੱਚੇ ਫਾਈਬਰ, ਕੁੱਲ ਊਰਜਾ ਮੁੱਲ, ਆਈਵੀਡੀਐਮਡੀ ਅਤੇ ਪੀਐਚ ਲਈ ਪਰਿਪੱਕ ਪੱਤੇ; ਅਤੇ ਸੁੱਕੇ ਪਦਾਰਥ, ਟੀਐਸਐਸ, ਹੇਮੀਸੈਲੂਲੋਜ਼, ਸੈਲੂਲੋਜ਼, ਫੀਨੋਲਸ, ਫਲੇਵੋਨੋਇਡਜ਼, ਟੈਨਿਨਸ, ਸੈਪੋਨੀਨਜ਼ ਅਤੇ ਆਕਸਲੇਟਸ ਲਈ ਟਵੀਜ਼। ਖਣਿਜ ਤੱਤਾਂ ਲਈ, ਸਿਆਣੇ ਪੱਤੇ Cu ਅਤੇ Zn ਨੂੰ ਛੱਡ ਕੇ N, P, K, Ca, Mg, S, Fe, Na, B, Mn ਅਤੇ Ni ਲਈ ਵਧੀਆ ਹਨ। ਟੈਂਡਰ ਦੇ ਪੱਤੇ ਬਹੁਤ ਘੱਟ ਭਾਰੀ ਧਾਤਾਂ ਜਿਵੇਂ Pb, Cd ਅਤੇ Cr ਦੇ ਘੱਟ ਹੁੰਦੇ ਹਨ। ਸਭ ਤੋਂ ਵੱਧ, ਪੀਏਯੂ ਸਥਾਨਕ ਸਰੋਤ (ਐਸ 14) ਮੁੱਖ ਪੌਸ਼ਟਿਕ ਤੱਤਾਂ ਜਿਵੇਂ K, Ca, Fe, Na ਅਤੇ Mg ਲਈ ਬਿਹਤਰ ਪਾਇਆ। ਸਾਰੇ ਗੁਣ ਵਿਸ਼ੇਸ਼ ਤੌਰ ਤੇ ਜੈਨੇਟਿਕ ਤੌਰ ਤੇ ਨਿਯੰਤਰਿਤ ਕੀਤੇ ਗਏ ਸਨ ਕਿਉਂਕਿ ਪਰਿਵਰਤਨ ਦਾ ਵਾਤਾਵਰਣਕ ਗੁਣਾ ਬਹੁਤ ਘੱਟ ਸੀ। ਸੁੱਕੇ ਪਦਾਰਥ ਨੇ ਜੈਵਿਕ ਪਦਾਰਥ, ਕੱਚੇ ਪ੍ਰੋਟੀਨ, ਚਰਬੀ ਅਤੇ ਫਾਈਬਰ ਨਾਲ ਸਕਾਰਾਤਮਕ ਸੰਬੰਧ ਦਰਸਾਇਆ, ਜਦੋਂ ਕਿ ਕਾਰਬੋਹਾਈਡਰੇਟ, ਟੀਐਸਐਸ ਅਤੇ ਐਨਐਫਵੀ ਨਾਲ ਨਕਾਰਾਤਮਕ, ਹਾਲਾਂਕਿ, ਟਵਿਕਸ ਵਿਚ ਸੀ ਪੀ ਨਾਲ ਨਕਾਰਾਤਮਕ ਹੈ। ਕੱਚੇ ਪ੍ਰੋਟੀਨ ਦਾ ਕੁੱਲ ਕਾਰਬੋਹਾਈਡਰੇਟ, ਟੀਐਸਐਸ ਅਤੇ ਐਨਐਫਵੀ ਨਾਲ ਨਕਾਰਾਤਮਕ ਸੰਬੰਧ ਸੀ।

ਰੁੱਜੀ ਸ਼ਬਦ: ਮੇਰਿੰਗਾ ਓਲੀਫੇਰਾ, ਬੀਜ ਸਰੋਤ, ਜੈਨੇਟਿਕ ਪਰਿਵਰਤਨਸ਼ੀਲਤਾ, ਪੌਸ਼ਟਿਕ ਮੁੱਲ, ਚਾਰੇ ਦੇ ਗੁਣ, ਐਂਟੀਨਟ੍ਰੀਐਂਟ, ਖਣਿਜ ਸਮੱਗਰੀ।

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LIST OF ABBREVIATIONS AND SYMBOLS

Sr. No.	Abbreviation	Meaning
1.	<i>M.</i>	<i>Moringa</i>
2.	spp	Species
3.	yr	year
4.	µg	Microgram
5.	g	gram
6.	mg	Milligram
7.	kg	Kilogram
8.	Kcal	Kilocalories
9.	Anon	Anonymous
10.	<i>i.e.</i>	That is
11.	<i>etc.</i>	etcetera (and so on)
12.	<i>viz.,</i>	Videlicet (Namely)

CHAPTER I

INTRODUCTION

Moringa oleifera Lam. [syn. *Moringa pterygosperma* Gaertn. Nom. Illeg, *Guilandina moringa* L. and *Hyperanthera moringa* (L.) Vahl] belongs to monogeneric family, Moringaceae which is native to the north-western India and also foot hills of Himalayan tracts including Pakistan, Bangladesh and Afghanistan. The family has one genus, *Moringa*, which has 13 species (Dangi *et al* 2002), of which, *Moringa oleifera* is well known and widely distributed and adapted (Lalas and Tsaknis 2002). In the Dravidian lingo (south Indian), it is known as several vernacular names but they are all found in the common root "Morunga". In English, it is well-known by several names, of which drumstick tree, horseradish tree and west Indian ben tree are more common (Ramachandran *et al* 1980). In local language, it is called as Sahjan (Hindi) and Sohanjana (Punjabi). *Moringa oleifera* is an indigenous tree from north-western India and is often cultivated in hedges and home yards for household uses. *Moringa oleifera* is a native of northern India but is now found in all tropical areas. The moringa is believed to be an important tree species in view of protection from dry spell and dry climatic conditions due to their tuberous roots (Padayachee and Baijnath 2012). *Moringa oleifera* is adapted to various types of soils and is successfully introduced in pacific tolls where soil pH is usually greater than 8.5, it does best when temperatures range from 25°C to 40°C and annual rainfall of 5,500 mm. It grows well from sea level to 1000 meters above mean sea level (Dalla 1993).

India is a major exporter country for moringa products with an annual production of 2.20-2.40 million tons of tender fruit with the area under cultivation of 38,000 ha and having productivity of approximately 63 tons per ha (Shekhar *et al* 2017). Across the country, Andhra Pradesh is the leading state who has maximum share in area under cultivation i.e. 15665 ha followed by 10280 ha in Karnataka and 7408 ha in Tamil Nadu. In these states, more than 52,000 farmers are directly or indirectly involved in commercial investment with an annual income of \$1,500 per hectare (Rajangam *et al* 2001; Patel *et al* 2010).

Among the 13 species of *Moringa* genus, *Moringa oleifera* is only observed as a store house of almost all type of nutrients like proteins, fats, fibres, carbohydrates, sugars, starches and essential amino acids (Stadtlander and Becker 2017). All parts of *M. oleifera* showed high amount of nutrients, of which tender leaves and immature fruits have maximum nutrients (Verma and Nigam 2014; Sohani 2018). Recently, researchers had proven that *M. oleifera* tree has highly digestible nutrients and carotenoids suitable to undernourishment concern in low economic countries (Olagbemide and Alikwe 2014; Gopalakrishnan *et al* 2016). All essential vitamins like vitamin B such as folic acid, pyridoxine and nicotinic acid, vitamin A, C, D and E which are crucial for body growth and development are present in *M. oleifera* (Mbikay 2012). Levels of nutrients in leaves of *M. oleifera* was quite high such as 27.51%

crude protein, 19.25% crude fibre, 2.23% crude fat, 43.88% carbohydrate content and 305.62 cal/g energy value (Oduro *et al* 2008). However, Yameogo *et al* (2011) observed similar amount of crude protein (27.2%) and 38.6% carbohydrates, while crude fat (17.1%) was very high in a plants grown under dry environment.

Moreover, *M. oleifera* leaves are excellent resource of natural antioxidants like phenols and flavonoides; and consequently improve the timeframe of practical usability of foods because of the presence of different kinds of antioxidant agents, for example, ascorbic acid, flavonoids, phenolic compounds and carotenoids (Dillard and Germany 2000; Siddhuraju and Becker 2003). *Moringa oleifera* leaves have adequate amount of mineral elements and utilized as substitute of iron and calcium tablets (Fuglie 2005). *Moringa oleifera* leaves are excellent source of essential elements i.e. Ca, K, Fe, Mg, Zn and Cu (Kasolo *et al* 2010). Study carried out by Asiedu-Gyekye *et al* (2014) revealed 35 components (14 macroelements and 21 microelements) from leaves.

Mulyaningsih and Yusuf (2018) observed that dried leaves contained Ca (3.45 %), Mg (0.66 %), K (3.35 %), Cl (0.25%), Fe (147.20 mg/kg), Na (152.52 mg/kg), Zn (35.71 mg/kg), Mg (102.10 mg/kg), Cr (4.76 mg/kg), Br (4.82 mg/kg), Co (0.16 mg/kg), and Al (150.40 mg/kg). Proximate analysis of *M. oleifera* leaves revealed that the anti-nutrients detected in leaves are very low in quantity and can be used in feeding of small ruminants and chickens to improve growth and health status (Ogbe and Affiku 2011).

In addition, a nutritious diet plays an important role in livestock to increase the milk yield. Amino acids, fatty acids, minerals and vitamins are important in the daily diet of animals. The chemical composition of fibre components affects feed digestion, which directly or indirectly affects animal feed consumption. It has been reported that the nutrient content in moringa leaves varies from place to place (Anjorin *et al* 2010). Several studies carried out by Richter *et al* 2003; Sanchez *et al* 2006; Mendieta-Araica *et al* 2011 examined the practices of growing moringa and its use as animal feed and fish feed. They have shown that moringa is as potential crop for animal feed and silage making. *Moringa* leaves possessed excellent nutritive and fodder values like crude protein (21.8%), carbohydrates (211.2 g kg⁻¹), acid detergent fiber (22.8%), neutral detergent fiber (30.8%), crude seed oil (412.0 g kg⁻¹), and less amount of inorganic compounds like ash (44.3 g kg⁻¹) (Oliveira *et al* 1999; Sanchez *et al* 2006).

In addition, low-fat diets or portions can be enhanced by mixing of leaf powder of moringa as a supplement, increasing dry feed intake and digestion of animal feed, as well as increasing protein intake in fish diets (Richter *et al* 2003). Intake of moringa leaves in livestock feed can increase up to 32% of daily body weight. Besides, mixture of green leaves up to 15 to 17 kg in daily diet of animal can increase milk production potential up to 43% than routine feed, and increase by 58% by mixing 2 kg of dry feed and by 65% when 3kg of dry feed of moringa is mixed (Foidl *et al* 2001).

It is an established fact that nutrient composition of *M. oleifera* different plant parts varies with the geographical location due to varying factors of locality. The nutritional composition varies with sources, cultural practices, environment, fertigation techniques, drying methods and storage conditions of plant parts (Dhakad *et al* 2019). Huge difference for the nutritional values was observed among the leaves of *M. oleifera* planted in three different countries (Leone *et al* 2015). Similar kind of results was obtained by Chelliah *et al* (2017) for the nutritional and phytochemical variability among the leaf samples collected from the two different regions. Fuglie (2005) mentioned in his study that nutrient concentrations fluctuate with the seasons or environmental conditions. In summer-rainy season, vitamin A has more concentration, whereas, vitamin C and iron content were observed more in cool season (Yang *et al* 2006). The high concentration of major bioactive ingredients reported in different plant parts during summer season may be responsible cause of higher usage of *M. oleifera* in summer season (Safaeian *et al* 2015), of which the concentration of phenolic compounds was observed more in winter season (Shih *et al* 2011). These results are in agreement of the facts reported by Moyo *et al* (2011) and revealed that the variability in nutritional value is considerably attributed by the factors of locality and ecology. Iqbal and Bhanger (2006), Joshi and Mehta (2010) stated that the variations could be due to several other factors like genotypes, cultivation techniques, harvesting time, storage conditions and drying methods.

However, several studies have been carried out to assess the variability in nutritional profile and concentration of mineral elements in different plant parts of *M. oleifera*, though phenophase variations are not so reported under Punjab conditions. It is an established fact that variations for nutritional, mineral and fodder traits are due to environmental conditions (Forster *et al* 2015) but these salient findings should be confirmed in field plantation areas of *M. oleifera* in north Indian conditions. Likewise, moringa is getting well known as a significant food commodity considering its present status as the "natural nutrition of the tropics, there is sufficient scope for characterization of wild land races and released varieties at nation level based on nutritional and fodder traits. The wide genetic variability found in the moringa cultivars and genotypes is straightforwardly connected to the high level of biodiversity, which is conceivably valuable for high productivity followed by nutritional food security and biological sustainability. However, no complete study could be found among the seed sources of *M. oleifera* allowing comparisons of nutritive, mineral and fodder values for different phenophases like tender leaves, mature leaves and twigs. Keeping in view the above realities and facts, the current study has been planned with the following objectives:

- 1) To study variations among seed sources of *Moringa oleifera* for nutritional value and mineral content
- 2) To study variations among seed sources of *Moringa oleifera* for fodder and antinutritional characteristics

CHAPTER II

REVIEW OF LITERATURE

The review of literature provides basis for preparing the research proposal and conceptualization of different ideas given by different researchers. In the present case, the relevant literatures with particular focused on nutritional, mineral and fodder evaluation of *Moringa oleifera* has been reviewed with the following heads:

a) Nutritional evaluation of *Moringa oleifera* seed sources

b) Fodder quality evaluation of *Moringa oleifera* seed sources

c) Mineral quality evaluation of *Moringa oleifera* seed sources

(a) Nutritional evaluation of *Moringa oleifera* seed sources

Makkar and Becker (1996) studied the *M. oleifera* leaves and reported that the crude protein contents of extracted and unextracted leaves were 43.5% and 25.1%, respectively. The true protein content of these leaves were 93.8% and 81.3% of the total crude protein (non protein nitrogen contents of 2.7 and 4.7% were observed in the extracted and unextracted leaves). Fuglie (2005) reported that 8 g dried leaf powder will satisfy a child within ages 1-3 with 14% of the protein, 40% of the calcium, 23% of the iron, and nearly all the vitamin A that the child needs in a day. Elkhaliif *et al* (2007) studies the nutritional value of the leaves of the *M. oleifera* grown in Sudan and the results showed that, the moisture content was 74.42%, 16.7% protein, 3.5% fiber, 8% ash, and 1.7% fat. In addition, the mineral content was clarified (Eliphalifa AO, Ahmed SA, Adam S. 2007). Examination of the healthy diet of *M. oleifera* leaves and extracts.

Nutrient content in *M. oleifera* leaves were determined using standard analytical methods by Oduro *et al* (2008). The crude protein was 27.51%, crude fibre 19.25%, crude fat 2.23%, ash content 7.13%, moisture content 76.53%, carbohydrate content 43.88%, and the calorific value 1296.00 KJ/g (305.62 cal/g). These results reveal that the leaves contain an appreciable amount of nutrients and can be included in diets to supplement our daily nutrient needs. Juliani *et al* (2009) evaluated nutritional value of *M. oleifera* leaves collected from Senegal (Massar region, Niaye). The results showed that moringa leaves have low moisture content, low percentage of total phenols (3-4%) and high protein content (13-14%).

Jongrungruangchok *et al* (2010) was made a comparison of nutritional status among the moringa leaves collected from 11 agricultural climatic regions of Thailand. The leaves were found to contain 19.15-28.80% protein; 2.06-2.47% fat and 16.30-23.89% fiber content. Gastelum *et al* (2010) carried out study in order to compare the biochemical characteristics from three edible parts of the multipurpose tree *M. oleifera* i.e. leave, flowers, and immature pods. The chemical composition (of leaves dry weight) ranged from 19.34% to 22.42% for

protein, 1.28% to 4.96% for lipids, 7.62% to 14.60% for ash, and 30.97% to 46.78% for dietary fiber.

Moyo *et al* (2011) conducted a study to assess the nutritional value of moringa leaves from the South African ecotype. Proximate and Van Soest methods were used to determine the nutritional value of moringa leaves. The dried leaves had crude protein levels of 30.30% and 19 amino acids. A study of chemical composition and nutritional value of *M. oleifera* leaves was carried out by Yameogo *et al* (2011) and leaves were collected from three different regions of Ouagadougou, Burkina Faso country. Nutritional content analysis including elemental was done using the recommended analytical method. The result analysis shows that the percentage (%) of protein, moisture, fat, carbohydrate are respectively 11.9; 73.9; 1.1 and 10.6% on the cool matter. In the dry matter, the content of protein, moisture, fat and carbohydrate respectively is 27.2; 5.9; 17.1 and 38.6%.

Ogbe and Affiku (2011) harvested the leaves of *M. oleifera* from Lafia in Nasarawa State of Nigeria during the rainy season. The results of proximate analysis revealed the presence of high crude protein ($17.01\% \pm 0.1$) and carbohydrate ($63.11\% \pm 0.09$). The leaves also contained appreciable amounts of crude fibre ($7.09\% \pm 0.11$), ash ($7.93\% \pm 0.12$), crude fat ($2.11\% \pm 0.11$) and fatty acid ($1.69\% \pm 0.09$). Samples of *M. oleifera* leaves from China and Rwanda were used for proximate analysis (Mukunzi *et al* 2011). The Chinese sample showed higher fat (3.56%) and protein (29.54%) than Rwandan sample fat (3.48%) and protein (25.26%). The ash content was found to be higher in the Rwandan sample than the Chinese sample by 17.26% and 13.44%, respectively. The total polyphenol content and total flavonoid content of Chinese and Rwandan samples, respectively followed the Chinese sample (24.65 mg GAE / g dry weight and 39.08 mg Rutin Eq / g and dry weight) and the Rwandan sample (30.01 mg GAE / g dry weight Rutin 52 ;7.7). Eq / g dry weight).

The study on three drying methods (sun drying, multi-purpose drying and air drying) on *M. oleifera* leaves has been investigated by Foline *et al* (2011). Three hundred grams of leaves were harvested, cleaned, collected in 100 grams and dried in a dryer for labor (50°C), air drying (room temperature) and solar drying (farmers and locals do). They are all undergoing a thorough and minimally invasive analysis of bacteria including new moringa leaves. Carbohydrate, protein, crude fiber, ash, fat, moisture content and pH of fresh were recorded $2.18 \pm 2.11\%$, $13.13 \pm 0.29\%$, $10.67 \pm 0.27\%$, $4.66 \pm 0.14\%$, $1.50 \pm 0.32\%$, $75.90 \pm 3.12\%$, $6.32 \pm 1.01\%$, respectively.

Study carried out by Mutiara *et al* (2012) showed the food preservation in *M. oleifera* leaving flour. Unblanching *M. oleifera* leaves powder contains 340 mg 100 g⁻¹ dry vitamin C, 16.51 mg 100 g⁻¹ mass β -carotene and 24.59% of the protein. Blanching treatment of *M. oleifera* Lamk led to a decrease in vitamin C levels by about 120-238 mg 100 g⁻¹ dry, an increase in β -carotene levels by about 19.36-21.52 mg 100 g⁻¹ dry, an increase in this level β -

carotene by approximately 24.70-30.68% (excluding steam blanching 5 minutes). Sharma *et al* (2012) discussed the nutritional composition and nutraceutical value of green leaves and wild-mixed foods in an area with residual food production in Kanpur. The level of other nutrients in the leaves of *M. oleifera* and *Amaranthus viridis* throughout the pot was determined using standard analytical methods. In the leaves of *M. oleifera*, crude protein was 20.51%, crude fiber 19.25%, crude fat 2.63%, ash content 5.13%, moisture content 71.73%, carbohydrate content 43.78% and energy value 430.41 kcal.

The phytochemical, nutritional and anti-bacterial properties of dried leaf powder of *M. oleifera* used as a dietary supplement, or vegetable source in soup preparation were investigated in this study carried out by Mensah *et al* (2012). Phytochemicals identified in leaf powder include tannis, saponins, alkaloids, phenols flavonoids and glycosides. A healthy diet study revealed the presence of carbohydrates (29.08%), ascorbic acid (140mg / 100g); fiber (2.1%), protein (6.88%) and iron (70mg/100g), calcium (1530mg/100g)), vitamin C (17.8mg/100g)) potassium (255mg/100g)), magnesium (250mg/100g) and vitamin A (19.9mg/100g).

Madukwe *et al* (2013) examined the composition of the dried nutrients of the *M. oleifera* leaf and the organoleptic properties of dry powder. The composition of proximate, mineral, vitamin and phytochemical extract of the leaf was analyzed. The results showed that the content of ash, crude fiber, fat and moisture in the dry leaf powder was 0.04, 0.00, 0.001 and 96.68%, respectively. The protein and carbohydrate content was 0.66 and 2.63%, respectively. The content of flavonoids and alkaloids was 0.20 and 0.07%, respectively. Teixeira *et al* (2013) characterized the leaves of *M. oleifera* in terms of their nutritional quality. The whole leaf flour contained 28.7% crude protein, 7.1% fat, 10.9% ash and 44.4% carbohydrate. The protein profile revealed levels of 3.1% albumin, 0.3% globulins, 2.2% prolamin, 3.5% glutelin and 70.1% insoluble proteins. β -carotene and lutein stood out as major carotenoids, with concentrations of 161.0 and 47.0 $\mu\text{g g}^{-1}$ leaf, respectively.

The study aims to explore the nutritional and phytochemical properties of the *M. oleifera* leaf grown in Ado Ekiti, Nigeria (Okiki *et al* 2015). Samples of *M. oleifera* leaf are found in six moringa growing areas in Ado Ekiti. A close analysis of the dried leaf of *M. oleifera* has been shown to be very rich in protein ($28.00 \pm 0.33\%$) and saturated energy (2625.25 ± 79.30 Kcal / Kg), saturated fat (3.88%), ash (9.88%), raw fiber (12.57%) and carbohydrate (37.87%).

The phytochemical and Nutrition properties of the dry leaf powder of *M. oleifera* used as nutraceuticals, dietary supplements, active foods or a source of vegetables in food preparation were consumed in this study carried out by Isitua *et al* (2015). Physico-chemical analysis using standardized methods and gas chromatography revealed the following: protein (24.31%), carbohydrate (55.97%), ash (11.50%), raw fiber (10.28%), total fat (9.22%),

moisture (6.12%), calorie intake (404.10 Kcal / 100g) and fatty acids (3.77%), fatty acids (5.45%), monounsaturated fatty acids (0.87%), polyunsaturated fatty acids (4.58%) and Trans fatty acid (0.00%) profile fatty acid.

Methanol extract of leaves and pods was analyzed for phytoconstituents, antioxidant properties, nutrients, minerals and vitamins (Raghavendra et al 2015). The IC₅₀ values of DPPH's major excretion function were 150, 240 and 14µg / ml of leaf, pod and standard respectively. The pod was a good source of carbohydrates, lipids, proteins and amino acids than leaves. Moisture, ash and crude lipid of the leaves were 80.02%, 6.85% and 1.83% respectively; those of the pods were 74.06%, 7.18% and 2.32%, respectively. Solana *et al* (2015) evaluated the chemical composition and nutritional value of *M. oleifera* leaf powder collected in two different regions in Mexico. All samples of *M. oleifera* showed humidity levels ranging from 3.06 to 3.34%, lipids from 10.21 to 10.31%, fiber from 7.29 to 9.46%, ash from 10.71 to 11.18 %, lean protein from 10.74 to 11.48%, and carbohydrates from 54.61 to 57.61%.

Ambeye (2016) evaluated the chemical composition and nutritional values of dried *M. oleifera* leaf powder collected from supermarket in Mekelle. All samples of *M. oleifera* exhibited moisture levels varying from 3.06 to 3.34%, lipids from 10.21 to 10.31%, fiber from 7.29 to 9.46%, ashes from 10.71 to 11.18%, crude protein from 10.74 to 11.48%, and carbohydrates from 54.61 to 57.61%. Mune *et al* (2016) evaluated the nutritional status of the protein from *Mori'nga* seed oil and leaves. Extracted flour was rich in protein (18.63% of leaves) and carbohydrates. The total amino acids and lysine content of leaf flour were (42.76 g / 16 g N) and (3.78 g / 16 g N). In addition, leaf flour showed high chemical concentrations (72.40%), as well as a protein efficiency ratio (3.47-371).

Nutrient levels were determined from extracts from unripe leaves in *M. oleifera* by Biel *et al* (2017). The protein content of the extracted and extruded leaves was 13.6 and 31.6% of dry matter (d.M.), respectively. No raw fiber was found in the extraction of moringa leaf. Dried leaves contain 8% d.m. of crude fiber. Complete carbohydrates are found in extracts than dried leaves (71 and 50% d.M., respectively). Ciencias *et al* (2017) conducted a study on the composition of chemicals, fatty acids (FA) and the chemical content of phenolic in two varieties of *M. oleifera* leaves grown in Sinaloa, Mexico. The leaves of the two varieties of *M. oleifera* exhibited high protein content (31.69-36.83%, db). The main fatty acids were linolenic acid (62.72-66.19%) with the highest concentrations, followed by palmitic (17.13-17.26%), linoleic (9.65-7.64%), oleic (3.24- 2.14%), and stearic acid (2.71-2.66%). Two varieties of moringa showed complete phenolic and flavonoids content of 71.08-76.63 mg EAG g⁻¹ (db) and 55.7-60.3 mg QE g⁻¹ (db), respectively.

Dried moringa leaves of PKM-1 prepared flour using a cabinet dryer at 60-70°C for 6-8 hours and grinded it into fine flour (Rajput *et al* 2017). The new dried moringa powder

showed moisture levels ranging from 72.83 to 77.43%, extracting ether from 4.59 to 9.53%, raw fiber from 5.75 to 22.03%, protein refined from 5.29 to 20.42%, and carbohydrates from 10.57 to 50.16%. Phytochemical properties have shown that ascorbic acid and phenols in total are fresh and dried moringa leaves ranging from (231.28 to 106.28) and (62.32 to 253.00) mg / 100 g, respectively.

Mikore and Mulugeta (2017) made a comparison between *M. oleifera* minerals and *M. stenopetala* leaves collected from two different regions namely Arbaminch Zuria and Konso in the Southern Nation Nationalities and Peoples Region (SNNPR), Ethiopia. The results of this study revealed that, leaf samples of *M. oleifera* from the sub-sites of the Secha and Karar samples showed normal moisture, ash, raw fiber, crude lipid and protein content at 6.88 ± 0.88 , 15.3 ± 1.02 , 5.51 ± 0.08 , 7.11 ± 0.52 , $24.8 \pm 1.80\%$ and 6.60 ± 0.79 , 15.6 ± 1.11 , 6.13 ± 0.22 , 7.35 ± 0.48 , $24.3 \pm 1.73\%$, respectively. Medium moisture, ash, crude, crude lipid and protein content $7.92 \pm 0.85\%$, $14.9 \pm 0.93\%$, $5.03 \pm 0.12\%$, $3.65 \pm 0.11\%$, $27.3 \pm 2.10\%$ and $7.73 \pm 0.96\%$, $14.1 \pm 0.087\%$, $5.87 \pm 0.21\%$, $4.29 \pm 0.12\%$, $30.2 \pm 2.61\%$ was determined by samples of M leaves Stenopetals from Sicela and Gato, respectively.

Oladeji *et al* (2017) evaluated and made a comparison of nutritional composition and antioxidant power of bioactive compounds of *M. oleifera* seeds and leaves was conducted in the Department of Food and Technology, Obafemi Awolowo University, Nigeria. To achieve this, leaf powder and seed flour were obtained by drying fresh leaves and seeds in a hot air conditioner. The results showed that crude protein, whole ash, and fat content in leaf were $20.29 \pm 0.41\%$, $7.27 \pm 0.25\%$ and $1.79 \pm 0.17\%$ and that of seeds were $33.82 \pm 0.21\%$, $5.17 \pm 0.41\%$ and $38.69 \pm 0.38\%$, respectively.

The leave extract of moringa by Abbas *et al* (2018) evaluated total protein, amino acid, vitamins, minerals, total fat and crude fiber under the semi-arid conditions of Sudan. It was found that carbohydrates (9.1 g), dietary fiber (2.1 g), fat (1.7 g), protein (8.1 g), vitamin A (80 μ g), thiamine (B1; 0.103 mg), Riboflavin (B2; 0.112 mg), Niacin (B3; 1.5 mg), pantothenic acids (B5; 0.48 mg), Pyridoxine (B6; 0.129 mg), folic acid (B9; 41 μ g), Vitamin C (8.6 μ g) were observed out of 100 gm of total edible leaves. *Moringa oleifera* leaves are harvested from different parts of the Namakkal region of Tamilnadu by Ajantha *et al* (2018). The stem and branches are cut from moringa trees and spread under shade to dry at 35°C for 7-days. The leaves were removed by hand, ground into a powder and stored for use. Proximate analysis of moisture content, crude protein, raw fiber, ether extraction, complete ash is performed according to AOAC (1995). The leaf sample had moisture (75.36%), crude protein (26.01%), ether extract (6.58%), raw fiber (7.08%) and total ash (9.41%).

The study led by Jozef Fejer *et al* (2019) focused on the chemical analysis of key nutrients and antioxidants in dried leaves of *M. oleifera* in the Caribbean island. The total amount of lipids, proteins, and vitamin E was (12.48%, 20.54%, and 178.10mg/kg) in dry

powdered leaves. The main constituent of fatty acids produced oleic acid (25.01%), palmitic (24.84%), and linolenic (24.71%) acids in leaves and Total phenols in powdered leaves were extracted (635.6mg GAE/L). The average amount of protein, fat, fiber, moisture, ash, carbohydrate, and leaf energy was 15.5%, 11.04%, 12%, 10.418%, 11.40% 37.48% and 319.92 kcal, respectively in *M. oleifera* samples collected from the Lahore, Pakistan (Yasmeen *et al* 2020). The polyphenols of the leaves and stems were 10.95µg and 20.02µg, respectively. Vitamin A and C were 12.80mg and 232mg of leaves respectively.

b) Fodder quality evaluation of *Moringa oleifera* seed sources

Aregheore (2002) compared four treatment diets viz., batik grass (M_0) was used as a control, and three levels of *M. oleifera* left by 20% (M_{20}), 50% (M_{50}) and 80% (M_{80}) of the daily daily allotment. The DMI of goats in the M_0 , M_{20} , M_{50} and M_{80} diet was 50.6, 50.9, 51.0 and 46.8 g/kg, respectively. DMI was significantly lower ($P < 0.05$) in goats in the M_{80} diet. Goats in the M_{20} and M_{50} diet benefited significantly and higher digestion of DM, crude protein (CP), detergent fiber (NDF), OM and energy than goats in the M_0 and M_{80} . He suggested from his study that 50% of the total daily income of livestock can be used as a cheap protein supplement in goat-based diets.

Richter *et al* (2003) performed a study to evaluate the nutritional value of dried moringa leaves as another source of protein for *Nile tilapia* fish breed. The three experimental diets were designed to consist of a diet of moringa leaves at 10%, 20% and 30% total protein intake (Foods 2, 3 and 4, respectively) and one serving as a control (Food 1) inclusive only fish meal and wheat meal as sources of protein. Foods with high levels of moringa leaf intake (Foods 3 and 4) significantly suppressed fish growth performance (SGR: 2.0% in both groups) compared to diets 1 and 2 (SGR: 2.7% and 2.4%, respectively). The most complete phenolics (0.7% and 1%), nonhaemolytic saponin (1.5% and 2.3%) and phytic acid (0.5% and 0.8%) in diets 3 and 4, respectively, and NDF (3.8% and 5.7%) and ADF (3.0% and 4.5%) in the above diets may contribute to poor growth performance in these groups. Thus, moringa leaf meal can be used to incorporate 10% of *Nile tilapia* protein diet without a significant reduction in growth.

A study was conducted in Nicaragua to find the effects of feeding different levels of leaves from *M. oleifera* to dairy cows in diet, digestion and milk production (Sanchez *et al* 2006). They were feed with *Brachiaria brizantha* hay either alone and supplemented with 2 kg or 3 kg of moringa in dry form (DM). *Moringa* supplementation increased ($P < 0.05$) DM intake from 8.5 to 10.2 and 11.0 kg of DM per day and milk production from 3.1 to 4.9 and 5.1 kg per day of -B brizantha hay only with 2 kg and 3 kg DM of moringa, respectively. Milk fat, solid foods and whole protein and organoleptic properties, smell, taste and color, were not significantly different between meals. The apparent digestive coefficients of DM, OM, CP, NDF and ADF were increased ($P < 0.05$) in the diet supplemented with moringa

compared to *B. brizantha* hay alone. The results showed that the inclusion of moringa as a protein supplement in a low-fat diet improved DM intake and digestion and increased milk production but did not affect milk production.

The nutritional value of *M. oleifera* leaves and fodder crops was tested by *in vitro* gas production tests by Chaudhary *et al* (2006). Methane gas production and *in vitro* digestibility were higher with rhythm leaves compared to berseem where two fodders were tested as a substrate alone but the difference was reduced when fodders were tested by mixing concentrate and straw in the same dose fed to animals. Cross-cut sheep (10; 4 m aged 17.2 kg BW) are distributed in two equal groups and given 400 g green berseem (CP 14.8; NDF 55.9; ADF 41.3; EE 2.0) or 500 g of green moringa leaves (CP 22.9 ; NDF 41.5; ADF 20.5; EE 8.9) added with a mixture of 100 g of mix and wheat grass. DM detection, nutrient digestion and the amount of healthy food were similar in both groups. The results show that the leaves of the moringa can be used as a protein supplement in diet to sheep.

Njidda and Nasiru (2010) performed a study to determine the chemical composition, *in vitro* dry matter digestibility and *in vivo* fermentation of four endangered species in the experimental region (*Leuceana leucocephala*, *Moringa oleifera*, *Acacia tortilis* and *Ziziphus mucronata*). Crude protein (CP) (from 13.96% DM for *A. tortilis* to 19.42% DM for *L. leucocephala*) without *M. oleifera* held the highest DM (21.42% DM). The range of lignocelluloses (acid detergent fiber, ADF) ranged from 21.16 g/100g D of *A. tortilis* went to 31.39 g/100g DM of *M. oleifera*. Netral detergent fiber ranges from 33.31 g/100g DM of *M. oleifera* to 58.81 g/100g DM. Crude fibres, crude fats and ash were 20.00% DM range. *Ziziphus mucronata* went to 32.53% DM for *M. oleifera*, 3.03% DM for *A. tortilis* to 5.33% DM for *Z. mucronata* with 10.76% DM of *A. tortilis* accounted for 17.76% DM of *L. leucocephala*. Total condensed tannin (TCT) ranged from 0.25 mg / g DM of *M. oleifera* to 2.96 mg/g DM *L. leucocephala*. *Z. mucronata* had very high levels of Ca, Mg, Na and K without P. Production of *in vitro* gas and methane was very high at *Z. mucronata*. IVDMD ranges from 70.66-72.00%. Crude protein and TCT have shown a positive relationship with IVDMD.

Moyo *et al* (2011) evaluated the *M. oleifera* leaves for the fiber content and reported that fibre content was neutral detergent fibre (NDF) (11.4%), acid detergent fibre (ADF) (8.49%), acid detergent lignin (ADL) (1.8%) and acid detergent cellulose (ADC) (4.01%).

Moringa oleifera, either fresh or freshly breed, was compared to Elephant grass as the main basis for dairy cows by Araica *et al* (2011). With the same modified energy intake the intake of protein and fiber differed ($p < 0.001$) between all meals where the new moringa had the highest diet and the elephant grass diet which was the least nutritious. Compared to controlled diets, moringa was made to have a higher digestion ($P < 0.05$) of both protein and fiber. With the exception of DM digestion, there is no difference in the digestive tract

between moringa's new treatment and moringa. Milk production was no different between any treatment and an estimated cow day of 13.7 kg⁻¹. Milk production was the same among all other treatments. The milk from moringa's new treatment, however, had a grassy taste and aroma, which was very different from the other two treatments, even though it was common in color and appearance. No organoleptic differences were found between milk from control and moringa silage treatment. They concluded that moringa silage can be fed to dairy cows in large quantities to produce the same amount and quality of milk as traditional feed.

Moringa oleifera is known to be one of the leading fodder plants in the arid regions with little water availability. The study conducted by Nouman *et al* (2013) was designed to test the solidity of *M. oleifera* as a field plant by harvesting at various heights (30, 90, and 150 cm). The quality of a healthy diet (minerals such as P, K, Ca, Mg and proteins) is determined along with the antioxidant (SOD, CAT, POD, the complete phenolic content). The results showed that the moringa crop yielded high biomass (472 g plant⁻¹) with high mineral content in its leaves when harvested 30-cm high in the month of August, and small biomass (113.54 g plant⁻¹) was observed when the plants were harvested at a cutting height of 150 cm. High antioxidants, high content of phenolics, and photosynthetic pigs were recorded during the hot rainy season (July and August). Seasonal variation affects the mineral content of moringa leaves with highest observed in August. Thus, moringa tree, because of its high mineral content and antioxidant activities, can be cultivated as a garden crop as an alternative to animal feed.

Teixeira *et al* (2013) characterized the leaves of *M. oleifera* for cattles as feed. *Moringa oleifera* leaves contain 28.7% crude protein; that was mostly insoluble and has low *in vitro* digestibility, even after heat treatment and chemical attack. *In vivo* studies are needed to better assess the use of this leaf as a protein source in human feed. The studies were conducted to check the effects of *M. oleifera* leaf powder and the leafy diet of chicken & broiler feeds by Paguia *et al* (2014). The results showed that feed consumption, FCR, egg production, income over feed costs, egg taste characteristics and shell sizes of 27-42 layers and 89-101 weeks of age were significantly different ($P < 0.05$). Egg weight and feed cost per kg of egg produced by the forcibly dissolved layers was significantly different ($P > 0.05$). Broiler performance in terms of ADG, feed, FCR, storage weight and income in addition to feed costs was not best in control.

Dey *et al* (2014) examined the potency of *M. oleifera* leaves as an addition to wheat grass and examined the effects of the combination of *in vitro* rumen fermentation markers on the effects of healthy and natural foods. *Moringa oleifera* leaves and wheat grass (WS) incubated separately and in compounds (ML: WS; 5:95, 10:90 and 20: 80) 24 hours at 39°C in 100 ml glass syringes contain a fluid-filled rumen. *Moringa* leaves have been found to be a rich source of crude protein and low fiber with high degradation, gas production, short

chemical oil production and low methane production compared to wheat grass. The presence of ML in the compounds had a positive effect on fusion and fermentation which led to an increase in gas production (up to + 2.30%), actual dry matter degradation (up to + 11.47%), actual reduction of organic matter (up to + 13.39%) and production of -microbial biomass (up to + 35.60%) with a corresponding decrease in methanogenesis (up to - 18.11%). The result of the combination of WS-ML compounds has led to an increase in fatty acid production (up to + 5.48%). This study showed the effects of moringa leaf fusion on improving wheat grass fermentation and reducing methane emissions and promoting the potency of *M. oleifera* leaves as an addition to wheat grass to improve animal performance.

Sultana *et al* (2014) evaluated the effect of intermittent production on biomass production and the chemical composition of the various plant components of *M. oleifera*. Highly fresh and dried (DM) (t ha⁻¹ cut⁻¹) whole leaves, leaf and stem obtained during cutting 8 weeks followed by cutting intervals of 6 and 4 weeks. The leaf to stem ratio effect was not statistically significant ($P > 0.05$) between harvest periods. The CP content of whole leaves, leaf and stem was different ($P > 0.05$) at harvest time. ADF, NDF and ADL are significantly less important ($P < 0.01$) lower at intervals of 4 and 6 weeks than at intervals of eight weeks. The Ca and P content of the leaf and the whole leaves were not significantly different ($P > 0.05$). Values for IVDMD and IVOMD ranged from 772.0 to 802.0 and 761.0 to 798.0 g/kg, respectively. Both the harvest and the chemical composition of the moringa leaves and leaf suggest that the best cut interval was eight weeks during the rainy season from the mature moringa tree. These data suggest that high CP and low fiber content in the leaf indicate a good source of protein for poultry or other monogastric animals and moringa leaves can be a source of protein for light livestock.

Teixeira *et al* (2014) conducted a study to check the chemical composition of leaves of *M. oleifera* and to assess their quality of healthy food and the presence of inorganic substances. Whole leaf flour contained 28.7% raw protein, 7.1% fat, 10.9% ash, 44.4% carbohydrate and 3.0 mg/100g Ca and 103.1 mg/100g Fe. The profile reveals levels of 3.1% albumin, 0.3% globulins, 2.2% prolamin, 3.5% glutelin and 70.1% unsolved proteins. Hydrolysis of protein from leaf flour using sodium dodecyl sulfate (SDS) and 2-mercaptoethanol (ME) resulted in 39.5% and 29.5%, respectively. The total protein content for digested *in vitro* diet (31.8%). Contraindications to the experimental diet were tons (20.7 mg g⁻¹), trypsin inhibitor (1.45 TIU mg g⁻¹), nitrate (17 mg g⁻¹) and oxalic acid (10.5 mg g⁻¹), in the absence of cyanogenic chemicals. B-carotene and lutein stand out as major carotenoids, with concentrations of 161.0 and 47.0 lg g⁻¹ leaf, respectively. Although the leaves of *M. oleifera* contain a large amount of crude protein, this is highly soluble and has low *in vitro* digestibility, even after heat treatment and chemical attack.

Okiki *et al* (2015) carried out a study to assess the phytochemical constituents of *M. oleifera* leaves cultivated in Ado Ekiti, Nigeria. The analysis revealed high content of flavonoids (846.67±11.07 mg/100g), saponins (844.17±27.82 mg/100g) and alkaloids (446.67±12.11 mg/100g) respectively. The concentration of tannin was high but the oxalate content was low in the leaves.

Ojo *et al* (2016) performed an experiment to assess the effects of seasons and plant species on the chemical composition and *in vitro* maturation of *M. oleifera* and *Panicum maximum* (local) silage. Leaf samples of *M. oleifera* and *P. maximum* collected during the rainy and dry seasons from Federal University of Agriculture, Nigeria. Forage samples were spaced 2-3 cm long and separated by different values of 100%: 0%, 0%: 100%, 30%: 70%, 50%: 50% and 70%: 30%. The interdependence of plant species × season × is subject to certain chemical limitations and *in vitro* fermentation. The CP content of the samples was very high ($p < 0.05$) and from 69.9 to 165.5 g/kg and fiber concentrations from 246.3 to 710.5 g/kg, 193.2 to 578.0 g/kg and 63.5 to 133.3 g/kg for NDF, ADF and ADL, respectively. 100% Moringa + 0% Panicum silage recorded very high ($p < 0.05$; 165.5 g/kg) CP content in all tested silage. All silage has high Ca content (7.0-11.7 g/kg). 100% Moringa + 0% Panicum and all forage blends contain ingredients that can be used as additives for light animal feed during rainy and dry seasons.

A study conducted by Aderinboye *et al* (2016) to assess digestibility and gas production in Bunaji cattle, West African Dwarf (WAD) sheep and WAD goat using feeds of *M. oleifera*, *Millettia griffoniana*, *Enterolobium cyclocarpum* and *Gmelina arborea* leaves and compared to *in vitro* studies using incubation times ranging from 0 - 48 h. The concentration of CP (165 - 247 g .kg⁻¹ DM), NDF (413 - 538 g.kg⁻¹ DM) and ADF (300 - 346 g/kg) varied between species. Gas production between cattle, sheep and goats was included ($r = 0.98$; $P < 0.001$). The results showed that the production of non *in vitro* gas and the dry matter of the inorganic fluctuations vary due to the biological nature of the organism and not the source of the inoculums (feed).

The study led by Kholif *et al* (2018) looked at the effects of *M. oleifera* (MO) leaves instead of berseem clover (BC) on feed and lactational activity in Nubian goats. A total of 16 Nubian lactating patients, weighing 36.2 ± 0.8 kg, were randomly assigned to experimental treatment containing 0, 125, 250 and 375 g of MO per kg to include 0 (M_0), 25 (M_{25}), 50 (M_{50}) and 75% (M_{75}) of BC (dry base (DM)). MO food intake ($P < 0.01$) and nutritional digestion of MO diet is improved ($P < 0.01$). *Moringa* diet increased ($P < 0.01$) protein overall, albumin and sugar but lower ($P < 0.05$) cholesterol and triglycerides. Milk production and milk preparation capacity, and total milk intake, fat and energy content increased ($P < 0.01$) in MO diets. The fruit of dairy products and energy was greater ($P < 0.05$) for MO diets than control diets. They concluded that feeding MO to replace 75% DM BC with improved

consumption of feed, ruminal fermentation, and milk production and quality in Nubian mammals.

The use of local dietary supplements in animal feed can help to improve the sustainability of rabbit production. Vidjannagni *et al* (2018) carried out a study to test the digestion of *M. oleifera* leaves in rabbit food. Seven groups of 9 rabbits were given 7 different feeds: two commercial feeds (ProvA and ProvB), four dried *M. oleifera* (ML) (Mor10: 10% ML, Mor20: 20% FL, Mor30: 30% FL, and Mor40: 40% ML) and controlled diet (CTL). The natural digestion of commercial feeds was similar to feed feeds ($P > 0.05$). Eating dietary partners Mor10 (62.92%), Mor20 (61.62%) and Mor40 (62.75%) were similar ($P > 0.05$) and lower ($P < 0.05$). Weight gain, strength and power rating of the feed were similar ($P > 0.05$). Good protein digestion recorded with *M. oleifera* leaf feed indicates that these leaves can be used up to 40% of rabbit feed.

Siti *et al* (2019) investigated the effect of *M. oleifera* leaf powder on dietary reduction and egg quality indications for laying hens up to 32 weeks of age. One hundred and twenty-two weeks of hens laying hens with the same body weight. Laying of hens was randomly divided into four groups: M_0 : basic food without the handling of *M. oleifera* leaves, M_1 : basic food with 2% leaf of *M. oleifera*; M_2 : Basic food with *M. oleifera* leaves 4%; and M_3 : 6% leafy basal foods of *M. oleifera*, respectively. This study showed that the administration of 4-6% of moringa leaves a powder with increased organic matter and the digestion of organic matter, the percentage of yolks and shell eggs, and the size of the shell ($P < 0.05$), but not the egg albumen ($P > 0.05$). About 2-6% moringa treatment leaves flour in the diet leading to a high egg color ($P < 0.05$) of eggs, increased food intake and external qualities of eggs to lay hens up to 32 weeks of age.

A study was conducted at the ICAR-National Dairy Research Institute, Karnal (Haryana) to produce specific data on the nutritional properties of leaves, twigs and leaves containing fragments of parts of *M. oleifera* strains, namely the Rajasthan and Haryana local species (Arif *et al* 2020). The results showed that the highest amount of crude protein, ether extract, whole-grain, dry undigested, the amount of lactation-related feeds found in the Haryana leaves of the moringa area, however, the Rajasthan strain of the moringa area were also recorded. , whole ashes, dry matter digested and lactation energy leaves the Haryana area. The Rajasthan and Haryana branches in the moringa area are recorded according to the dry matter, the NDF and the ADF. The highest concentrations of N, Ca, Mg and Fe were found in the Haryana leaves of the moringa area. However, Rajasthan and Haryana leaves are in the moringa genus engraved on the numbers P, S, Ca, Mg, Zn, Cu and Mn.

c) Mineral evaluation of *Moringa oleifera* seed sources

Moringa oleifera has lot of minerals that are essential for growth and development among which, calcium and iron is considered as one of the important minerals for human

growth and development. While 8 ounces of milk can provide 300-400 mg, moringa leaves can provide 1000mg and moringa powder can provide more than 4000mg. *Moringa* powder can be used as a substitute for iron tablets, hence as a treatment for anemia. Beef has only 2mg of iron while moringa leaf powder has 28mg of iron. It has been reported that moringa contains more iron than spinach (Fuglie 2005). A 100g portion of leaves provide a woman with over a third of her daily need of calcium and give her important quantities of iron, protein, copper, sulphur, and B-vitamins.

Aslam *et al* (2005) studied the mineral composition of leaves and pods of *M. oleifera* from different agro climatic regions of Punjab, Pakistan. The contents i.e. K, Ca, Mg, Na in the leaves and pods of *M. oleifera* was found to be 19732-24397, 1839-2097; 18950-26349, 1292-1837; 98.2-109, 93.9-103.9 and 1635-2721, 1032-2105 mg kg⁻¹, respectively. The concentration of Fe, Cu, Mn and Zn was found to be 205-573, 155.2-435.9; 7.3-11.2, 20.9-32.1; 76.9-112.8, 40.2-72 and 20.9-34.1, 15.3-29 mg kg⁻¹, respectively. The level of P in the samples of leaves and pods was 1180-1450 and 1860-2125 mg kg⁻¹, respectively. The contents of different minerals in the leaves and pods of *M. oleifera* were significantly varied from region to region.

Jongrungruangchok *et al* (2010) compared the composition and mineral elements in the moringa leaves from the 11 agricultural climatic regions divided in Thailand. The content of Ca, K and Fe in moringa leaves (100 g dry weight) is found in the range 1510.41-2951.13 mg, 1504.23-2054.05 mg and 20.3137.60 mg, respectively. Elemental analysis of the leaves in mg/100g dry matter (DM) indicates the Ca and Fe content of *M. oleifera* were 2,009.00 and 28.29, respectively (Oduro *et al* 2008). The study carried out by Magat *et al* (2009) to assess the mineral, nutrient and other nutrients from the leaves of *M. oleifera* in the Philippines. The concentrations of macronutrients in leaves were as N (4.74%) > Ca (2.21%) > K (1.80%) > S (1.36%) > Mg (0.45%) > P (0.33%) > Cl (0.20%) > Na (0.06%), while micronutrient were as Fe (100 ppm) > B (50 ppm) > Mn (34 ppm) > Zn (24 ppm) > Cu (5 ppm).

Mineral composition of lamina, petiole, seed seeds, seed shell, seed kernel powder and seed oil from *M. oleifera* collected from two regions i.e. Sheda and Kuje, Nigeria were investigated (Anjorin *et al* 2010). The results showed that Ca, Mg, Fe and Cu in *M. oleifera* leaves, pods and seeds collected from Sheda were much higher than those from Kuje. The comparatively high content of Ca and Fe was found in the lamina shell and plant seeds respectively in both regions. The content of Mg (0.185 mg mL⁻¹) in the kernel oil of moringa seeds from Sheda was significantly lower ($P \leq 0.05$) than in other parts of the leaf and seeds. The Fe content in the seed shell from the Sheda was 0.2436 mg g⁻¹ higher than that from Kuje.

Moyo *et al* (2011) reported the mineral content in moringa dried leaves were calcium (3.65%), phosphorus (0.3%), magnesium (0.5%), potassium (1.5%), sodium (0.164%), sulphur

(0.63%), zinc (13.03mg/kg), copper (8.25%), manganese (86.8mg/kg), iron (490mg/kg) and selenium (363 mg/kg). Mutayoba *et al* (2011) reported values of 57.34, 21.70 and 5.73 ppm for Mn, Zn and Cu, respectively. However, the contents were Fe (318.81), Ca (2.47%), K (1.63%) and Mg (1.03%).

Ogbe and Affiku (2011) harvested the leaves of *M. oleifera* from Lafia in Nasarawa State of Nigeria. The total ash content showed Ca (1.91% $\pm$ 0.08), K (0.97% $\pm$ 0.01), Na (192.95 $\pm$ 4.4), Fe (107.48 $\pm$ 8.2), Mn (81.65 $\pm$ 2.31), Zn (60.06 $\pm$ 0.3) and P (30.15 $\pm$ 0.5) parts per million (ppm). Magnesium (0.38% $\pm$ 0.01) and copper (6.10 $\pm$ 0.19) were the least. A study of the chemical composition and nutritional value of *M. oleifera* leaves was performed by analyzing samples of this plant leaves collected from three different regions of Ouagadougou by Yameogo *et al* (2011). The mineral composition expressed in mg/100g of matter is 847.1; 151.3; 549.6; 17.5; 1.3; and 111.5 for Ca, Mg, K, Fe, Zn and P, respectively. The content of the same minerals analyzed for dry matter is 2098.1; 406.0; 1922.0; 28.3; 5.4 and 351.1, respectively. Study conducted by Sharma *et al* (2012) showed that *M. oleifera* leaves have a significant amount of nutraceuticals. Basic analysis of dry leaves (DM) reveals the Ca and Fe content of was important and were in amount of 2007.67 mg/100 g and 26.34 mg/100 g, respectively.

A proximate analysis of *M. oleifera* widely used as a nutritional and medicinal plant in Nigeria was done with a dry leaf powder by Aja *et al* (2013). Mineral analysis revealed that Ca (117.402 $\pm$ 0.02mg / l), Cl (0.319 $\pm$ 0.07 mg/l) and P (3.85 $\pm$ 0.04mg / 100g). The newly harvested *M. oleifera* was assessed for the mineral content in vegetable leaves by Sodamade *et al* (2013). The mineral content of the leaves showed concentrations mg/100g as K (23.20 $\pm$ 0.31), Na (214.00 $\pm$ 0.02), Ca (723.00 $\pm$ 0.04), Mg (677 $\pm$ 0.16), P (5.00 $\pm$ 0.12), Fe (187.00 $\pm$ 0.03), Mn (252.00 $\pm$ 0.15), Cu (55.00 $\pm$ 0.08) and Zn (548.00 $\pm$ 0.04).

Mineral composition of parts of *M. oleifera* (collectively) were recorded the samples collected from Badagry in Lagos State, Nigeria (Fakankun *et al* 2013). They observed mean concentrations of the mineral elements in *M. oleifera* plant were 26000, 643, 8210, 2980, 69.9, 169 and 15.3 mg/kg for Ca, Mg, K, Na, Mn, Fe and Zn, respectively. Co and Se, and heavy metals like Pb and Cd were not detected. The Ca (94900 mg/kg), Mg (762 mg/kg) and Na (9050 mg/kg) levels were highest in root bark, K (11300 mg/kg) in the seed, Mn (86 mg/kg) and Fe (214 mg/kg) in the leaves and Zn (18 mg/kg) in stem wood.

Moringa oleifera leaves and fruit collected from Metro Manila and two suppliers were analyzed by Mallillin *et al* (2014). The mineral content of the powdered leaves was Ca (1.3 $\pm$ 0.1 - 2.0 $\pm$ 0.0 g/100g) > Fe (5.7 $\pm$ 0.2 - 7.8 $\pm$ 0.0 mg/100g) > Zn (3.4 $\pm$ 0.1 - 4.8 $\pm$ 0.0 mg/100g; P <0.05). The availability of Zn (59.5 $\pm$ 0.1 - 93.8 $\pm$ 0.1%) from moringa leaves was significantly higher than Ca (25.0 $\pm$ 0.1 - 53.8 $\pm$ 0.2%) and Fe (7.0 $\pm$ 0.1 - 19.5 $\pm$ 0.1%; P <0.05).

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The mineral composition is analysed in the leaves of *M. oleifera* which was collected from Ado Ekiti, Nigeria (Okiki *et al* 2015). The leaf was found to be rich in minerals and vitamins. It contained high concentrations of Zn, Mg, Ca, K and K, respectively, 64.17 ± 2.04 , 643.33 ± 6.06 , 82.50 ± 6.89 , 430.00 ± 8.37 and 50.43 ± 2.05 mg/100g. Sohaimy *et al* (2015) examined the chemical and functional properties of the leaves of the Egyptian *M. oleifera*. A proximate analysis showed that moringa leaves contain essential minerals such as Na (289.34 ± 0.35), K (33.63 ± 0.24), Mg (25.64 ± 0.25) Ca (486.23 ± 0.11), P (105.23 ± 0.32) and Fe (9.45 ± 0.16) mg/100g, respectively. Solana *et al* (2015) recorded the chemical composition and nutritional value of dried *M. oleifera* leaf collected in two different regions in Mexico. The main components in leaf powder according to ICP-MS were Ca (2016.5-2620.5 mg/100g), K (1817-1845 mg/100g), and Mg (322.5-340.6 mg/100g).

Savitha *et al* (2015) determined mineral composition in various parts of drumstick genotypes during 2012-13. The leaves and pods of the six genotypes of drumstick KDM/S-11, MS/SP-11, MS/LP-11, KDM-01, S-6/4 and KDM/SR-11 were analyzed. Significant differences in mineral composition in the various parts were observed. Leaves contained the highest Fe (342.9 ppm). Among the genotypes, leaves and pods of S-6/4 had the highest Fe content (600.50 ppm), and 153.68 ppm, respectively. The leaves also contained Ca (3.64%) and pods (0.80%). Leaves (3.97%) of the KDM/S-11 genotype and KDM/SR-11 pods (0.93%) contain the highest Ca content. Among genotypes, the leaves (2.46%) S-6/4 pods of KDM/S-11 and MS/LP-11 (3.46% each) have high K content. The leaves (0.58%) were mostly followed by pods (0.50%). The leaves (0.76%) of the MS/SP-11 genotype and pods (0.63%) of MS / SP-11 contain the amount very high Mg.

Ambeye (2016) evaluated the chemical composition and nutritional values of dried *M. oleifera* leaf powder collected from supermarket in Mekelle. The elemental analysis of our samples revealed high contents of Ca (2016 to 2620 mg/100 g), Mg (322 to 340.6 mg/100 g), and K (1817 to 1845 mg/100 g), while Zn, Cu, and Se were 1, 1, and 0.1 mg/100 g, respectively. The minerals content in *M. oleifera* leaves collected from Okigwe, Nigeria were K (0.625%), Mg (1.277%) and Ca (2.91%) (Mgbemena and Obodo 2016). Airawashdeh *et al*

(2016) determined mineral composition for the leaves of *M. oleifera* collected from Jordan. Analysis of fruit and leaf showed high content of Mg (85.67 ppm), Zn (21.55 ppm) and Copper (2.14 ppm). Leaves also recorded high Fe (62.26 ppm) and (10.48 ppm).

Amengor *et al* (2017) determined the micromineral and β -carotene content of dried leaves of *M. oleifera*, and local dishes mixed with leaves. Minerals in leaf flour are determined by Atomic Absorption Spectrophotometry (AAS). Dried *M. oleifera* leaves contained high levels of micronutrients i.e. 0.36 ± 0.04 mg/100g (Cu); 5.80 ± 0.68 mg/100g Mn; 20.96 ± 1.37 mg/100g Fe; 6.79 ± 1.82 mg/100g Zn and 21.42 ± 1.67 mg/100g β -carotene. Korsor *et al* (2017) compared the relative mineral content of *M. oleifera* and *M. ovalifolia* growing together on the Neudamm Experimental Farm in central Namibia. The leaves of both species of moringa are harvested from shoots, the shade is dried every night and taken to a laboratory where it is ground and passed through a 1 mm filter for processing and mineral testing. Statistically, *M. oleifera* mineral value was significantly different ($P < 0.05$) from *M. ovalifolia* in K, Mg, Cu and Zn, but no differences in Ca, Na, P, Fe and Mn content. This means that both moringa species have the same amount of Ca, Na, P, Fe and Mn in their leaf tissues.

The mineral content of *M. oleifera* leaves is estimated by Mumtaz and Fatima (2017) using AOAC methods. The results show that leaves are a promising source of essential minerals. The minerals were Na (289mg), K (1,324mg), Mg (368mg), P (204mg), Fe (28.2mg), Cu (0.57mg), Ca (2,003 mg) and Mn (5.21mg) and Zn (3.29mg) per 100mg of dried leaf powder. Mineral analysis was performed by Tope *et al* (2017) for *M. oleifera* leaves and fruit juices collected from Kwara State University, Malete, Nigeria. The results showed that mineral content in the leaves was 12.81g (Fe), 27.50g (Zn), 0.80g (Ca) and 16.09g per kg (K) of the leaf sample.

Kumssa *et al* (2017) conducted the variation studies in *M. oleifera* leaves and fruits samples collected from Kenya. The overall mean concentrations of Ca, Cu, I, Fe, Mg, Se and Zn in *M. oleifera* leaves were 18300, 6.92, 0.218, 202, 5390, 4.25 and 35.6 mg/kg, respectively. Mineral element concentration of the *M. oleifera* leaves varied significantly ($p < 0.05$) between localities, except for Ca. The overall mean concentrations of Ca, Cu, Fe, Mg, Se and Zn in *M. oleifera* immature pods were 3600, 5.42, 65.4, 2860, 2.36 and 27.6 mg kg⁻¹ dw, respectively. There were significant differences ($p < 0.05$) in the Cu, Fe and Mg but not ($p < 0.05$) for Ca, Se and Zn mean concentrations of *M. oleifera* immature pods collected from different localities.

Study pertained by Ciencias *et al* (2017) showed that leaves of *M. oleifera* harvested in Sinaloa, Mexico contains the following minerals in sufficient amounts i.e. Ca (15.08-15.58 g/Kg), Mg (3.55-3.62 g/Kg), Na (1.42- 1.54 g/Kg), K (2.69-3.01 g/Kg), Fe (120.19-105.31 ppm), Mn (54.5-59.77 ppm), Zn (56.48-46.89 ppm) and Cu (10.92-7.96 ppm). Oladeji *et al*

(2017) examined the chemical composition and nutritional value of dried *M. oleifera* leaf. The results obtained showed that *M. oleifera* is rich in essential minerals (mg/100g) containing Ca (521.96 ± 0.32), Zn (12.28 ± 0.02) and Fe (7.86 ± 0.62). Mikore *et al* (2017) led a study on mineral analysis of *M. oleifera* and *M. stenopetala* leaves collected from two different natural habitats namely Arbaminch Zuria and Konso in the Southern Nation Nationalities and Peoples Region (SNNPR), Ethiopia. The concentrations of K, Na, Mg, Ca, Mn, Zn, Fe, and Cu were ranged 9570-14047, 1287-1298, 4273-4550, 18230-19026, 72.4-87.5, 21.357.6, 80.1-82.3 and 3.43-5.10 mg / Kg, respectively.

Rajput *et al* (2017) examined the chemical and phytochemical properties of newly formed and dried leaves of *M. oleifera* (PKM-1). The leaf powder has been shown to have a total mineral content ranging from 4.59 to 9.53%. The most prominent mineral elements in fresh and dried moringa leaf powder were Ca, Mg, K, Fe and Cu, 475.33, 40.33, 328.33, 7.63, 0.15 and 20.32, 387.83, 1545.33, 26.69, 0.83 mg/100g, respectively.

Mineral composition was determined in the leaves of the *M. oleifera* collected from Indonesia by Mulyaningsih and Yusuf (2018). Mineral content in the samples is determined using Neutron Activation Analysis (NAA). The results obtained indicate that *M. oleifera* is rich in essential minerals, mainly Ca, Mg, K, Zn, Fe and Cl. Content in dried leaves include: Ca (3.45 %), Mg (0.66 %), K (3.35 %), Cl (0.25%), Fe (147.20 mg/kg), Na (152.52 mg/kg), Zn (35.71 mg/kg), and Mn (102.10 mg/kg). Mo also contains other minerals such as Cr (4.76 mg/kg), Br (4.82 mg/kg), Co (0.16 mg/kg), and Al (150.40 mg/kg) in addition to other element. Compared with the results of existing studies, it showed that mineral composition in *M. oleifera* leaves varies depending on the locations.

Analysis of nutrients, minerals and vitamin *M. oleifera* leaf meal (MOLM) was analyzed by Ajantha *et al* (2018). *Moringa* leaves are harvested in different parts of the Namakkal region of Tamilnadu. A proximate analysis of minerals revealed that Ca (1.60%), K (1.38%), Fe (285ppm), Zn (38.02ppm) and Cu (5.90ppm), respectively were recorded in leaves.

Cookies are made from sweet detar, moringa leaf and a blend of wheat flour. These cookies' quality is determined along with nutritional composition, micronutrient composition (minerals and vitamins) and cookie sensory properties. The result obtained by Igbabul *et al* (2018) showed that the content of Ca, Fe, Zn and K from 21.26-86.12 mg/100g, 2.10-2.80 mg/100g, 0.91-0.99 mg/100g and 89.46-234.29 mg/100g, respectively.

Ali *et al* (2019) examined the phytochemical elements in *M. oleifera* leaves collected from Kano, Northern Nigeria. The leaves are dried for two weeks, then turned into fine powder and then diluted with water and ethanol by maceration. The results showed that the *M. oleifera* leaf contains Ca (1.93%), K (0.95%), Mg (0.39%), Zn 59.37p P (28.85ppm), Fe (105.20ppm) and Cu (7.05ppm). The study analyzes the mineral content of *M. oleifera* leaf

extract and ICP-OES (Inductive coupled plasma-optical emission spectroscopy) in Indonesia by Natsir *et al* (2019). Mineral analysis identified 13 essential minerals including Al, Ca, Co, Cr, Cu, Fe, K, Mg, Mn, Ni, P, Se and Zn. The highest concentrations of minerals are identified as Se (1097.84 ppm) and Cr (919.99 ppm), respectively. Na (68.83 ppm) and Mg (60.84 ppm) are found as low-concentration minerals.

Afzal *et al* (2020) conducted a study to understand the differences in the composition of leaf minerals collected from *M. oleifera* which grows mainly on the irrigated plains of Pakistan. A total of 90 samples were collected in three remote areas (regions) with the same climate and small site variations: Khanewal, Faisalabad and Kasur. Due to management practices and genetic variation, genetic variation at the three sites was identified with significant variability in Na, K, Mg, N and ash content. However, no significant differences were observed with Ca, protein, fiber and moisture content. Na was found high (1.26%) in Faisalabad, K in Kasur (2.37%), Mg in Khanwal (2.58%), and N (4.11%) and organic matter (99.25%) in Khanewal regions. Fresh *M. oleifera* leaves are collected in the local area of Kuvempu Nagara in the province of Tumakuru Karnataka, India to study their mineral content (Thippeswamy *et al* 2020). The mineral reported were Ca (2.4%), P (0.21%), Mg (0.5%), S (1.54%), K (0.48%), Zn (30.35 ppm), Co (1.15 ppm), Fe (19.05 ppm), Mn (34.25 ppm) and Cu (14.47 ppm).

CHAPTER III

MATERIALS AND METHODS

The present study entitled “Evaluation of *Moringa oleifera* Lam. seed sources for nutritional value and mineral content” was conducted in Department of Forestry and Natural Resources in collaboration with Forage and Millet Section, Department of Plant Breeding and Genetics; Department of Soil Science; Department of Microbiology, PAU, Ludhiana; & Department of Animal Nutrition, GADVASU, Ludhiana, Punjab during the year 2019-20. Detailed information of the experiments relating to experimental location, field evaluation of seed sources, laboratory procedures and methodology adopted for research are explained in this chapter.

Experiment No. 3.1

3.1.1 Name of the experiment

Evaluation of *Moringa oleifera* Lam. seed sources for nutritional value and mineral content

3.1.2 Climate and soil

The experimental site is located at an elevation of 247 m above mean sea level (30°54'N latitude and 75°48'E longitude). The area falls in the central plain agro-climatic zone of Punjab. The region is categorized by a semi-arid, sub-tropical to tropical environment. In April and June and in December through January, the region enjoys exceptionally hot summers and severe winter. The coldest temperature might fall to 4°C or even below, and in the summertime the maximum temperature might rise to more than 46°C. It is not usual to get frost. The land is deep, well drained, granular, low humus textured loam. The soil's pH is neutral. The average yearly rainfall is 760 mm and during June and September around three-fourth of this year's South-West Monsoon. The meteorological data during the study period (2019-20) has been depicted in Figure 3.1.

3.1.3 Study species

Seed of five promising varieties adopted at national level and four local germplasm of *M. oleifera* were procured from different states of India and simultaneously collected 5 local sources from PAU, Ludhiana campus. The details of seed sources are provided in Table 3.1. The samples were taken from the already established field evaluation trial planted since August 2017 at teaching area of Department of Forestry and Natural Resources, Punjab Agricultural University, Ludhiana, Punjab. The plants were pollarded every winter and summer for estimating green and dry biomass in both seasons. The samples were taken for the present study was tender leaves [Early leaf expansion stage (ELE)] within the 15 days of growth, mature leaves [Mature dark green leaf stage (MDGL)] after the 60 days of growth (Singh *et al* 2021) and twigs containing mature and tender leaves as well. Samples were taken in the last week of August, 2020. Fresh leaves were dried in shade for 6-7 days and then oven

dried at 105°C until the samples get constant weight. Samples were then crushed for the further nutritional analysis. For mineral analysis, 1 g of leaf sample for tender and mature leaves were taken for digestion with di-acid mixture (HNO₃:HClO₄ in 2:1 ratio) acids.

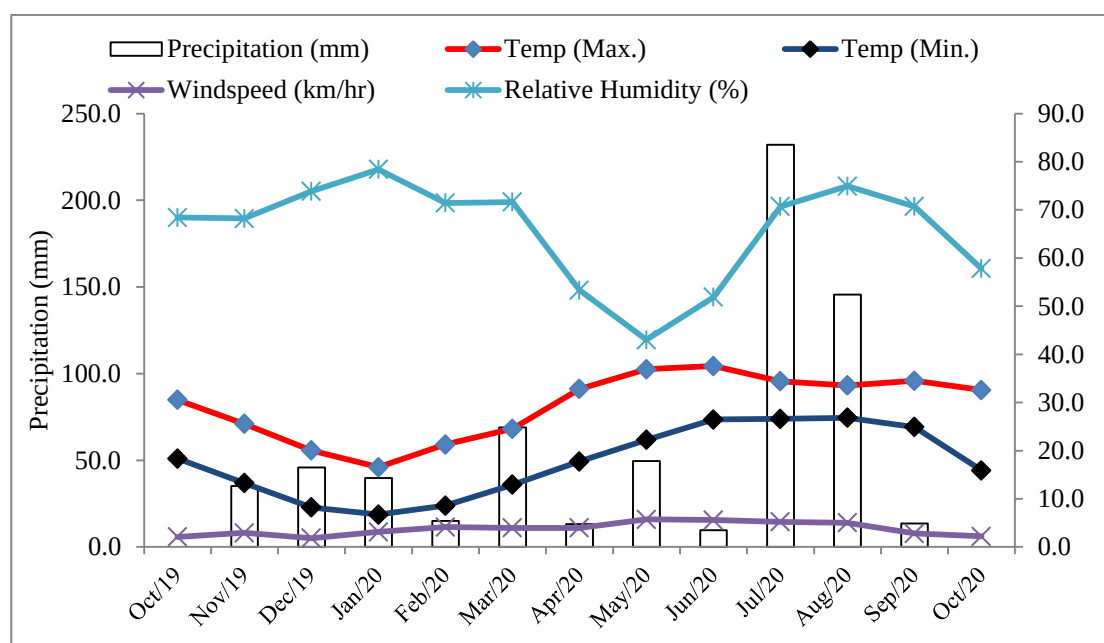


Figure 3.1: Mean monthly meteorological parameters of experimental site

Table 3.1: Details of *Moringa oleifera* seed sources

Code	Seed sources	Locality	Latitude (°N)	Longitude (°N)	Altitude (m)
S1	Bhagya	UHS Bagalkot, Karnataka	16.18	75.69	542
S2	Konkan Ruchira	Dapoli, Maharastra	17.75	73.18	164
S3	Dantiwara	Gujarat	25.24	73.32	311
S4	PAU-1	Ludhiana, Punjab	30.90	75.81	249
S5	PAU-2	Ludhiana, Punjab	30.90	75.81	250
S6	PAU-3	Ludhiana, Punjab	30.90	75.81	248
S7	PKM-1	TNAU, Tamil Nadu	11.31	76.93	310
S8	PKM-2	TNAU, Tamil Nadu	11.31	76.93	310
S9	ODC-3	IAF, Tamil Nadu	11.31	76.93	310
S10	CAZRI	Jodhpur, Rajasthan	26.25	72.99	236
S11	Mandya	Karnataka	12.52	76.89	683
S12	Mysore	Karnataka	12.31	76.64	772
S13	PAU-4	Ludhiana, Punjab	30.90	75.81	250
S14	PAU-5	Ludhiana, Punjab	30.90	75.81	250

3.1.4 Proximate analysis protocols and procedures

3.1.4.1 Estimation of Dry Matter (DM)

A well-mixed fresh sample in an aluminum tray was extracted in a fixed amount for estimation of dried matter and then dried in an oven at 100°C for 24 hours. As dry matter content of the sample, a weight of the dried sample was measured. The content of dry matter was determined using the following formulae:

$$\text{Dry Matter (\%)} = \frac{\text{Oven dry weight of the sample}}{\text{Initial fresh weight of the sample}} \times 100$$

3.1.4.2 Estimation of Total Ash

(A) Principle

Ash content is determined by ignition of known sample weight at 550°C in muffle furnace till all organic matter is oxidized and lost as CO₂ gas. The remainder is called ash, an inorganic component. The content is determined by using standard procedures of AOAC (2005).

(B) Procedure

Finely ground sample (5g) was collected three times over a hot plate in tarred crucibles, which were then ignited for 5 hours in muffle furnace after the crucibles were removed and stored in desiccator and weighed. The difference from the preliminary weight of the empty crucible to the end weight of the ash crust indicated the entire sample ash content and was represented as a percentage of DM (AOAC 2005). The weight loss was taken as organic matter following igniting in the muffle furnace.

$$\text{Ash (\%)} = \frac{\text{Weight of residue (g)}}{\text{Weight of sample (g)}} \times 100$$

3.1.4.3 Estimation of Crude Protein (CP)

(A) Principle

In the presence of a catalyst mixture (copper sulphate; potassium sulphate; 1:9 ratios), the sample is oxidized by concentrated sulphuric acid producing carbon dioxide, water and ammonia. Ammonia is caught in the form of ammonium sulphate solution in sulphuric acid. After that solution is to release the ammonia which is absorbed by excess of boric acid through steam distilled by sodium hydrate. Boric acid absorbs ammonia by the titration with standard sulphuric acid. The crude protein is determined by using standard procedures of AOAC (2005).

(B) Reagents

- i) Digestion mixture: Mixture of copper sulphate and potassium sulphate in the ratio of 1:9.
- ii) 40% NaOH: Dissolve 40 g NaOH flakes to distilled water to make volume 100 ml.

- iii) Indicator: 0.2 g methyl red and 0.3 g bromocresol green dissolved in 400 ml of 90% ethanol.
- iv) 4% Boric acid solution: 4 g boric acid was dissolved in distilled water to make volume 100 ml.
- v) 0.1 N H₂SO₄

(C) Procedure

Macro-Kjeldahl technique was used to quantify the N content (AOAC 2005). Sample of 0.5g, 4-5 g digestion combination was administered to the digestive tract solution (Copper sulphate: potassium sulphate, 1:9). The samples were digested at 450°C for 2 to 3 hours after 10-12 ml of concentrated sulfuric acid in auto digestion units in Kel Plus till a clear blueish green solution was found. Nitrogen in the sample was transformed in to ammonium sulphate through the digesting process. In the presence of 40% sodium hydroxide, the product was distilled after digestion. The NH₄⁺ liberated was received on the other hand or condenser having 250 ml flask containing the 25 ml of 4% boric acid mixed indicator solution. By using green bromocresol and methyl red, a 5:1 ratio of 95% ethanol was created by the mixed indicator. The distillation took place until the distillate nearly doubled the volume. Titrated with the 0.1 N H₂SO₄ standard, the distillate becomes bright pink. The blank reading was recorded as well. By multiplying the nitrogen by 6.25 the CP (percent) concentration was computed. The computed percent of nitrogen used the formula:

$$\text{Nitrogen (\%)} = \frac{\text{N} \times \text{Volume of 0.1N H}_2\text{SO}_4 \text{ used} \times 14 \times \text{dilution factor}}{1000 \times \text{Weight of sample (g)}} \times 100$$

3.1.4.4 Estimation of Crude Fibre

(A) Principle

The sample is weighed and digested under specific conditions using 1.25% of H₂SO₄ and 1.25% NaOH. The dried residue is ashed inside muffle furnace, and weight loss is measured as the content of crude fibre. To estimated crude fibre, standard procedure of AOAC (2005) is followed.

(B) Reagents

- i) 1.25% H₂SO₄ solution: 1.25 ml of conc. H₂SO₄ added to distilled water to make volume 100ml.
- ii) 1.25% NaOH solution: 1.25 g NaOH added to distilled water to make volume 100ml.

(C) Procedure

About 200 ml of 1.25% H₂SO₄ were applied to 1g moisture-free sample. This mixture was heated for 30 minutes and then filtered through Buchner funnel and filtration apparatus. The remaining waste was rinsed with water and transferred to a beaker to remove the acid. The residue was digested again for 30 minutes with 200 ml of 1.25% NaOH. The waste was

filtered again and rinsed with water. Residues were transported to pre weighted crucibles and dried in a hot air oven to a constant weight of 100°C. This material was ashed and weight loss recorded in muffle furnace. The formula used to compute crude fibre:

$$\text{Crude fibre (\%)} = \frac{\text{Weight of residue} - \text{Weight of ash after ignition}}{\text{Weight of sample (g)}} \times 100$$

3.1.4.5 Estimation of Crude Fat

(A) Principle

Petroleum ether is volatilized, condensed continuously to extract ether soluble components and passed through the moisture free sample. After the completion of the process, ether is recovered and the remaining crude fat is obtained ether free and weighed. The crude fat is determined by using standard procedures of AOAC (2005).

(B) Procedure

The Soxhlet technique (AOAC 2005) was used for estimating crude fat. For this, 3g completely dried sample was taken in a thimble for extraction. The sample was extracted with petroleum ether (60-80°C) in Soxhlet apparatus for 8 hours. In flasks (200 ml) petroleum ether was obtained and devices fitted to condensers. A tap for cold water circulation was linked to the condenser. The procedure was performed for 8 hours. After 8 hours, the surplus oil ether was gathered from the Soxhlet device and a tiny portion was transferred from the bottom into the tarred 100 ml beaker. In a constant weight oven, the beaker was dried. The sample's ether extract was determined as:

$$\text{Crude fat (\%)} = \frac{\text{Final weight (g)} - \text{Empty weight}}{\text{Weight of samples (g)}} \times 100$$

3.1.4.6 Estimation of Total Soluble Sugars (TSS)

3.1.4.6.1 Extraction

The sample of 0.4 g has been extracted using 15 ml 80% ethanol and re-extracted using 70% ethanol by maintaining the tubes 20 minutes in boiling water with condensing agents. Pool the supernatants of each extraction procedures. The samples were kept for water bath at 50°C to eliminate alcohol from the supernatants. The extracts was diluted with water in order to produce a total volume of 8 ml and used for free sugar estimation. The sugar-free residues was utilized to extract and estimate starch content. Total soluble sugars were determined by using standard procedures of Dubois *et al* (1956).

3.1.4.6.2 Estimation

(A) Reagents

- i) Concentrated sulphuric acid
- ii) 5% Phenol

(B) Procedure

Sequentially, 1 ml phenol (5 percent) and 5 ml sulphuric acid were taken in 1 ml of sugar aliquot, which was diluted appropriately. In order to assure the correct mixing of the solution, the concentrated sulfuric acid has been introduced to the test tube centre. At room temperature, the reaction blend was incubated for 30 minutes. The absorption was then measured against the blank at 490 nm spectrophotometer. The total soluble sugar concentrations were computed on the base of the simultaneous glucose levels (10-50 µg).

3.1.4.7 Estimation of Cell Wall Constituents

3.1.4.7.1 Estimation of Neutral Detergent Fibre (NDF)

(A) Principle

A neutral detergent solution is used to digest the sample and dissolve the cell contents, the residual residues being known as neutral fibre. It contains cellulose, lignin and hemicelluloses. Neutral detergent fibre is determined by using standard procedures of Van Soest *et al* (1991).

(B) Reagents

Composition of 1 litre neutral detergent solution

i) Disodium Ethylene diamino tetra acetate dehydrate	18.61 g
ii) Sodium borate decahydrate	6.81 g
iii) Sodium lauryl sulphate	30.0 g
iv) Di-sodium hydrogen phosphate (anhydrous)	4.56 g
v) 2-ethoxyethanol (ethylene glycol mono ethyl ether)	10 ml

Preparation of Neutral Detergent Solution (NDS)

A, 6.81 g sodium borate decahydrate and 700 ml of distilled water were placed in 2 litre beaker capacity to make neutral detergent solution 18.61 g EDTA, and was heated until dissolved entirely. A 30 g sodium lauryl and 10 ml 2-ethoxyethanol had been added to this solution. This solution transferred into another beaker containing 4.56 g of disodium hydrogen phosphate in 100 ml distilled water. Both solutions were mixed together and moved to a volumetric 1 litre bottle. With distilled water, the final volume was made 1 litre. The solution's pH between 6.9-7.1 was maintained.

(C) Procedure

A 1 g sample was taken into beaker with the addition of 100 ml of neutral detergent solution. After boiling began, the sample and NDS were refluxed for one hour. The contents had been filtered through the sintered (G-1) glass crucible, which has previously been tarred, were cleaned with hot water and then washed with acetone. The residue had been dried over the night at 80°C in a hot air oven. The crucibles were cooled and weighed in a desiccator. By applying the following formula NDF has been determined as a percentage:

$$\text{NDF (\%)} = \frac{(\text{Weight of crucible + Fibre}) - \text{Weight of crucible}}{\text{Weight of sample (g)}} \times 100$$

3.1.4.7.2 Estimation of Acid Detergent Fibre (ADF)

(A) Principle

Acid-detergent solutions are used for the sample, which dissolve the cell content and hemicelluloses and the left over residue is called the acid detergent fibre. It contains cellulose, lignin and silica. Acid detergent fibre is determined by using standard procedures of AOAC (2005).

(B) Reagents

- i) Cetyltrimethyl ammonium bromide (CTAB) 20 g
- ii) 1 N H₂SO₄ upto 1 litre

Preparation of acid detergent solution (ADS)

A 20 g CTAB was dissolved in 500 ml of 1 N H₂SO₄ and final volume was made 1 litre with 1 N H₂SO₄.

(C) Procedure

One gram sample was transferred to a clean beaker, adding 100 ml of acid detergent. For one hour the contents were refluxed. The contents were filtered through a weighted sintered glass crucible (G-1), rinsed with warm water and rinsed with acetone. The waste has been dried over the night in a heated air oven at 80°C. The sinks were cooled and weighed into a desiccator. By the following formula, ADF was determined in percentage:

$$\text{ADF (\%)} = \frac{(\text{Weight of crucible + Fibre}) - \text{Weight of crucible}}{\text{Weight of sample (g)}} \times 100$$

3.1.4.7.3 Estimation of Acid Detergent Lignin (ADL)

(A) Principle

The acid detergent fibre (ligno cellulose + acid insoluble ash) is treated with 72% (w/w) sulphuric acid, which dissolves the cellulose. The ADL can then be determined by the loss in weight due to ignition. Acid detergent lignin is determined by using standard procedures of AOAC (2005).

(B) Procedure

In the sintered crucible containing ADF, sulphuric acid (72% w/w) was added and maintained for 3 hours at room temperature. After the acid was drained, it was dried over the night in a warm air oven and weighed afterwards. In a muffle furnace at 500°C, it was then heated for 3 hours. The weight loss after ignition was ADL, which was expressed on a DM basis as percentage (Robertson and Van Soest 1991).

3.1.4.8 Estimation of *In Vitro* Dry Matter Digestibility (IVDMD)

(A) Reagents

i) Solution A

Disodium hydrogen orthophosphate (anhydrous) 18.5g

Sodium Hydrogen Carbonate 49.0 g

These two were dissolved in distilled water and volume was made to 1 litre.

ii) Solution B

Sodium chloride 23.5 g

Potassium chloride 28.5 g

Magnesium chloride 6.0 g

Calcium chloride 2.0 g

These were dissolved in distilled water and volume was made to 1000 ml.

Stock solution: In a ratio of 9:1 a mixed solution A and B was developed for the stock solution. Solution B was introduced only following the dissolution of phosphate and bicarbonate in solution A.

iii) Solution C

One part of the aforementioned solution was diluted shortly before use with four parts of water and heated up to $39 \pm 1^\circ\text{C}$. CO_2 was bubbled until the solution was clear for this cloudy solution.

iv) Buffer nutrient solution: One section of strained rumen liquor was added immediately prior to use to four sections of solution C.

(B) Procedure

Using conventional Tilley and Terry (1963) techniques, digestibility *in vitro* dry matter was measured. It was determined by using a 250 ml centrifugal tube equipped with gas release stopper in 0.5 g of oven dried sample. Every tube has been loaded with nutrient buffer solution (50 ml). For 10 seconds, the CO_2 gas passed over the tube's surface, and at 39°C the tube was immediately shut and incubated. During incubation, the pipes were softly shaken to replace the substrate. The tube content was filtered after 48 hours *via* a muslin cloth, which was placed on top of the funnel under suction of Buckner. The residue has been suspended again in 0.2% 0.1 NHCL in 50 ml of pepsin. The tubes were incubated at 39°C for 24 hours and then filtered using G-1 grade sintered glass crucibles. The residue has been dried over night and weighed at 100°C . The IVDMD has been determined as per the formulae:

Weight of empty crucible = W_1

Weight of (crucible + residual material) = W_2

Weight of sample = W_3

Weight of residual material = $W_2 - W_1 = W_4$

$$\text{IVDMD (\%)} = \frac{W_3 - W_4}{W_3} \times 100$$

3.1.4.9 Estimation of pH

The pH of powdered leaves and twigs samples were determined by using standard procedures of AOAC (1999). To estimate this, 2.0 g of sample was dissolved 100 ml of distilled water and the pH was measured by using the GLP pH meter at 25°C.

3.1.4.10 Quantification of Anti-nutritional Compounds

3.1.4.10.1 Total Phenols

3.1.4.10.1.1 Extraction

For 1 hour, about 0.4 mg sample was refluxed with 80% aqueous methanol 5 ml. The substance has been filtered and 10 ml washed with heat 80 per cent of methanol to produce the final volume. This extract has been used to estimate total phenols. Total phenols were determined by using standard procedures of Swain and Hills (1959).

3.1.4.10.1.2 Estimation

(A) Reagents

- i) Folin-phenol reagent
- ii) Saturated solution of sodium carbonate: Dissolve 17.5 g sodium carbonate in 50 ml of distilled water with 1 drop of H₂SO₄.
- iii) Standard tannic acid solution (10-50 µg)

(B) Procedure

About 0.5 ml methanol's aliquot has been evaporated to dryness and 0.5 ml of H₂O has been dissolved in the residue. This included 0.5 ml folin-phenol reagent and vigorously shaken into cyclo mixer. About 1 ml of saturated sodium carbonate solution was added after 5 minutes. The developed intensity of the blue colour was evaluated against the blank reagent after 1 hour at 760 nm. The total phenol quantity was estimated using standard tannic acid curve in spectrophotometer

3.1.4.10.2 Flavonoids

3.1.4.10.2.1 Extraction

The 400 mg sample was refluxed with 6 ml of distilled water for 1 hour. The refluxed material was filtered with Whatman no. 1 filter paper and the final volume was made to 10 ml by distilled water. This extract was used for the estimation of total flavonoids. Flavonoids were determined by using standard procedures of Chang *et al* (2002).

3.1.4.10.2.2 Estimation

(A) Reagents

- i) 10 % Aluminium chloride
- ii) 1 M Potassium acetate

(B) Procedure

The extract of 1 ml from the sample was collected and 1 ml water was added. In reaction mixture, the cyclo mixer has been introduced and mixed for 5 minutes in 0.1 ml of 10% aluminium chloride, 0.1 ml of 1 M potassium acetate and 2.8 ml of double distilled water. The test pipes were kept for 30 minutes at room temperature, followed by the absorption at 415 nm. A standard routinely (10-50µg) estimated the quantity of total flavonoids from the standard curve in spectrophotometer

3.1.4.10.3 Tannins

3.1.4.10.3.1 Extraction

The 0.05g sample was extracted for 1 hour with 5 ml of 80% aqueous methanol. The refluxed material had been filtered and the final volume consisting of hot 80% methanol had been washed to 10 ml. This extract had been applied to estimate total tannins. Tannis were determined by using standard procedures of Sadasivan and Manickam (1992).

3.1.4.10.3.2 Estimation

(A) Reagents

- i) Folin-Denis reagent: dissolve in appropriate flask with 100 g sodium and 20 g phosphomolybic acid and 50 ml phosphoric acid. Reflux the solution for 2 hours and the final volume was made 1 litre with of distilled water. Protect the reagent against light exposure by retaining a brown bottle.
- ii) Solution of sodium carbonate: dissolve 35 g of Na_2CO_3 in 100 ml of H_2O distilled at $70^\circ\text{-}80^\circ\text{C}$.
- iii) Standard solution for tannic acid: 0.1 g tannic acid dissolved in H_2O distilled 100 ml.

(B) Procedure

One ml of aliquot, 6.5 ml of distilled water and 0.5 ml of folin-denis reagent were added. About 1 ml sodium carbonate solution has been added after 5 minutes. The final volume of distilled water was 10 ml and the cyclomixer was firmly agitated. The development of the colour intensity was evaluated against blank reagent at 700 nm after 30 minutes. Tannic acid in the range 0-100 µg was applied to the standard curve in spectrophotometer

3.1.4.10.4 Saponins

3.1.4.10.4.1 Extraction

Approximately 500 mg of material were homogenized in 5 ml of acetone and left at room temperature for 24 hours. The 5 ml methanol as solvent was added and the procedure was repeated. The methanol extract was filtered and by the addition of methanol the final volume was produced up to 15 ml. Saponins were determined by using standard procedures of Fenwick and Oakenfull (1983).

3.1.4.10.4.2 Estimation

(A) Reagents

- i) Reagent A: Anisaldehyde (0.5 ml) mixed with 99.5 ml of ethyl acetate
- ii) Reagent B: Concentrated sulphuric acid
- iii) Standard saponin solution (10-100 µg)

(B) Procedure

The 1 ml of the sample extracted was collected in a test tube, held at 100°C to eliminate alcohol in a boiling water bath. About 2 ml of ethyl acetate have been added after cooling. The 1 ml of reagent A and 1 ml of reagent B have been added to this, respectively. The contents of the cyclo mixers were agitated for 2-3 minutes and the test tubes maintained for ten minutes at room temperature. The intensity was measured at 430 nm in red hue in spectrophotometer. Saponin was used as a standard solution to calculate the amount of saponin.

3.1.4.10.5 Nitrate-N

3.1.4.10.5.1 Extraction

The 0.1 g of powdered sample was added 10 ml of distilled water. The tubes were placed in water bath for 1 hour at 70°C. Then samples were filtered and used for the estimation of nitrate-N. The nitrate content was determined by using standard procedures of Cotaldo *et al* (1975).

3.1.4.10.5.2 Estimation

(A) Reagents

- i) 2 N NaOH
- ii) 5% Salicylic acid solution: 5 g of salicylic acid in 100 ml conc. H₂SO₄
- iii) KNO₃ standard (0-5 µg)

(B) Procedure

The test tube was filled with 0.2 ml of extract and 0.8 ml of 5% salicylic acid solution. The substance was properly mixed and stored for 20 minutes at room temperature. In order to boost the pH above 12, 19 ml of 2 N NaOH is added. The samples were cooled to room temperature and 410 nm of absorption was achieved. A standard curve created simultaneously with the standard KNO₃ sample was calculated to the amount of nitrate-N.

3.1.4.10.6 Oxalates

(A) Reagents

- 1) 6 N HCl
- 2) Methyl red indicator (0.1%) in absolute alcohol
- 3) Ammonia solution
- 4) 5% calcium chloride solution
- 5) 20% H₂SO₄ solution

6) N/10 KMnO₄ solution

(B) Procedure

The oxalate content was determined by using standard procedures of Abezaet al (1968). About 2 g grounded sample was placed in a conical flask containing 190 ml of distilled water and 10 ml of 6N HCl. The contents were digested for one hour on a boiling water bath, then cooled and transferred in to a 250 ml volumetric flask and the volume was made up to the mark. 50 ml aliquot (in duplicate) was taken in 250 ml beakers and 20 ml 6N HCl (HCl: H₂O; 1:1) was added to each beaker to dissolve pectins. The mixture was evaporated to one-half volume and filtered through Whatman no.1 filter paper. The residue was washed with warm distilled water. To the filtrate, a few drops of methyl red indicator were added and after that concentrated ammonia solution was poured until the solution turns faint yellow. The contents were allowed to boil, cool and filtered to remove, precipitate containing ferrous ions, which were formed after the addition of ammonia followed by heating). Again the filtrate was heated to boil and without delay, 10 ml of calcium chloride solution was added slowly with constant stirring. The contents were kept overnight for the complete precipitation of oxalates. Next day contents were filtered through Whatman no.42 filter paper. The calcium oxalate precipitate was washed repeatedly with distilled water until free of calcium ions (tested with a few ml of 5% oxalate solution). The funnel containing filter paper and precipitate was placed back in to the original beaker in which the precipitation was done. A Hole was punched in the bottom of filter paper with the glass rod and precipitation was washed in to the beaker with 50 ml of (20% v/v) sulphuric acid. The contents were heated to pre-boiling stage and titrated against N/10 KMnO₄ to a light pink colour. Then the filter paper was dropped in to the solution and titration was completed to a point till the light pink colour persisted for half a minute.

$$\text{Oxalate (\%)} = \frac{\text{Volume of N/10 KMnO}_4 \text{ used} - \text{blank used} \times 0.0045 \times \text{volume made}}{\text{Aliquot taken} \times \text{sample taken}} \times 100$$

3.1.4.11 Estimated characteristics

(A) Organic Matter (Henneberg and Stohmann 1865)

It is calculated by the following formula:

$$\text{Organic Matter \%} = \text{Dry Matter} - \text{Ash Content}$$

(B) Total Carbohydrate (Martin and Coolidge 1978)

It is calculated by addition of Crude Protein, Crude Fat and Ash Content; subtracted from 100.

$$\text{Total Carbohydrate \%} = 100 - (\% \text{crude protein} + \% \text{crude fat} + \% \text{ash content})$$

(D) Energy Value (Food value) (Kcal/100g) (Martin and Coolidge 1978)

It is calculated by:

$$\text{Energy Value} = 4 \times \% \text{crude protein} + 9 \times \% \text{crude fat} + 4 \times \% \text{carbohydrate}$$

(E) Nitrogen Free Extract (NFE) (Detmann and Filho 2010)

Calculation formula:

$$\text{NFE \%} = 100 - (\% \text{ash content} + \% \text{crude protein} + \% \text{crude fat} + \% \text{crude fibre})$$

(G) Hemicellulose (Goering and Vansoest 1975)

Formula:

$$\text{Hemicellulose \%} = \text{Neutral detergent fibre (NDF)} - \text{Acid detergent fibre (ADF)}$$

(H) Cellulose (Goering and Vansoest 1975)

It is calculated by formula:

$$\text{Cellulose \%} = \text{Acid detergent fibre (ADF)} - \text{Acid detergent lignin (ADL)}$$

(I) Dry Matter Intake (DMI, % of body weight) (Horrocks and Vallentine 1999)

It is calculated by dividing 120 with NDF value.

$$\text{DMI \%} = 120 / \% \text{NDF}$$

(J) Digestible Dry Matter (DDM, % DM) (Horrocks and Vallentine 1999)

It is calculated by following formula:

$$\text{DDM \%} = 88.9 - (0.779 \times \text{Acid detergent fibre (\%ADF)})$$

(K) Relative Feed Value (RFV) (Horrocks and Vallentine 1999)

It is calculated by multiplying DMI and DDM and then dividing it by 1.29.

$$\text{RFV \%} = (\text{DMI} \times \text{DDM}) / 1.29$$

3.1.4.12 Estimation of Minerals

The plant samples were collected from the 14 seed sources as mentioned in Table 3.1. The leaf samples for each tender and mature phenophases in triplicate were oven dried and grinded in a willy-mill containing stainless steel blades and passed through 0.5 mm sieve and the powdered samples were used for further analysis.

3.1.4.12.1 Digestion of sample for ICP-MS analysis

About 1 g of sample was taken and 10 ml of di-acid mixture ($\text{HNO}_3:\text{HClO}_4$ in 2:1 ratio) was taken in 100 ml conical beaker. Content was kept overnight for digestion. Firstly temperature was kept low and after that it was increased slowly. Digestion was completed in 1 hour when white fumes start emerging out of the flasks. The flasks were removed from digestion and allowed to cool. After cooling, contents were diluted with distilled water and filtered with whatman no. 1 filter paper. The volume was made to 50 ml with distilled water after filtration.

The elements determined during study were phosphorous (P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), zinc (Zn), copper (Cu), boron (B), manganese (Mn), nickel (Ni), sodium (Na), cadmium (Cd), chromium (Cr) and lead (Pb). All these mineral elements were determined by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) as per the procedures described in APHA (2005).

3.1.4.12.2 Nitrogen determination

The nitrogen (%) was calculated by dividing the crude protein with 6.25 factor.

3.1.4.12.3 Sulphur determination

(A) Principle

A known amount of digested plant sample is treated with barium chloride in the presence of gum acacia solution. The turbidity delivered because of precipitation of sulphate as barium sulphate is measured with colorimeter, utilizing a blue channel at a wave length of 420 μm . Gum acacia goes about as a balancing out specialist and doesn't permit the hasten of barium sulphate to settle down rapidly.

(B) Reagents

(a) Sodium acetate acetic acid buffer:

About 100 mg of sodium acetate was dissolved in 500 ml of distilled water. Then 30 ml of 99.5% acetic acid was added and made final volume to one litre.

(b) Barium chloride:

Grind BaCl_2 crystals until all these passed through 30 mesh sieve and were retained on a 60 mesh sieve.

(c) Gum acacia solution:

About 0.25 g of gum acacia was dissolved in distilled water and diluted it to 100 ml of volume.

(d) Standard sulphur solution (100 ppm S)

About 0.5434 g of the reagent grade potassium sulphate was dissolved in distilled water and diluted to one litre.

(C) Procedure

Pipette out 5 ml of above digested plant solution in 25 ml volumetric flask. About 5 ml of sodium acetate-acetic acid buffer solution was added and then 1.0 g of barium chloride crystals. the flask was swirled for one minute to dissolve the crystals and then added 1 ml of 0.25% of solution of gum acacia. The total volume up to 25 ml in every flask with distilled water were made and shaken well. The turbidity readings were taken within 5-30 minutes at wave length of 420 μm .

3.1.5 Statistical analysis

The mean data recorded on various nutritional, minerals, fodder and anti-nutritional traits were subjected to statistical analysis as per the method laid down for Complete Randomized Design (CRD). The experimental data were analyzed using analysis of variance technique (Panse and Sukhatme 1989). The significance of treatment effects was judged with the help of 'F' test (Variance ratio). The least significant difference (LSD) was used to compare the treatment effects at $P < 0.05$. The details of statistical analysis are given below:

3.1.5.1 Mean

The mean value of each parameter was worked out by dividing the sum by corresponding number of observations.

$$\text{Mean } (\bar{A}) = \frac{\sum A_{ij}}{N}$$

Where,

A_{ij} = Any observation in i^{th} seed source and j^{th} replication

N = Total number of observations

3.1.5.2 Analysis of variance (ANOVA)

The analysis of variance (ANOVA) was carried out as per the procedure laid out by Gomez and Gomez (1984). The significant test was carried out by referring to the standard “F” table of Snedecor (1961). The calculated F values were compared with the tabulated ‘F’ values. If the calculated ‘F’ value was higher than the tabulated, it was considered to be significant. The following metrics were further analysed for those characters that revealed substantial changes across the seed sources. Parameters of variability were calculated as per formula given by Burton (1952).

3.1.5.3 Least Significant difference (LSD)

Least Significant difference was estimated as follows:

$$\text{LSD} = \text{SE}_d \times t_{0.05 \text{ error d.f.}}$$

Where,

S.E. = standard error of the difference of the treatment means to be compared.

$$\text{SE}_d = \frac{\sqrt{2 MSe}}{r}$$

and ‘t’ = table value of ‘t’ at 5 % level of significance for error degree of freedom.

3.1.5.4 Genetic variability studies

3.1.5.4.1 Coefficients of variability

Genotypic and phenotypic variance was estimated as per the method given by Johnson *et al* (1955). Coefficients of variability was calculated by the formula given by Burton and Devane (1953).

$$\text{PCV}\% = \frac{\sqrt{V_p}}{\bar{X}} \times 100$$

$$\text{GCV}\% = \frac{\sqrt{V_g}}{\bar{X}} \times 100$$

Where,

V_p = Phenotypic variance

V_g = Genotypic variance

PCV = Phenotypic Coefficient of Variability

GCV = Genotypic Coefficient of Variability

$\bar{X}$ = Population mean

3.1.5.4.2 Heritability

Heritability in narrow sense was calculated by the formula suggested by Johnson *et al* (1955)

$$h^2 = \frac{V_A}{V_p} \times 100$$

Where, h^2 = narrow sense heritability

3.1.5.4.3 Genetic advance

The genetic advance was estimated by the formula suggested by Lush (1940) and further used by Burton and De-Vane (1953) and Johnson *et al* (1955).

$$\text{Genetic advance (GA)} = \left[\frac{V_g}{V_p} \right] - \left(\sqrt{V_p} \right) - K$$

Where, V_g = Genotypic variance

V_p = Phenotypic variance

K = Selection differential at 5 % selection intensity. The value of $K = 2.06$ (Allard 1960).

3.1.5.4.4 Genetic gain

Genetic gain was calculated by the formula suggested by Johnson *et al* (1955) as under:

$$\text{Genetic gain (\%)} = \frac{\text{genetic advance}}{\bar{X}} \times 100$$

3.1.5.5 Correlation studies

3.1.5.5.1 Calculation of correlation coefficients

Genotypic and phenotypic correlation coefficients were calculated according to the methods suggested by Goulden (1952). Correlation parameters and path analysis parameters were statistically analyzed using OPSTAT software. The simple correlation coefficients (Pearson 1901) were worked out by using the following formula (Panse and Sukhatme 1989).

$$r(XY) = \frac{\text{Cov. } XY}{\sqrt{V(x) \cdot V(y)}} \times 100$$

Where,

$r(XY)$ = Simple correlation Between X and Y

$V(X)$ = Variance of X character

$V(Y)$ = Variance of Y character

The significance of V values was tested against (n-2) degree of freedom by using Fisher and Yates tables. For testing simple correlation, the f value was calculated by the following formula.

$$t = \frac{r}{\sqrt{1-r^2}} \times \sqrt{n-2}$$

Where,

r = Simple correlation

n = Number of observations in the sample.

Analysis of covariance was worked out as per the procedure suggested by Panse and Sukhatme (1989). The different components of variances (genotypic, phenotypic and environmental correlation coefficients) were worked out as per Singh and Chaudhary (1985).

CHAPTER IV

RESULTS AND DISCUSSION

The present study entitled “Evaluation of *Moringa oleifera* Lam. seed sources for nutritional value and mineral content” was conducted in Department of Forestry and Natural Resources in collaboration with Forage and Millet Section, Department of Plant Breeding and Genetics; Department of Soil Science; Department of Microbiology, PAU, Ludhiana; & Department of Animal Nutrition, GADVASU, Ludhiana, Punjab during the year 2019-2020. The data for nutritional, fodder antinutritional characteristics and mineral contents were recorded on dry matter (DM) basis. The results pertaining to study are explained under following heads:

4.1 Nutritional characteristics

4.2 Fodder characteristics

4.3 Antinutritional characteristics

4.4 Mineral characteristics

4.1 Nutritional characteristics

4.1.1 Dry Matter

The recorded data for dry matter (DM) of three phenophases i.e. tender leaves, mature leaves and twigs of 14 seed sources of *M. oleifera* are presented in Table 4.1 which showed significant variability. The mean values of dry matter for tender leaves ranged from 17.12-21.12 g/100g. Seed source S13 registered maximum mean value (21.12 g/100g) and it was at par with S14 (20.71 g/100g) and S12 (20.04 g/100g). However, minimum mean value (17.12 g/100g) was recorded in S6. The mean value for mature leaves ranged from 17.83-22.69 g/100g. Maximum mean value was recorded in seed source S13 (22.69 g/100g) and it was followed by S14 (21.81 g/100g), S8 (20.84 g/100g) and S12 (20.49 g/100g), where as minimum mean value was noticed in S7 (17.83 g/100g). The average value of dry matter for twigs varied from 20.96-26.80 g/100g. Seed source S6 (26.80 g/100g) showed maximum mean value which was succeeded by S14 (25.34 g/100g), S13 (24.53 g/100g) and S4 (23.41 g/100g) but the minimum mean value was showed by seed source S7 (20.96 g/100g).

4.1.2 Ash Content

Ash content was estimated from the dry matter by igniting the samples. Once the organic matter is oxidized then the residue left is known as ash content. The 14 seed sources exhibited significant variation for ash content of tender leaves, mature leaves and twigs of *M. oleifera* which are presented in Table 4.1. The ash content for tender leaves ranged from 7.75-11.27 g/100g. The highest mean value was registered in S7 (11.27 g/100g) which was at par with seed source S1 (11.24 g/100g) and S13 (11.13 g/100g). However, the least mean value (7.75 g/100g) was possessed by S10 source. The mature leaves registered the largest mean

value in seed source S13 (12.08 g/100g) which was statistically at par with S7 (11.93 g/100g) and lowest in S8 (10.74 g/100g). The mean values for mature leaves ranged from 10.74-12.08 g/100g. The average value recorded for twigs ranged from 8.62-11.60 g/100g. The seed source S8 possessed minimum mean value (8.62 g/100g) and S13 had maximum mean value (11.60 g/100g) for twigs which was at par with S5 seed source (11.53 g/100g).

4.1.3 Organic Matter

It was calculated from the dry matter and ash content. Significant differences were observed for the organic matter for all three phenophases of *M. oleifera* which are provided in Table 4.2 which showed significant difference among all the seed sources. The mean value for organic matter for tender leaves ranged from 4.80-10.75 g/100g. The highest mean value was recorded in S10 (10.75 g/100g) which was at par with S12 (10.70 g/100g), S14 (10.56 g/100g), S13 (9.99 g/100g) and S19 (9.70 g/100g), whereas, the lowest mean value was observed in S7 (4.80 g/100g). The average value for mature leaves lied between 5.90-11.06 g/100g in which the minimum value was seen in seed source S7 (5.90 g/100g) and the maximum in S14 (11.06 g/100g) which was at par with S13 (10.61 g/100g). The range for OM in twigs varied from 11.23-15.62 g/100g. The maximum value was observed in S6 (15.62 g/100g), succeeded by S14 (14.47 g/100g), S2 (14.37 g/100g) and S8 (13.23 g/100g). However, minimum value was recorded in S11 seed source (11.23 g/100g).

4.1.4 Crude Protein

Huge variations were reported for the all phenophases and among 14 seed sources, 5 seed sources showed high crude protein content than average value which are presented in Table 4.2. The CP increased from tender to mature leaves. The average value registered for tender leaves ranged from 8.92-22.22 g/100g DM. The highest value was recorded in S12 (22.22 g/100g DM) which was succeeded by S9 (19.86 g/100g DM), S10 (18.64 g/100g DM) and S7 (17.41 g/100g DM). S5 (8.92 g/100g DM) showed the lowest amount of protein. The mature leaves possessed maximum mean value in S9 (28.70 g/100g DM), statistically at par with S12 (28.09 g/100g DM). The mean values varied from 19.16-28.70 g/100g DM and the minimum value noticed in S14 (19.16 g/100g DM). Likewise mature leaves, twigs also showed largest protein content in seed source S9 (18.81 g/100g DM) which was at par with S12 (18.64 g/100g DM). The mean value ranged from 11.64-18.81 g/100g DM, with least value in S2 (11.64 g/100g DM).

4.1.5 Crude Fat

All seed sources showed adequate amount of genetic variations for crude fats among tender, mature leaves and twigs of *M. oleifera* which are presented in Table 4.3. The mean values of crude fat for tender leaves ranged from 1.20-5.73 g/100g DM. Seed source S14 registered maximum mean value (5.73 g/100g DM) followed by S13 (5.63 g/100g DM), S12

(4.50 g/100g DM) and S8 (4.20 g/100g DM). However, minimum mean value (1.20 g/100g DM) was recorded in S5. The mean value for mature leaves ranged from 3.93-5.87 g/100g DM. The highest mean value was recorded in S2 and S14 (5.87 g/100g DM) and they were followed by S13 (5.83 g/100g DM), S8 (5.70 g/100g DM) and S1 (5.17 g/100g DM), where as minimum mean value was noticed in S5 (3.93 g/100g DM). The average value of crude fat for twigs varied from 2.95-4.69 g/100g DM. The seed source S14 (4.69 g/100g DM) showed largest mean value which was succeeded by S2 (4.40 g/100g DM), S13 (4.08 g/100g DM) and S8 (3.99 g/100g DM), while the minimum had by S5 source (2.95 g/100g DM).

4.1.6 Crude Fibre

Crude fibre is the insoluble residue of an acid hydrolysis followed by alkaline concentration. The residue contains true cellulose and insoluble lignin. Different seed sources of *M. oleifera* showed wide variability for tender, mature leaves and twigs. The mean value for crude fibre for tender leaves varied from 15.05-20.95 g/100g DM. The highest value was recorded in S12 (20.95 g/100g DM) followed by S4 (19.10 g/100g DM), S11 (19.05 g/100g DM) and S2 (18.80 g/100g DM), whereas, the lowest mean value was observed in S8 (15.05 g/100g DM) (Table 4.3). The average value for mature leaves lied between 21.10-28.15 g/100g DM in which the minimum value was seen in seed source S5 (21.10 g/100g DM) and the most in S12 (28.15 g/100g DM) which was statistically at par with seed source S2 (27.80 g/100g DM), S8 (27.50 g/100g DM) and S4 (27.15 g/100g DM). The range for twigs recorded was 14.50-21.90 g/100g DM. The maximum value was observed in S1 (21.90 g/100g DM), followed by S13 (20.70 g/100g DM), S11 (20.40 g/100g DM) and S2 (20.20 g/100g DM). However, minimum value was registered in S7 (14.50 g/100g DM).

4.1.7 Total Carbohydrates

It is the major active ingredient of food that is used to provide energy. The carbohydrates in tender leaves, mature leaves and twigs among 14 seed sources of *M. oleifera* are included in Table 4.4 which showed significant difference. The mean values of carbohydrates for tender leaves ranged from 63.94-79.19 g/100g DM. Seed source S5 registered highest mean value (79.19 g/100g DM) followed by S3 (78.56 g/100g DM), S4 (77.60 g/100g DM) and S2 (76.82 g/100g DM). However, lowest mean value (63.94 g/100g DM) was recorded in S12. The mean value for mature leaves ranged from 55.93-64.22 g/100g DM. The maximum average value was recorded in seed source S14 (64.22 g/100g DM) followed by S2 (62.00 g/100g DM), S3 (61.57 g/100g DM) and S1 (60.85 g/100g DM), where as minimum mean value was observed in S9 (55.93 g/100g DM). The average value for twigs varied from 67.17-75.05 g/100g DM. The seed source S2 (75.05 g/100g DM) showed largest mean value which was succeeded by S1 (73.03 g/100g DM), S3 (71.75 g/100g DM)

and S4 (71.37 g/100g DM) and the least mean value was showed by seed source S12 (67.17 g/100g DM).

4.1.9 Total Soluble Sugars (TSS)

The recorded data for total soluble sugars of tender leaves, mature leaves and twigs of 14 seed sources of *M. oleifera* are included in Table 4.4. The table showed significant variability among the sources. The mean values of total soluble sugars for tender leaves ranged from 7.45-11.49 g/100g DM. Seed source S3 registered maximum mean value (11.49 g/100g DM) followed by S2 (11.33 g/100g DM), S1 (11.27 g/100g DM) and S4 (11.12 g/100g DM). However, minimum mean value (7.45 g/100g DM) was recorded in S8. The mean value for mature leaves ranged from 4.85-9.48 g/100g DM. The highest mean value was recorded in seed source S2 (9.48 g/100g DM) succeeded by S1 (8.38 g/100g DM), S11 (7.46 g/100g DM) and S14 (6.99 g/100g DM), where as minimum mean value was noticed in S7 (4.85 g/100g DM). The average value for twigs varied from 6.64-23.17 g/100g DM. The seed source S4 (23.17 g/100g DM) showed largest mean value which was followed by S7 (21.06 g/100g DM), S1 (18.88 g/100g DM) and S11 (14.59 g/100g DM) and the minimum mean value was showed by seed source S10 (6.64 g/100g DM).

4.1.10 Nitrogen Free Extract (NFE)

It consist of carbohydrates, sugar, starch and a major portion of material classified as hemicelluloses in feed. The recorded data for nitrogen free extract of tender leaves, mature leaves and twigs of 14 seed sources of *M. oleifera* are included in Table 4.5. The table showed significant variability among the sources. The mean value for nitrogen free extract for tender leaves varied from 42.99-61.31 g/100g DM. The highest value was recorded in S3 (61.31 g/100g DM) which was at par with S5 (61.04 g/100g DM), whereas the lowest mean value was observed in S12 (42.99 g/100g DM). The average value for mature leaves lied between 27.86-41.02 g/100g DM in which the minimum value was seen in seed source S12 (27.86 g/100g DM) and the most in S14 (41.02 g/100g DM) and it was at par with seed source S3 (39.72 g/100g DM) and S6 (39.43 g/100g DM). The range for twigs recorded was 47.17-56.17 g/100g DM. The maximum value was observed in S4 (56.17 g/100g DM) which was at par with S3 (56.05 g/100g DM). However, minimum value was registered in S13 (47.17 g/100g DM).

4.1.11 Total Energy Value (Kcal/100g) for Food

Total energy value for human food is estimated by the crude protein, fats and carbohydrates. The recorded data for total energy value (kcal/100g) for food of tender leaves, mature leaves and twigs of 14 seed sources of *M. oleifera* are included in Table 4.5 which showed significant variability among all the seed sources. The mean values of total energy value (kcal/100g) for tender leaves ranged from 363.24-388.07 kcal/100g. Seed source S14 registered highest mean value (388.07 kcal/100g) followed by S12 (385.14 kcal/100g), S10

(384.67 kcal/100g) and S9 (384.23 kcal/100g). However, lowest mean value (363.24 kcal/100g) was recorded in S5. The mean value for mature leaves ranged from 374.11-386.33 kcal/100g. The maximum average value was recorded in seed source S14 (386.33 kcal/100g) which was at par with S2 (386.05 kcal/100g) and S8 (385.54 kcal/100g), where as minimum mean value was observed in S5 (374.11 kcal/100g). The average value for twigs varied from 371.15-386.32 kcal/100g. The seed source S2 (386.32 kcal/100g) showed largest mean value which was at par with S8 (385.47 kcal/100g) and the least mean value was showed by seed source S6 (371.15kcal/100g).

It is clear from the present study that all 14 seed sources of *M. oleifera* revealed significant variations for nutritional traits. These variations could be due to either genetic source or environmental conditions. Present study on moringa seed sources showed that the twigs contain highest dry matter content followed by mature leaves. The higher dry matter content in the twigs of moringa might be due to the facts that twigs contain less water content and soft or semi hard stem as compared to leaf samples. Dry matter content is inversely proportional to moisture content. Similar observations of variability in dry matter of the leaves from different accessions have been reported by Fuglie, (2001); Magat *et al* 2009 and Oduro *et al* (2008).

Ash includes total mineral content of plant tissues or inorganic substances. Ash content represents the incombustible component remaining after a sample of the furnace oil is completely burned. It is concluded from the result that ash content increases with the increase in age. Among the different parts of moringa, leaves contain higher value whereas twigs contain lower value of total ash content (Nouman *et al* 2013; Verma and Nigam 2014). Similarly, ash contents were also higher in the studies conducted by Olugbemi *et al* (2010) and Mutayoba *et al* (2011). These differences might be due to geographical variations and developmental stage of *M. olifera* plant.

The crude protein represents the nutritional quality of crop plants. The concentrations of crude protein vary significantly among tender leaves, mature leaves and twigs. The maximum value of protein was recorded in mature leaves. The crude protein in mature leaves and twigs was in excess of recommended the minimum requirement for growth (11.3%) and lactation (12.0%) in ruminant animal (ARC, 1984). The results obtained for the range of protein levels in the moringa are similar to levels documented by Fuglie (2001), Elkhailifa *et al* (2007) and Oduro *et al* (2008). This makes the leaves of moringa a good source of protein since plant food that provides more than 12% of its calorific value from protein are considered good source of protein (Pearson 1976). Olugbemi *et al* (2010) reported that higher value of crude protein content was observed in moringa leaves. Nouman *et al* (2013) also reported that highest and lowest value of ether extract was obtained in moringa leaves and twigs respectively.

Table 4.1: Variability for Dry Matter (g/100g) and Ash Content (g/100g) for different phenophases of *Moringa oleifera* seed sources

<i>Moringa</i> Sources	Dry Matter			Ash Content		
	Tender $\pm$ SE	Mature $\pm$ SE	Twigs $\pm$ SE	Tender $\pm$ SE	Mature $\pm$ SE	Twigs $\pm$ SE
S1	18.86 $\pm$ 0.74	20.29 $\pm$ 0.40	21.91 $\pm$ 0.35	11.24 $\pm$ 0.08	11.32 $\pm$ 0.05	10.41 $\pm$ 0.05
S2	19.17 $\pm$ 0.34	20.24 $\pm$ 0.14	23.29 $\pm$ 0.18	10.23 $\pm$ 0.08	10.82 $\pm$ 0.07	8.92 $\pm$ 0.07
S3	18.08 $\pm$ 0.61	19.92 $\pm$ 0.26	22.09 $\pm$ 0.29	9.56 $\pm$ 0.05	11.37 $\pm$ 0.06	9.47 $\pm$ 0.05
S4	18.31 $\pm$ 0.46	20.41 $\pm$ 0.30	23.41 $\pm$ 0.28	10.61 $\pm$ 0.08	11.76 $\pm$ 0.05	10.95 $\pm$ 0.06
S5	19.34 $\pm$ 0.42	19.57 $\pm$ 0.34	23.35 $\pm$ 0.33	10.69 $\pm$ 0.04	11.39 $\pm$ 0.05	11.53 $\pm$ 0.05
S6	17.12 $\pm$ 0.52	19.08 $\pm$ 0.32	26.80 $\pm$ 0.21	10.73 $\pm$ 0.03	11.13 $\pm$ 0.08	11.18 $\pm$ 0.03
S7	16.07 $\pm$ 0.28	17.83 $\pm$ 0.23	20.96 $\pm$ 0.34	11.27 $\pm$ 0.05	11.93 $\pm$ 0.06	9.56 $\pm$ 0.09
S8	18.55 $\pm$ 0.30	20.84 $\pm$ 0.32	21.85 $\pm$ 0.30	10.13 $\pm$ 0.03	10.74 $\pm$ 0.07	8.62 $\pm$ 0.05
S9	18.85 $\pm$ 0.35	19.80 $\pm$ 0.20	22.17 $\pm$ 0.25	9.15 $\pm$ 0.05	10.90 $\pm$ 0.07	9.77 $\pm$ 0.08
S10	18.50 $\pm$ 0.32	18.78 $\pm$ 0.19	22.73 $\pm$ 0.26	7.75 $\pm$ 0.08	11.82 $\pm$ 0.07	10.06 $\pm$ 0.07
S11	17.16 $\pm$ 0.72	19.92 $\pm$ 0.35	20.92 $\pm$ 0.30	10.25 $\pm$ 0.08	11.21 $\pm$ 0.10	9.69 $\pm$ 0.08
S12	20.04 $\pm$ 0.32	20.49 $\pm$ 0.36	22.15 $\pm$ 0.29	9.34 $\pm$ 0.05	10.84 $\pm$ 0.05	10.65 $\pm$ 0.12
S13	21.12 $\pm$ 0.50	22.69 $\pm$ 0.30	24.53 $\pm$ 0.38	11.13 $\pm$ 0.06	12.08 $\pm$ 0.07	11.60 $\pm$ 0.12
S14	20.71 $\pm$ 0.22	21.81 $\pm$ 0.23	25.34 $\pm$ 0.35	10.15 $\pm$ 0.05	10.75 $\pm$ 0.09	10.87 $\pm$ 0.06
Mean $\pm$ SE_m	18.70 $\pm$ 0.46	20.11 $\pm$ 0.29	22.96 $\pm$ 0.30	10.16 $\pm$ 0.06	11.29 $\pm$ 0.07	10.23 $\pm$ 0.07
LSD_{0.05}	1.35	0.85	0.86	0.17	0.20	0.21

Note: **S1** - Bhagya, UHS, Bhagalkot (Karnataka); **S2** - Konkan Ruchika, Dapoli (Maharashtra); **S3** – Dantiwara (Gujarat); **S4** - PAU-1, Ludhiana; **S5** - PAU-2, Ludhiana; **S6** - PAU-3, Ludhiana; **S7** - PKM-2, Tamil Nadu; **S8** - PKM-2, Tamil Nadu; **S9** - ODC-3, Tamil Nadu; **S10** - CAZRI, Jodhpur (Rajasthan); **S11** - Mandya, Karnataka; **S12** - Mysore, Karnataka; **S13** - PAU-4, Ludhiana; **S14** - PAU-5, Ludhiana (Punjab).

Table 4.2: Variability for Organic Matter (g/100g) and Crude Protein (g/100g DM) for different phenophases of *Moringa oleifera* seed sources

<i>Moringa</i> Sources	Organic Matter			Crude Protein		
	Tender $\pm$ SE	Mature $\pm$ SE	Twigs $\pm$ SE	Tender $\pm$ SE	Mature $\pm$ SE	Twigs $\pm$ SE
S1	7.62 $\pm$ 0.66	8.97 $\pm$ 0.45	11.50 $\pm$ 0.30	16.89 $\pm$ 0.25	22.66 $\pm$ 0.15	12.69 $\pm$ 0.15
S2	8.94 $\pm$ 0.27	9.42 $\pm$ 0.21	14.37 $\pm$ 0.25	10.59 $\pm$ 0.15	21.31 $\pm$ 1.13	11.64 $\pm$ 0.15
S3	8.52 $\pm$ 0.56	8.55 $\pm$ 0.20	12.62 $\pm$ 0.24	10.41 $\pm$ 0.15	21.96 $\pm$ 0.15	14.96 $\pm$ 0.15
S4	7.70 $\pm$ 0.39	8.65 $\pm$ 0.26	12.46 $\pm$ 0.22	9.62 $\pm$ 0.20	27.30 $\pm$ 0.20	14.09 $\pm$ 0.15
S5	8.65 $\pm$ 0.46	8.18 $\pm$ 0.40	11.82 $\pm$ 0.38	8.92 $\pm$ 0.20	26.86 $\pm$ 0.25	14.96 $\pm$ 0.25
S6	6.39 $\pm$ 0.49	7.95 $\pm$ 0.40	15.62 $\pm$ 0.25	9.45 $\pm$ 0.20	24.06 $\pm$ 0.15	16.54 $\pm$ 0.15
S7	4.80 $\pm$ 0.33	5.90 $\pm$ 0.30	11.40 $\pm$ 0.25	17.41 $\pm$ 0.15	25.55 $\pm$ 0.20	17.59 $\pm$ 0.25
S8	8.42 $\pm$ 0.27	10.10 $\pm$ 0.25	13.23 $\pm$ 0.25	15.05 $\pm$ 0.10	26.69 $\pm$ 0.15	18.02 $\pm$ 0.20
S9	9.70 $\pm$ 0.30	8.90 $\pm$ 0.27	12.40 $\pm$ 0.18	19.86 $\pm$ 0.15	28.70 $\pm$ 0.20	18.81 $\pm$ 0.15
S10	10.75 $\pm$ 0.25	6.96 $\pm$ 0.12	12.67 $\pm$ 0.19	18.64 $\pm$ 0.25	25.46 $\pm$ 0.25	17.67 $\pm$ 0.20
S11	6.91 $\pm$ 0.64	8.71 $\pm$ 0.45	11.23 $\pm$ 0.22	17.32 $\pm$ 0.20	23.71 $\pm$ 0.15	17.76 $\pm$ 0.25
S12	10.70 $\pm$ 0.27	9.65 $\pm$ 0.40	11.50 $\pm$ 0.41	22.22 $\pm$ 0.20	28.09 $\pm$ 0.25	18.64 $\pm$ 0.15
S13	9.99 $\pm$ 0.44	10.61 $\pm$ 0.37	12.93 $\pm$ 0.26	17.15 $\pm$ 0.10	21.53 $\pm$ 0.10	16.45 $\pm$ 0.20
S14	10.56 $\pm$ 0.27	11.06 $\pm$ 0.14	14.47 $\pm$ 0.41	14.53 $\pm$ 0.10	19.16 $\pm$ 0.15	16.89 $\pm$ 0.15
Mean $\pm$ SE_m	7.77 $\pm$ 0.42	8.82 $\pm$ 0.32	12.72 $\pm$ 0.28	14.86 $\pm$ 0.18	24.50 $\pm$ 0.35	16.19 $\pm$ 0.19
LSD_{0.05}	1.23	0.93	0.81	0.52	1.02	0.55

Note: **S1** - Bhagya, UHS, Bhagalkot (Karnataka); **S2** - Konkan Ruchika, Dapoli (Maharashtra); **S3** – Dantiwara (Gujarat); **S4** - PAU-1, Ludhiana; **S5** - PAU-2, Ludhiana; **S6** - PAU-3, Ludhiana; **S7** - PKM-2, Tamil Nadu; **S8** - PKM-2, Tamil Nadu; **S9** - ODC-3, Tamil Nadu; **S10** - CAZRI, Jodhpur (Rajasthan); **S11** - Mandya, Karnataka; **S12** - Mysore, Karnataka; **S13** - PAU-4, Ludhiana; **S14** - PAU-5, Ludhiana (Punjab).

Table 4.3: Variability for Crude Fats (g/100g DM) and Crude Fibre (g/100g DM) for different phenophases of *Moringa oleifera* seed sources

<i>Moringa</i> Sources	Crude Fats			Crude Fibre		
	Tender $\pm$ SE	Mature $\pm$ SE	Twigs $\pm$ SE	Tender $\pm$ SE	Mature $\pm$ SE	Twigs $\pm$ SE
S1	3.77 $\pm$ 0.00	5.17 $\pm$ 0.00	3.87 $\pm$ 0.01	15.90 $\pm$ 0.17	23.10 $\pm$ 0.40	21.90 $\pm$ 0.23
S2	2.37 $\pm$ 0.02	5.87 $\pm$ 0.01	4.40 $\pm$ 0.01	18.80 $\pm$ 0.40	27.80 $\pm$ 0.35	20.20 $\pm$ 0.29
S3	1.47 $\pm$ 0.01	5.10 $\pm$ 0.01	3.82 $\pm$ 0.01	17.25 $\pm$ 0.38	21.85 $\pm$ 0.43	15.70 $\pm$ 0.23
S4	2.17 $\pm$ 0.01	4.80 $\pm$ 0.01	3.60 $\pm$ 0.01	19.10 $\pm$ 0.23	27.15 $\pm$ 0.38	15.20 $\pm$ 0.35
S5	1.20 $\pm$ 0.01	3.93 $\pm$ 0.01	2.95 $\pm$ 0.01	18.15 $\pm$ 0.38	21.10 $\pm$ 0.40	16.80 $\pm$ 0.23
S6	3.23 $\pm$ 0.00	4.23 $\pm$ 0.01	3.17 $\pm$ 0.01	17.20 $\pm$ 0.17	21.15 $\pm$ 0.61	19.80 $\pm$ 0.35
S7	4.07 $\pm$ 0.01	5.10 $\pm$ 0.01	3.82 $\pm$ 0.01	17.65 $\pm$ 0.38	23.80 $\pm$ 0.58	14.50 $\pm$ 0.40
S8	4.20 $\pm$ 0.01	5.70 $\pm$ 0.01	3.99 $\pm$ 0.01	15.05 $\pm$ 0.61	27.50 $\pm$ 0.64	18.10 $\pm$ 0.35
S9	4.17 $\pm$ 0.01	4.47 $\pm$ 0.00	3.13 $\pm$ 0.01	17.90 $\pm$ 0.35	26.35 $\pm$ 0.84	19.80 $\pm$ 0.40
S10	3.13 $\pm$ 0.01	4.50 $\pm$ 0.01	3.08 $\pm$ 0.00	17.40 $\pm$ 0.46	24.20 $\pm$ 0.40	19.20 $\pm$ 0.35
S11	3.67 $\pm$ 0.01	4.57 $\pm$ 0.01	3.04 $\pm$ 0.01	19.05 $\pm$ 0.38	26.50 $\pm$ 0.46	20.40 $\pm$ 0.23
S12	4.50 $\pm$ 0.02	5.07 $\pm$ 0.01	3.55 $\pm$ 0.01	20.95 $\pm$ 0.20	28.15 $\pm$ 0.43	18.20 $\pm$ 0.23
S13	5.63 $\pm$ 0.01	5.83 $\pm$ 0.02	4.08 $\pm$ 0.00	17.05 $\pm$ 0.26	24.25 $\pm$ 0.55	20.70 $\pm$ 0.23
S14	5.73 $\pm$ 0.00	5.87 $\pm$ 0.01	4.69 $\pm$ 0.01	17.90 $\pm$ 0.40	23.20 $\pm$ 0.52	16.90 $\pm$ 0.23
Mean $\pm$ SE_m	3.52 $\pm$ 0.01	5.01 $\pm$ 0.01	3.66 $\pm$ 0.01	17.81 $\pm$ 0.36	24.72 $\pm$ 0.52	18.39 $\pm$ 0.30
LSD_{0.05}	0.03	0.03	0.02	1.04	1.49	0.87

Note: **S1** - Bhagya, UHS, Bhagalkot (Karnataka); **S2** - Konkan Ruchika, Dapoli (Maharashtra); **S3** – Dantiwara (Gujarat); **S4** - PAU-1, Ludhiana; **S5** - PAU-2, Ludhiana; **S6** - PAU-3, Ludhiana; **S7** - PKM-2, Tamil Nadu; **S8** - PKM-2, Tamil Nadu; **S9** - ODC-3, Tamil Nadu; **S10** - CAZRI, Jodhpur (Rajasthan); **S11** - Mandya, Karnataka; **S12** - Mysore, Karnataka; **S13** - PAU-4, Ludhiana; **S14** - PAU-5, Ludhiana (Punjab).

Table 4.4: Variability for Total Carbohydrate (g/100g DM) and TSS (g/100g DM) for different phenophases of *Moringa oleifera* seed sources

<i>Moringa</i> Sources	Total Carbohydrates			Total Soluble Sugars		
	Tender $\pm$ SE	Mature $\pm$ SE	Twigs $\pm$ SE	Tender $\pm$ SE	Mature $\pm$ SE	Twigs $\pm$ SE
S1	68.11 $\pm$ 0.34	60.85 $\pm$ 0.20	73.03 $\pm$ 0.21	11.27 $\pm$ 0.02	8.38 $\pm$ 0.02	18.88 $\pm$ 0.03
S2	76.82 $\pm$ 0.24	62.00 $\pm$ 1.06	75.05 $\pm$ 0.23	11.33 $\pm$ 0.02	9.48 $\pm$ 0.03	9.45 $\pm$ 0.03
S3	78.56 $\pm$ 0.21	61.57 $\pm$ 0.23	71.75 $\pm$ 0.20	11.49 $\pm$ 0.03	6.21 $\pm$ 0.03	13.27 $\pm$ 0.02
S4	77.60 $\pm$ 0.28	56.14 $\pm$ 0.14	71.37 $\pm$ 0.10	11.12 $\pm$ 0.02	5.10 $\pm$ 0.03	23.17 $\pm$ 0.03
S5	79.19 $\pm$ 0.15	57.82 $\pm$ 0.21	70.56 $\pm$ 0.19	9.60 $\pm$ 0.01	5.49 $\pm$ 0.02	9.81 $\pm$ 0.03
S6	76.59 $\pm$ 0.23	60.58 $\pm$ 0.22	69.11 $\pm$ 0.13	9.34 $\pm$ 0.03	6.70 $\pm$ 0.03	8.36 $\pm$ 0.03
S7	67.25 $\pm$ 0.11	57.42 $\pm$ 0.13	69.03 $\pm$ 0.15	8.29 $\pm$ 0.02	4.85 $\pm$ 0.03	21.06 $\pm$ 0.03
S8	70.63 $\pm$ 0.08	56.88 $\pm$ 0.08	69.37 $\pm$ 0.15	7.45 $\pm$ 0.03	6.14 $\pm$ 0.02	9.13 $\pm$ 0.03
S9	66.82 $\pm$ 0.11	55.93 $\pm$ 0.13	68.29 $\pm$ 0.08	10.13 $\pm$ 0.03	6.70 $\pm$ 0.02	13.11 $\pm$ 0.04
S10	70.48 $\pm$ 0.17	58.22 $\pm$ 0.32	69.19 $\pm$ 0.13	10.49 $\pm$ 0.03	5.41 $\pm$ 0.03	6.64 $\pm$ 0.02
S11	68.76 $\pm$ 0.27	60.51 $\pm$ 0.04	69.51 $\pm$ 0.33	9.85 $\pm$ 0.03	7.46 $\pm$ 0.03	14.59 $\pm$ 0.01
S12	63.94 $\pm$ 0.14	56.01 $\pm$ 0.20	67.17 $\pm$ 0.03	8.57 $\pm$ 0.03	6.17 $\pm$ 0.09	10.31 $\pm$ 0.03
S13	66.09 $\pm$ 0.18	60.56 $\pm$ 0.19	67.87 $\pm$ 0.32	7.58 $\pm$ 0.02	4.97 $\pm$ 0.03	9.00 $\pm$ 0.03
S14	69.59 $\pm$ 0.05	64.22 $\pm$ 0.08	67.55 $\pm$ 0.10	9.13 $\pm$ 0.03	6.99 $\pm$ 0.03	11.42 $\pm$ 0.03
Mean $\pm$ SE_m	71.46 $\pm$ 0.20	59.19 $\pm$ 0.33	69.92 $\pm$ 0.19	9.69 $\pm$ 0.02	6.43 $\pm$ 0.03	12.73 $\pm$ 0.03
LSD_{0.05}	0.58	0.96	0.54	0.07	0.10	0.08

Note: **S1** - Bhagya, UHS, Bhagalkot (Karnataka); **S2** - Konkan Ruchika, Dapoli (Maharashtra); **S3** – Dantiwara (Gujarat); **S4** - PAU-1, Ludhiana; **S5** - PAU-2, Ludhiana; **S6** - PAU-3, Ludhiana; **S7** - PKM-2, Tamil Nadu; **S8** - PKM-2, Tamil Nadu; **S9** - ODC-3, Tamil Nadu; **S10** - CAZRI, Jodhpur (Rajasthan); **S11** - Mandya, Karnataka; **S12** - Mysore, Karnataka; **S13** - PAU-4, Ludhiana; **S14** - PAU-5, Ludhiana (Punjab).

Table 4.5: Variability for NFE (g/100g DM) and Total Energy value (Kcal/100g) for different phenophases of *Moringa oleifera* seed sources

<i>Moringa</i> Sources	NFE			Total Energy Value		
	Tender $\pm$ SE	Mature $\pm$ SE	Twigs $\pm$ SE	Tender $\pm$ SE	Mature $\pm$ SE	Twigs $\pm$ SE
S1	52.21 $\pm$ 0.51	37.75 $\pm$ 0.20	51.13 $\pm$ 0.44	373.89 $\pm$ 0.72	380.55 $\pm$ 0.42	377.73 $\pm$ 0.43
S2	58.02 $\pm$ 0.65	34.20 $\pm$ 0.71	54.85 $\pm$ 0.52	370.91 $\pm$ 0.49	386.05 $\pm$ 1.52	386.32 $\pm$ 0.51
S3	61.31 $\pm$ 0.58	39.72 $\pm$ 0.21	56.05 $\pm$ 0.03	369.09 $\pm$ 0.39	380.02 $\pm$ 0.46	381.24 $\pm$ 0.48
S4	58.50 $\pm$ 0.51	28.99 $\pm$ 0.52	56.17 $\pm$ 0.45	368.39 $\pm$ 0.61	376.96 $\pm$ 0.17	374.20 $\pm$ 0.07
S5	61.04 $\pm$ 0.52	36.72 $\pm$ 0.19	53.76 $\pm$ 0.04	363.24 $\pm$ 0.21	374.11 $\pm$ 0.14	368.63 $\pm$ 0.22
S6	59.39 $\pm$ 0.41	39.43 $\pm$ 0.82	49.31 $\pm$ 0.47	373.25 $\pm$ 0.42	376.65 $\pm$ 0.58	371.15 $\pm$ 0.06
S7	49.60 $\pm$ 0.27	33.62 $\pm$ 0.70	54.53 $\pm$ 0.25	375.25 $\pm$ 0.01	377.78 $\pm$ 0.11	380.88 $\pm$ 0.04
S8	55.58 $\pm$ 0.53	29.38 $\pm$ 0.56	51.27 $\pm$ 0.20	380.48 $\pm$ 0.01	385.54 $\pm$ 0.02	385.47 $\pm$ 0.15
S9	48.92 $\pm$ 0.45	29.58 $\pm$ 0.97	48.49 $\pm$ 0.48	384.23 $\pm$ 0.01	378.73 $\pm$ 0.04	376.55 $\pm$ 0.10
S10	53.08 $\pm$ 0.29	34.02 $\pm$ 0.72	49.99 $\pm$ 0.22	384.67 $\pm$ 0.11	375.22 $\pm$ 0.72	375.18 $\pm$ 0.04
S11	49.71 $\pm$ 0.11	34.01 $\pm$ 0.50	49.11 $\pm$ 0.57	377.33 $\pm$ 0.68	377.99 $\pm$ 0.13	376.46 $\pm$ 0.69
S12	42.99 $\pm$ 0.06	27.86 $\pm$ 0.23	48.97 $\pm$ 0.20	385.14 $\pm$ 0.20	381.97 $\pm$ 0.23	375.13 $\pm$ 0.24
S13	49.04 $\pm$ 0.08	36.31 $\pm$ 0.36	47.17 $\pm$ 0.09	383.65 $\pm$ 0.37	380.85 $\pm$ 0.39	374.02 $\pm$ 0.79
S14	51.69 $\pm$ 0.45	41.02 $\pm$ 0.44	50.65 $\pm$ 0.33	388.07 $\pm$ 0.04	386.33 $\pm$ 0.17	379.99 $\pm$ 0.06
Mean $\pm$ SE_m	53.65 $\pm$ 0.43	34.47 $\pm$ 0.57	51.53 $\pm$ 0.35	376.97 $\pm$ 0.39	379.91 $\pm$ 0.53	377.35 $\pm$ 0.37
LSD_{0.05}	1.25	1.64	1.02	1.14	1.52	1.08

Note: **S1** - Bhagya, UHS, Bhagalkot (Karnataka); **S2** - Konkan Ruchika, Dapoli (Maharashtra); **S3** – Dantiwara (Gujarat); **S4** - PAU-1, Ludhiana; **S5** - PAU-2, Ludhiana; **S6** - PAU-3, Ludhiana; **S7** - PKM-2, Tamil Nadu; **S8** - PKM-2, Tamil Nadu; **S9** - ODC-3, Tamil Nadu; **S10** - CAZRI, Jodhpur (Rajasthan); **S11** - Mandya, Karnataka; **S12** - Mysore, Karnataka; **S13** - PAU-4, Ludhiana; **S14** - PAU-5, Ludhiana (Punjab).

Crude fats consist of unsaturated fatty acids, oil-soluble pigments (chlorophyll and carotenoids), wax, cholesterol, free fatty acids and phospholipids. They act as messengers and help protein to do their work. Mature leaves possessed highest amount of fats followed by tender leaves. Among the different parts of moringa, leaves contain higher value whereas twigs contain lower values of crude protein and ether extract (Verma and Nigam 2014). The results were familiar to results presented by Mutayoba *et al* (2011) and Olugbemi *et al* (2010).

Crude fibre is a measure of indigestible cellulose, pentosans, lignin and other related components. Crude fibre is mainly cellulose material obtained as a residue after digestion with dilute acid or alkali. It usually serves as structural and protective part of plant. The mature leaves possessed maximum value of crude fibre content. Similar results were recorded in the studies conducted by Olugbemi *et al* (2010) and Mutayoba *et al* (2011).

Carbohydrates are naturally occurring sugars, starches and fibres in any food substance. All *carbohydrates* are made up of sugar molecules which are linked together to form starches and fiber. In the body, starches and sugars are broken down in the digestive system to glucose. The highest amount of carbohydrate content was noticed in tender leaves followed by twigs and mature leaves. The same values of carbohydrate in moringa leaves were also recorded by Nweze *et al* (2014), Ogbe and Afiku (2012).

Total energy value is the energy released from carbohydrates, fats, proteins, and other organic compounds. As the amount of food consumption increases in humans or animals, the value of total energy obtained is also increased. The tender leaves and twigs possessed high amount of energy content. The high amount of crude protein content could meet both protein and energy requirement and may be helpful in making mental and physical health; and boost immune system (Brisibe *et al* 2009). The high amount of crude protein and carbohydrate may be making it as supplementary food (Moyo *et al* 2011). Similar results were reported by Yameogo *et al* (2011) and Melesse *et al* (2011) for total energy values (kcal/100g) of moringa leaves, respectively.

In the analysis of foods and animal feedings, Nitrogen-Free Extract (NFE), is the fraction that contains the sugars, starches plus small amounts of other materials. It is the largest component of rations of animals, representing 40-70% of total dry matter. Tender leaves possessed highest amount of NFE content. The values for NFE content noticed were to the results of Mahima *et al* (2014).

4.2 Fodder Characteristics

4.2.1 Neutral Detergent Fibre (NDF)

The recorded data for NDF of tender leaves, mature leaves and twigs of 14 seed sources of *M. oleifera* are presented in Table 4.6 which showed significant difference among the seed sources and phenophases. The mean values of NDF for tender leaves ranged from

30.30-47.65 g/100g DM. Seed source S5 registered maximum mean value (47.65 g/100g DM) followed by S7 (44.95 g/100g DM), S4 (40.95 g/100g DM) and S6 (39.95 g/100g DM). However, minimum mean value (30.30 g/100g DM) was recorded in S11. The mean value for mature leaves ranged from 37.00-51.05 g/100g DM. The highest mean value was recorded in S6 (51.05 g/100g DM) followed by S8 (43.55 g/100g DM), S9 (43.20 g/100g DM) and S2 (42.40 g/100g DM), whereas, minimum mean value was noticed in S12 (37.00 g/100g DM). The average value of NDF for twigs varied from 38.80-52.20 g/100g DM. The seed source S7 (52.20 g/100g DM) showed largest mean value which was at par with S12 (51.80 g/100g DM) and the minimum mean value was showed by seed source S5 (38.80 g/100g DM).

4.2.2 Acid Detergent Fibre (ADF)

The average value registered for tender leaves ranged from 18.70-37.55 g/100g DM (Table 4.6). The highest value was recorded in S5 (37.55 g/100g DM) which was statistically at par with sources S7 (34.15 g/100g DM), S4 (30.35 g/100g DM) and S6 (29.55 g/100g DM). Source S11 (18.70 g/100g DM) showed the lowest amount of ADF. The mature leaves possessed maximum mean value in S6 (34.18 g/100g DM), statistically at par with S8 (32.45 g/100g DM) and S9 (32.00 g/100g DM). The mean values varied from 22.85-34.18 g/100g DM and the minimum value noticed in S12 (22.85 g/100g DM). Twigs showed largest ADF content in seed source S7 (38.35 g/100g DM) followed by S13 (36.55 g/100g DM), S11 (36.30 g/100g DM) and S6 (36.20 g/100g DM). The norm value ranged from 28.15-38.35 g/100g DM, in which the least value was recorded in S8 (28.15 g/100g DM).

4.2.3 Acid Detergent Lignin (ADL)

The data on ADL of tender leaves, mature leaves and twigs of 14 seed sources of *M. oleifera* are depicted in Table 4.7 which showed significant variability among the seed sources. The mean values of ADL for tender leaves ranged from 2.95-12.55 g/100g DM. Seed source S7 registered maximum mean value (12.55 g/100g DM) followed by S4 (11.00 g/100g DM), S5 (8.80 g/100g DM) and S13 (7.70 g/100g DM). However, minimum mean value (2.95 g/100g DM) was recorded in S1. The mean value for mature leaves ranged from 6.25-13.95 g/100g DM. The highest mean value was recorded in seed source S4 (13.95 g/100g DM) succeeded by S5 (11.70 g/100g DM), S2 (11.65 g/100g DM) and S7 (10.85 g/100g DM), where as minimum mean value was noticed in S1 (6.25 g/100g DM). The average value for twigs varied from 6.05-13.55 g/100g DM. The seed source S7 (13.55 g/100g DM) showed largest mean value which was followed by S11 (11.70 g/100g DM), S10 (11.15 g/100g DM) and S12 (10.80 g/100g DM) and the minimum mean value was showed by seed source S8 (6.05 g/100g DM).

4.2.4 In Vitro Dry Matter Digestibility (IVDMD)

The digestivity of dry matter of tender leaves, mature leaves and twigs of 14 seed sources of *M. oleifera* were assessed in lab conditions and observations recorded are presented in Table 4.7. The IVDMD content for tender leaves ranged from 65.30-78.50 %.

The highest mean value was registered in S14 (78.50 %) which was at par with two seed sources S2 (77.30 %) and S8 (77.30 %). However the least mean value (65.30 %) was possessed by S5. The mature leaves registered the largest mean value in seed source S5 (81.90 %), statistically at par with S4 (81.50 %), S6 (81.35 %), S2 (81.10 %) and S7 (80.40 %), while lowest mean value in S9 (65.90 %). The mean values for mature leaves ranged from 65.90-81.90 %. The average value recorded for twigs ranged from 58.50-81.00 %. The seed source S2 possessed minimum mean value (58.50 %) and S15 had maximum mean value (81.00 %) for twigs which was at par with S4 (80.60 %), S1 (80.10 %) and S8 (79.60 %).

4.2.5 Hemicellulose

The recorded data for hemicelluloses of tender leaves, mature leaves and twigs of 14 seed sources of *M. oleifera* are presented in Table 4.8 which showed significant difference among all the seed sources for hemicellulose and cellulose. The mean value for hemicellulose for tender leaves varied from 10.10-12.75 g/100g DM. The highest value was recorded in S8 (12.75 g/100g DM) at par with S9 (12.55 g/100g DM) and S13 (12.09 g/100g DM), whereas, the lowest mean value was observed in S5 (10.10 g/100g DM). The average value for mature leaves lied between 10.65-16.88 g/100g DM in which the minimum value was seen in seed source S2 (10.65 g/100g DM) and the most in S6 (16.88 g/100g DM) which was statistically at par with seed source S14 (14.70 g/100g DM). The range for twigs recorded was 4.90-20.30 g/100g DM. The maximum value was observed in S12 (20.30 g/100g DM) followed by S8 (17.85 g/100g DM), S4 (16.75 g/100g DM) and S9 (15.60 g/100g DM). However, minimum means value was registered in S6 source (4.90 g/100g DM).

4.2.6 Cellulose

The norm values of cellulose for tender leaves ranged from 13.10-28.75 g/100g DM (Table 4.8). Seed source S5 registered maximum mean value (28.75 g/100g DM) followed by S6 (25.55 g/100g DM), S7 (21.60 g/100g DM) and S3 (20.55 g/100g DM). However, minimum mean value (13.10 g/100g DM) was recorded in S12. The mean value for mature leaves ranged from 12.10-24.93 %. Maximum mean value was recorded in seed source S6 (24.93 g/100g DM) which was at par with S8 (24.10 g/100g DM) and S9 (23.15 g/100g DM). Whereas, minimum mean value was noticed in S12 (12.10 g/100g DM). The average value for twigs varied from 20.70-26.90 g/100g DM. Seed source S6 (26.90 g/100g DM) showed maximum mean value which was at par with S13 (26.40 g/100g DM) but the minimum mean value was showed by seed source S12 (20.70 g/100g DM).

4.2.7 Dry Matter Intake (DMI)

Estimated daily DMI was calculated taking the tender leaves, mature leaves and twigs of 14 seed sources of *M. oleifera* which is presented included in Table 4.9 which showed significant variability among all the seed sources. The mean values of DMI for tender leaves

ranged from 2.52-3.96 g/100g DM. Seed source S11 registered highest mean value (3.96 g/100g DM) followed by S9 (3.81 g/100g DM), S12 (3.73 g/100g DM) and S14 (3.67 g/100g DM). However, lowest mean value (2.52 g/100g DM) was recorded in S5. The mean value for mature leaves ranged from 2.35-3.24 g/100g DM. The maximum average value was recorded in seed source S12 (3.24 g/100g DM) followed by S11 (3.11 g/100g DM), S7 (3.08 g/100g DM) and S4 (3.07 g/100g DM), where as minimum mean value was observed in S6 (2.35 g/100g DM). The average value for twigs varied from 2.30-3.09 g/100g DM. The seed source S5 (3.09 g/100g DM) showed largest mean value which was succeeded by S6 (2.92 g/100g DM), S2 (2.90 g/100g DM) and S3 (2.74 g/100g DM) and the least mean value was showed by seed source S7 (2.30 g/100g DM).

4.2.8 Digestible Dry Matter (DDM)

DDM was significantly higher for tender leaves followed by mature leaves and twigs. The DDM content for tender leaves ranged from 59.65-74.33 g/100g DM (Table 4.9). The highest mean value was registered in S11 (74.33 g/100g DM) which was at par with seed source S9 (74.10 g/100g DM) and S12 (73.21 g/100g DM). However the least mean value (59.65 g/100g DM) was possessed by S5. The mature leaves registered the largest mean value in seed source S12 (71.10 g/100g DM) followed by S14 (69.00 g/100g DM), S11 (68.57 g/100g DM) and S4 (68.22 g/100g DM). The mean values for mature leaves ranged from 62.28-71.10 g/100g DM. However, minimum mean value (62.28 g/100g DM) was recorded in S6. The average value recorded for twigs ranged from 59.03-66.97 g/100g DM. The seed source S7 possessed minimum mean value (59.03 g/100g DM) and S8 had maximum mean value (66.97 g/100g DM) for twigs which was statistically at par with source S9 (66.15 g/100g DM).

4.2.9 Relative Feed Value (RFV)

RFV was calculated from the estimates of DMI and DDM. The recorded data for RFV of tender leaves, mature leaves and twigs of 14 seed sources of *M. oleifera* are presented in Table 4.10 which showed significant variations. The mean value for relative feed value for tender leaves varied from 116.50-228.30 g/100g DM. The highest value was recorded in S11 (228.30 g/100g DM) which was at par with S9 (218.63 g/100g DM), whereas the lowest mean value was observed in S5 (116.50 g/100g DM). The average value for mature leaves lied between 113.46-178.84 g/100g DM, in which minimum value was noticed in seed source S6 (113.46 g/100g DM) and the most in S12 (178.84 g/100g DM) followed by S11 (165.51 g/100g DM), S7 (162.37 g/100g DM) and S4 (162.10 g/100g DM). The range for twigs recorded was 105.21-157.26 g/100g DM. The maximum value was observed in S5 (157.26 g/100g DM) succeeded by S2 (142.93 g/100g DM), S9 (137.42 g/100g DM) and S6 (137.40 g/100g DM). However, minimum value was registered in S7 (105.21 g/100g DM).

4.2.9 pH

The recorded data for pH of tender leaves, mature leaves and twigs of 14 seed sources of *M. oleifera* are included in Table 4.10 which showed significant difference among all the seed sources. The mean value for pH for tender leaves varied from 5.11-6.25. The highest value was recorded in S14 (6.25) followed by S7 (5.95), S9 (5.90) and S13 (5.81) whereas, the lowest mean value was observed in S12 (5.11). The average value for mature leaves lied from 5.98-6.59, in which the minimum value was seen in seed source S4 (5.98) and the most in S7 (6.59) which was succeeded by seed source S9 (6.45), S11 (6.40) and S14 (6.36). The range for twigs recorded was 5.66-6.24. The maximum value was observed in S1 (6.24) followed by S2 (6.14), S11 (6.12) and S7 (6.11). However, minimum means value was registered in S8 source (5.66).

Neutral detergent fibre (NDF) represents total fibre fraction (cellulose, hemicelluloses, lignin and silica content) that make up cell wall of plant tissue. NDF is good indicator of feed quality. Forages with high concentrations of fibre generally support less milk production because forages with high concentration of fibre contain less available energy and are consumed in lesser amounts by livestock. Acid detergent fibre (ADF) is the percentage of high indigestible plant material that contains cellulose, lignin and silica content. It is major indicator of digestibility and negatively affect feed quality (Han *et al* 2003). Low ADF values means higher energy values and digestibility.

The maximum amount of NDF and ADF content are recorded in twigs followed by mature leaves. Nouman *et al* (2013) reported that comparative analysis of different parts of moringa revealed that NDF and ADF were found in the order of twigs > leaves. Lower NDF and ADF content in moringa leaves show its better fodder quality. Aregheore (2002) also reported that mixtures with different proportions of moringa leaves, twigs, or branches have different NDF contents. Among the sources, level of ADF ranged from 19.0-37.5% which falls within the range where browse substrates are expected to be digestible (Belyea and Rickets 1993) and would not have negative impact on bioavailability of crude protein.

Acid detergent lignin (ADL) represents the lignin and silica components of cell wall. The presence of lignin is regarded as a negative index for forage digestibility. Due to absence of ligninase lignin cannot be broken down in rumen. Thus, it has important effect on livestock production through effects on degradability and feed intake. The lowest content was observed in tender leaves and highest in mature leaves. The results were indential to the findings of Mahima *et al* (2014).

In vitro dry matter digestibility (IVDMD) parameter is directly related to digestibility of the animal feed intake. This is most important parameter of forage quality. As the value of IVDMD increases of forage more is the digestibility.

Table 4.6: Variability for NDF (g/100g DM) and ADF (g/100g DM) for different phenophases of *Moringa oleifera* seed sources

<i>Moringa</i> Sources	Neutral Detergent Fibre			Acid Detergent Fibre		
	Tender $\pm$ SE	Mature $\pm$ SE	Twigs $\pm$ SE	Tender $\pm$ SE	Mature $\pm$ SE	Twigs $\pm$ SE
S1	33.60 $\pm$ 0.12	40.85 $\pm$ 0.32	50.10 $\pm$ 0.49	22.45 $\pm$ 0.61	27.60 $\pm$ 0.40	35.10 $\pm$ 0.46
S2	33.25 $\pm$ 0.66	42.40 $\pm$ 0.40	41.40 $\pm$ 0.52	21.75 $\pm$ 0.66	31.75 $\pm$ 0.55	32.50 $\pm$ 0.52
S3	35.60 $\pm$ 0.64	40.05 $\pm$ 0.20	43.80 $\pm$ 0.23	23.75 $\pm$ 0.61	27.00 $\pm$ 0.29	32.25 $\pm$ 0.32
S4	40.95 $\pm$ 0.20	39.15 $\pm$ 0.20	48.20 $\pm$ 0.55	30.35 $\pm$ 0.49	26.55 $\pm$ 0.32	31.45 $\pm$ 0.72
S5	47.65 $\pm$ 0.55	41.25 $\pm$ 0.20	38.80 $\pm$ 0.49	37.55 $\pm$ 0.72	28.85 $\pm$ 0.26	29.95 $\pm$ 0.38
S6	39.95 $\pm$ 0.32	51.05 $\pm$ 0.20	41.10 $\pm$ 0.46	29.55 $\pm$ 0.49	34.18 $\pm$ 2.67	36.20 $\pm$ 0.52
S7	44.95 $\pm$ 0.43	38.95 $\pm$ 0.14	52.20 $\pm$ 0.55	34.15 $\pm$ 0.55	26.85 $\pm$ 0.43	38.35 $\pm$ 0.38
S8	34.00 $\pm$ 0.46	43.55 $\pm$ 0.72	46.00 $\pm$ 0.38	21.25 $\pm$ 0.49	32.45 $\pm$ 0.43	28.15 $\pm$ 0.26
S9	31.55 $\pm$ 0.49	43.20 $\pm$ 0.17	44.80 $\pm$ 0.52	19.00 $\pm$ 0.69	32.00 $\pm$ 0.52	29.20 $\pm$ 0.64
S10	33.75 $\pm$ 0.20	39.55 $\pm$ 0.55	50.70 $\pm$ 0.55	22.75 $\pm$ 0.61	27.10 $\pm$ 0.52	35.15 $\pm$ 0.49
S11	30.30 $\pm$ 0.35	38.55 $\pm$ 0.43	45.70 $\pm$ 0.64	18.70 $\pm$ 0.52	26.10 $\pm$ 0.23	36.30 $\pm$ 0.52
S12	32.20 $\pm$ 0.75	37.00 $\pm$ 0.46	51.80 $\pm$ 0.55	20.15 $\pm$ 0.55	22.85 $\pm$ 0.61	31.50 $\pm$ 0.52
S13	34.05 $\pm$ 0.26	39.55 $\pm$ 0.38	47.10 $\pm$ 0.55	21.97 $\pm$ 0.42	27.45 $\pm$ 0.38	36.55 $\pm$ 0.61
S14	32.70 $\pm$ 0.52	40.25 $\pm$ 0.26	47.70 $\pm$ 0.55	21.25 $\pm$ 0.38	25.55 $\pm$ 0.49	32.85 $\pm$ 0.55
Mean $\pm$ SE_m	36.04 $\pm$ 0.46	41.10 $\pm$ 0.37	46.39 $\pm$ 0.51	24.62 $\pm$ 0.56	28.31 $\pm$ 0.83	33.25 $\pm$ 0.51
LSD_{0.05}	1.34	1.07	1.48	1.64	2.39	1.46

Note: **S1** - Bhagya, UHS, Bhagalkot (Karnataka); **S2** - Konkan Ruchika, Dapoli (Maharashtra); **S3** – Dantiwara (Gujarat); **S4** - PAU-1, Ludhiana; **S5** - PAU-2, Ludhiana; **S6** - PAU-3, Ludhiana; **S7** - PKM-2, Tamil Nadu; **S8** - PKM-2, Tamil Nadu; **S9** - ODC-3, Tamil Nadu; **S10** - CAZRI, Jodhpur (Rajasthan); **S11** - Mandya, Karnataka; **S12** - Mysore, Karnataka; **S13** - PAU-4, Ludhiana; **S14** - PAU-5, Ludhiana (Punjab).

Table 4.7: Variability for ADL (g/100g DM) and IVDMD (g/100g DM) for different phenophases of *Moringa oleifera* seed sources

<i>Moringa</i> Sources	Acid Detergent Lignin			In Vitro Dry Matter Digestibility		
	Tender $\pm$ SE	Mature $\pm$ SE	Twigs $\pm$ SE	Tender $\pm$ SE	Mature $\pm$ SE	Twigs $\pm$ SE
S1	2.95 $\pm$ 0.14	6.25 $\pm$ 0.26	10.00 $\pm$ 0.35	71.10 $\pm$ 0.52	76.50 $\pm$ 1.21	80.10 $\pm$ 0.75
S2	3.40 $\pm$ 0.23	11.65 $\pm$ 0.61	8.25 $\pm$ 0.38	77.30 $\pm$ 0.75	81.10 $\pm$ 0.52	58.50 $\pm$ 1.21
S3	3.20 $\pm$ 0.17	7.05 $\pm$ 0.20	9.00 $\pm$ 0.40	67.50 $\pm$ 0.40	76.70 $\pm$ 1.56	73.60 $\pm$ 0.81
S4	11.00 $\pm$ 0.52	13.95 $\pm$ 0.49	9.55 $\pm$ 0.32	69.80 $\pm$ 1.04	81.50 $\pm$ 1.10	80.60 $\pm$ 0.69
S5	8.80 $\pm$ 0.23	11.70 $\pm$ 0.46	6.25 $\pm$ 0.38	65.30 $\pm$ 0.52	81.90 $\pm$ 1.21	81.00 $\pm$ 0.69
S6	4.00 $\pm$ 0.23	9.25 $\pm$ 0.32	9.30 $\pm$ 0.35	73.80 $\pm$ 0.69	81.35 $\pm$ 1.47	73.80 $\pm$ 0.81
S7	12.55 $\pm$ 0.38	10.85 $\pm$ 0.32	13.55 $\pm$ 0.43	68.60 $\pm$ 0.58	80.40 $\pm$ 1.27	70.00 $\pm$ 0.81
S8	4.45 $\pm$ 0.14	8.35 $\pm$ 0.32	6.05 $\pm$ 0.43	77.30 $\pm$ 0.52	67.00 $\pm$ 1.50	79.60 $\pm$ 0.81
S9	5.25 $\pm$ 0.20	8.85 $\pm$ 0.26	6.15 $\pm$ 0.20	71.40 $\pm$ 0.46	65.90 $\pm$ 0.40	72.70 $\pm$ 1.10
S10	7.15 $\pm$ 0.26	9.20 $\pm$ 0.35	11.15 $\pm$ 0.26	65.70 $\pm$ 0.75	74.60 $\pm$ 1.04	72.00 $\pm$ 1.39
S11	5.85 $\pm$ 0.20	9.05 $\pm$ 0.14	11.70 $\pm$ 0.23	73.30 $\pm$ 0.87	73.70 $\pm$ 1.10	70.00 $\pm$ 1.04
S12	7.05 $\pm$ 0.32	10.75 $\pm$ 0.20	10.80 $\pm$ 0.23	82.90 $\pm$ 1.33	75.50 $\pm$ 1.10	70.10 $\pm$ 1.44
S13	7.70 $\pm$ 0.17	10.65 $\pm$ 0.43	10.15 $\pm$ 0.26	73.50 $\pm$ 1.10	70.30 $\pm$ 1.21	68.80 $\pm$ 1.73
S14	5.95 $\pm$ 0.49	9.65 $\pm$ 0.32	9.20 $\pm$ 0.17	78.50 $\pm$ 0.64	77.50 $\pm$ 0.98	67.80 $\pm$ 1.50
Mean $\pm$ SE_m	6.38 $\pm$ 0.29	9.80 $\pm$ 0.36	9.36 $\pm$ 0.32	72.57 $\pm$ 0.77	76.00 $\pm$ 1.16	72.76 $\pm$ 1.11
LSD_{0.05}	0.84	1.03	0.94	2.23	3.37	3.21

Note: **S1** - Bhagya, UHS, Bhagalkot (Karnataka); **S2** - Konkan Ruchika, Dapoli (Maharashtra); **S3** – Dantiwara (Gujarat); **S4** - PAU-1, Ludhiana; **S5** - PAU-2, Ludhiana; **S6** - PAU-3, Ludhiana; **S7** - PKM-2, Tamil Nadu; **S8** - PKM-2, Tamil Nadu; **S9** - ODC-3, Tamil Nadu; **S10** - CAZRI, Jodhpur (Rajasthan); **S11** - Mandya, Karnataka; **S12** - Mysore, Karnataka; **S13** - PAU-4, Ludhiana; **S14** - PAU-5, Ludhiana (Punjab).

Table 4.8: Variability for Hemicellulose (g/100g DM) and Cellulose (g/100g DM) for different phenophases of *Moringa oleifera* seed sources

<i>Moringa</i> Sources	Hemicellulose			Cellulose		
	Tender $\pm$ SE	Mature $\pm$ SE	Twigs $\pm$ SE	Tender $\pm$ SE	Mature $\pm$ SE	Twigs $\pm$ SE
S1	11.15 $\pm$ 0.49	13.25 $\pm$ 0.09	15.00 $\pm$ 0.95	19.50 $\pm$ 0.75	21.35 $\pm$ 0.14	25.10 $\pm$ 0.81
S2	11.50 $\pm$ 0.00	10.65 $\pm$ 0.14	8.90 $\pm$ 0.00	18.35 $\pm$ 0.89	20.10 $\pm$ 0.06	24.25 $\pm$ 0.14
S3	11.85 $\pm$ 0.03	13.05 $\pm$ 0.09	11.55 $\pm$ 0.09	20.55 $\pm$ 0.43	19.95 $\pm$ 0.09	23.25 $\pm$ 0.09
S4	10.60 $\pm$ 0.29	12.60 $\pm$ 0.12	16.75 $\pm$ 0.18	19.35 $\pm$ 0.03	12.60 $\pm$ 0.81	21.90 $\pm$ 1.04
S5	10.10 $\pm$ 0.17	12.40 $\pm$ 0.06	8.85 $\pm$ 0.12	28.75 $\pm$ 0.49	17.15 $\pm$ 0.72	23.70 $\pm$ 0.00
S6	10.40 $\pm$ 0.17	16.88 $\pm$ 2.87	4.90 $\pm$ 0.98	25.55 $\pm$ 0.72	24.93 $\pm$ 2.99	26.90 $\pm$ 0.17
S7	10.80 $\pm$ 0.12	12.10 $\pm$ 0.29	13.85 $\pm$ 0.18	21.60 $\pm$ 0.17	16.00 $\pm$ 0.75	24.80 $\pm$ 0.06
S8	12.75 $\pm$ 0.03	11.10 $\pm$ 0.29	17.85 $\pm$ 0.12	16.80 $\pm$ 0.64	24.10 $\pm$ 0.12	22.10 $\pm$ 0.17
S9	12.55 $\pm$ 0.20	11.20 $\pm$ 0.35	15.60 $\pm$ 0.12	13.75 $\pm$ 0.49	23.15 $\pm$ 0.26	23.05 $\pm$ 0.84
S10	11.00 $\pm$ 0.40	12.45 $\pm$ 0.03	15.55 $\pm$ 0.07	15.60 $\pm$ 0.87	17.90 $\pm$ 0.17	24.00 $\pm$ 0.23
S11	11.60 $\pm$ 0.17	12.45 $\pm$ 0.20	9.40 $\pm$ 1.15	12.85 $\pm$ 0.32	17.05 $\pm$ 0.38	24.60 $\pm$ 0.75
S12	12.06 $\pm$ 0.20	14.15 $\pm$ 0.14	20.30 $\pm$ 1.07	13.10 $\pm$ 0.87	12.10 $\pm$ 0.81	20.70 $\pm$ 0.75
S13	12.09 $\pm$ 0.16	12.10 $\pm$ 0.00	10.55 $\pm$ 1.16	14.27 $\pm$ 0.60	16.80 $\pm$ 0.81	26.40 $\pm$ 0.87
S14	11.45 $\pm$ 0.14	14.70 $\pm$ 0.23	14.85 $\pm$ 1.10	15.30 $\pm$ 0.12	15.90 $\pm$ 0.17	23.65 $\pm$ 0.72
Mean $\pm$ SE_m	11.42 $\pm$ 0.23	12.79 $\pm$ 0.79	13.14 $\pm$ 0.71	18.24 $\pm$ 0.60	18.51 $\pm$ 0.94	23.89 $\pm$ 0.60
LSD_{0.05}	0.66	2.28	2.05	1.73	2.71	1.73

Note: **S1** - Bhagya, UHS, Bhagalkot (Karnataka); **S2** - Konkan Ruchika, Dapoli (Maharashtra); **S3** – Dantiwara (Gujarat); **S4** - PAU-1, Ludhiana; **S5** - PAU-2, Ludhiana; **S6** - PAU-3, Ludhiana; **S7** - PKM-2, Tamil Nadu; **S8** - PKM-2, Tamil Nadu; **S9** - ODC-3, Tamil Nadu; **S10** - CAZRI, Jodhpur (Rajasthan); **S11** - Mandya, Karnataka; **S12** - Mysore, Karnataka; **S13** - PAU-4, Ludhiana; **S14** - PAU-5, Ludhiana (Punjab).

Hence, best for feeding the animals. The mature leaves of moringa possessed high IVDMD content followed by twigs and tender leaves. The local seed sources were observed best for the IVDMD followed by S1 source. The values for Neutral detergent fibre (NDF), *in vitro* dry matter digestibility (IVDMD) and acid detergent fibre (ADF) observed were identical to the results of Sanchez *et al* (2006).

The hemicellulose content was estimated from the difference between neutral detergent fibre and acid detergent fibre content. It has dual functions- first, it acts as a link between lignin and cellulose fibres and secondly, it provides additional rigidity to the whole cellulose - hemicelluloses - lignin network. The highest value of hemicellulose was observed in twigs, which was followed by mature and tender leaves. The cellulose is a major component of lignocellulosic biomass and its concentration is ranged from 40-50% on dry weight basis. The maximum amount of cellulose was recorded in twigs. Mahima *et al* (2014) recorded similar results for the hemicellulose and cellulose content.

Further, tender leaves, mature leaves and twigs of *M. oleifera* recorded significant variation in digestible dry matter (DDM) and dry matter intake (DMI). ADF and NDF are used to predict the DDM and DMI, respectively. DDM is negatively correlated with ADF, whereas, DMI is negatively correlated with NDF. The tender leaves possessed highest content of both DDM and DMI because of low neutral and acid detergent fibre content. Thus, there will be a fast rate of passage through rumen, resulting gut fill which will cause increase animals to increase their uptake. The values observed are lower than the values recorded by Arif *et al* 2020. Horrocks and Vallentine (1999) also reported that where NDF is high the values for DMI are low.

Relative feed value (RFV) is an index which is used to predict intake and energy value of forage which is derived from DMD and DMI (Lithourgidis *et al* 2006). According to Horrocks and Vallentine (1999), forage with RFV value >151 is considered prime. The calculated values for RFV are identical to this result, in which tender leaves possessed highest amount of RFV content. Hence, it is assumed that tender, mature leaves along with twigs of moringa can be used as a valuable fodder. High RFV value for tender leaves suggests that harvest should be taken frequently to avoid the maturity of leaves and as a result decrease in RFV of cattle feed of moringa.

The pH value parameter is directly related to the green fodder uptake capacity. Less pH in tender leaves might be due to high amount of carbohydrates and secondary metabolites. The pH value of twigs was in between of pH of tender and mature leaves as the twigs contain mixture of tender leaves, mature leaves and apical meristem, whereas the mature leaves pH value was similar to the finding of Foline *et al* (2011). The mature leaves possessed optimum pH value for the animal consumption.

Table 4.9: Variability for DMI (g/100g DM) and DDM (g/100g DM) for different phenophases of *Moringa oleifera* seed sources

<i>Moringa</i> Sources	Dry Matter Intake			Digestible Dry Matter		
	Tender $\pm$ SE	Mature $\pm$ SE	Twigs $\pm$ SE	Tender $\pm$ SE	Mature $\pm$ SE	Twigs $\pm$ SE
S1	3.57 $\pm$ 0.01	2.94 $\pm$ 0.02	2.40 $\pm$ 0.02	71.41 $\pm$ 0.47	67.40 $\pm$ 0.31	61.56 $\pm$ 0.36
S2	3.61 $\pm$ 0.07	2.83 $\pm$ 0.03	2.90 $\pm$ 0.04	71.96 $\pm$ 0.52	64.17 $\pm$ 0.43	63.58 $\pm$ 0.40
S3	3.37 $\pm$ 0.06	3.00 $\pm$ 0.02	2.74 $\pm$ 0.01	70.40 $\pm$ 0.47	67.87 $\pm$ 0.22	63.78 $\pm$ 0.25
S4	2.93 $\pm$ 0.01	3.07 $\pm$ 0.02	2.49 $\pm$ 0.03	65.26 $\pm$ 0.38	68.22 $\pm$ 0.25	64.40 $\pm$ 0.56
S5	2.52 $\pm$ 0.03	2.91 $\pm$ 0.01	3.09 $\pm$ 0.04	59.65 $\pm$ 0.56	66.43 $\pm$ 0.20	65.57 $\pm$ 0.29
S6	3.00 $\pm$ 0.02	2.35 $\pm$ 0.01	2.92 $\pm$ 0.03	65.88 $\pm$ 0.38	62.28 $\pm$ 2.08	60.70 $\pm$ 0.40
S7	2.67 $\pm$ 0.03	3.08 $\pm$ 0.01	2.30 $\pm$ 0.02	62.30 $\pm$ 0.43	67.98 $\pm$ 0.34	59.03 $\pm$ 0.29
S8	3.53 $\pm$ 0.05	2.76 $\pm$ 0.05	2.61 $\pm$ 0.02	72.35 $\pm$ 0.38	63.62 $\pm$ 0.34	66.97 $\pm$ 0.20
S9	3.81 $\pm$ 0.06	2.78 $\pm$ 0.01	2.68 $\pm$ 0.03	74.10 $\pm$ 0.54	63.97 $\pm$ 0.40	66.15 $\pm$ 0.49
S10	3.56 $\pm$ 0.02	3.04 $\pm$ 0.04	2.37 $\pm$ 0.03	71.18 $\pm$ 0.47	67.79 $\pm$ 0.40	61.52 $\pm$ 0.38
S11	3.96 $\pm$ 0.05	3.11 $\pm$ 0.03	2.63 $\pm$ 0.04	74.33 $\pm$ 0.40	68.57 $\pm$ 0.18	60.62 $\pm$ 0.40
S12	3.73 $\pm$ 0.09	3.24 $\pm$ 0.04	2.32 $\pm$ 0.02	73.21 $\pm$ 0.43	71.10 $\pm$ 0.47	64.36 $\pm$ 0.40
S13	3.52 $\pm$ 0.03	3.03 $\pm$ 0.03	2.55 $\pm$ 0.03	71.79 $\pm$ 0.33	67.52 $\pm$ 0.29	60.43 $\pm$ 0.47
S14	3.67 $\pm$ 0.06	2.98 $\pm$ 0.02	2.52 $\pm$ 0.03	72.35 $\pm$ 0.29	69.00 $\pm$ 0.38	63.31 $\pm$ 0.43
Mean $\pm$ SE_m	3.39 $\pm$ 0.05	2.94 $\pm$ 0.03	2.61 $\pm$ 0.03	69.72 $\pm$ 0.44	66.85 $\pm$ 0.64	63.00 $\pm$ 0.39
LSD_{0.05}	0.14	0.08	0.08	1.27	1.87	1.14

Note: **S1** - Bhagya, UHS, Bhagalkot (Karnataka); **S2** - Konkan Ruchika, Dapoli (Maharashtra); **S3** – Dantiwara (Gujarat); **S4** - PAU-1, Ludhiana; **S5** - PAU-2, Ludhiana; **S6** - PAU-3, Ludhiana; **S7** - PKM-2, Tamil Nadu; **S8** - PKM-2, Tamil Nadu; **S9** - ODC-3, Tamil Nadu; **S10** - CAZRI, Jodhpur (Rajasthan); **S11** - Mandya, Karnataka; **S12** - Mysore, Karnataka; **S13** - PAU-4, Ludhiana; **S14** - PAU-5, Ludhiana (Punjab).

Table 4.10: Variability for RFV (g/100g DM) and pH of different phenophases of *Moringa oleifera* seed sources

<i>Moringa</i> Sources	Relative Feed Value			pH		
	Tender $\pm$ SE	Mature $\pm$ SE	Twigs $\pm$ SE	Tender $\pm$ SE	Mature $\pm$ SE	Twigs $\pm$ SE
S1	197.72 $\pm$ 1.99	153.51 $\pm$ 1.91	114.31 $\pm$ 0.47	5.40 $\pm$ 0.03	6.04 $\pm$ 0.03	6.24 $\pm$ 0.02
S2	201.53 $\pm$ 5.47	140.82 $\pm$ 2.28	142.93 $\pm$ 2.70	5.52 $\pm$ 0.02	6.35 $\pm$ 0.02	6.14 $\pm$ 0.02
S3	184.11 $\pm$ 4.52	157.65 $\pm$ 1.32	135.46 $\pm$ 1.24	5.45 $\pm$ 0.02	6.21 $\pm$ 0.02	5.98 $\pm$ 0.04
S4	148.26 $\pm$ 1.60	162.10 $\pm$ 1.42	124.34 $\pm$ 2.50	5.44 $\pm$ 0.02	5.98 $\pm$ 0.03	5.69 $\pm$ 0.02
S5	116.50 $\pm$ 2.44	149.81 $\pm$ 1.19	157.26 $\pm$ 2.69	5.26 $\pm$ 0.02	6.11 $\pm$ 0.02	5.88 $\pm$ 0.02
S6	153.44 $\pm$ 2.11	113.46 $\pm$ 3.34	137.40 $\pm$ 0.63	5.30 $\pm$ 0.02	6.12 $\pm$ 0.02	5.98 $\pm$ 0.03
S7	128.96 $\pm$ 2.13	162.37 $\pm$ 1.41	105.21 $\pm$ 1.63	5.95 $\pm$ 0.02	6.59 $\pm$ 0.02	6.11 $\pm$ 0.02
S8	198.04 $\pm$ 3.74	135.99 $\pm$ 2.98	135.45 $\pm$ 1.52	5.73 $\pm$ 0.02	6.30 $\pm$ 0.02	5.66 $\pm$ 0.02
S9	218.63 $\pm$ 4.99	137.76 $\pm$ 1.42	137.42 $\pm$ 2.62	5.90 $\pm$ 0.02	6.45 $\pm$ 0.02	6.10 $\pm$ 0.02
S10	196.21 $\pm$ 2.48	159.53 $\pm$ 3.17	112.91 $\pm$ 1.92	5.45 $\pm$ 0.02	6.20 $\pm$ 0.02	5.97 $\pm$ 0.01
S11	228.30 $\pm$ 3.85	165.51 $\pm$ 2.29	123.42 $\pm$ 0.89	5.40 $\pm$ 0.02	6.40 $\pm$ 0.03	6.12 $\pm$ 0.02
S12	211.78 $\pm$ 6.18	178.84 $\pm$ 3.42	115.58 $\pm$ 0.51	5.11 $\pm$ 0.02	6.01 $\pm$ 0.03	5.81 $\pm$ 0.02
S13	196.16 $\pm$ 2.40	158.84 $\pm$ 2.20	119.35 $\pm$ 0.47	5.81 $\pm$ 0.01	6.12 $\pm$ 0.02	5.90 $\pm$ 0.02
S14	205.94 $\pm$ 4.11	159.49 $\pm$ 1.91	123.47 $\pm$ 0.60	6.25 $\pm$ 0.01	6.36 $\pm$ 0.02	6.08 $\pm$ 0.03
Mean $\pm$ SE_m	184.68 $\pm$ 3.71	152.55 $\pm$ 2.29	127.47 $\pm$ 1.69	5.57 $\pm$ 0.02	6.23 $\pm$ 0.02	5.98 $\pm$ 0.02
LSD_{0.05}	10.74	6.64	4.90	0.06	0.07	0.06

Note: **S1** - Bhagya, UHS, Bhagalkot (Karnataka); **S2** - Konkan Ruchika, Dapoli (Maharashtra); **S3** – Dantiwara (Gujarat); **S4** - PAU-1, Ludhiana; **S5** - PAU-2, Ludhiana; **S6** - PAU-3, Ludhiana; **S7** - PKM-2, Tamil Nadu; **S8** - PKM-2, Tamil Nadu; **S9** - ODC-3, Tamil Nadu; **S10** - CAZRI, Jodhpur (Rajasthan); **S11** - Mandya, Karnataka; **S12** - Mysore, Karnataka; **S13** - PAU-4, Ludhiana; **S14** - PAU-5, Ludhiana (Punjab).

4.3 Anti-Nutritional Characteristics

4.3.1 Total Phenols

The recorded data for total phenols of tender leaves, mature leaves and twigs of 14 seed sources of *M. oleifera* presented in Table 4.11 showed significant variations among the seed sources. The mean values of total phenols for tender leaves ranged from 7.63-12.76 mg/g. Seed source S2 registered maximum mean value (12.76 mg/g) which was followed by S3 (12.16 mg/g), S11 (11.53 mg/g) and S7 (11.11 mg/g). However, minimum mean value (7.63 mg/g) was recorded in S1. The mean value for mature leaves ranged from 6.37-11.05 mg/g. The highest mean value was recorded in seed source S11 (11.05 mg/g) succeeded by S5 (9.62 mg/g), S3 (9.28 mg/g), S2 (9.23 mg/g) and S13 (9.23 mg/g), where as minimum mean value was noticed in S8 (6.37 mg/g). The average value for twigs varied from 5.12-10.24 mg/g. The seed source S6 (10.24 mg/g) showed largest mean value which was followed by S4 (9.03 mg/g), S5 (8.53 mg/g) and S10 (7.99 mg/g) and the minimum mean value was showed by seed source S3 (5.12 mg/g).

4.3.2 Flavonoids

The mean values of flavonoids for tender leaves ranged from 0.58-3.56 mg/g (Table 4.11). Source S7 registered maximum mean value (3.56 mg/g) followed by S3 (3.05 mg/g), S11 (2.48 mg/g) and S9 (2.33 mg/g), whereas, minimum mean value was observed in S6 (0.58 mg/g). The norm value for mature leaves ranged from 0.60-2.47 mg/g. The largest mean value was recorded in seed source S6 (2.47 mg/g) succeeded by S5 (2.31 mg/g), S7 (2.11 mg/g) and S8 (1.73 mg/g), where as minimum mean value was noticed in S12 (0.60 mg/g). The average value for twigs lied between 0.47-1.90 mg/g. The seed source S11 (1.90 mg/g) showed highest mean value which was followed by S2 (1.48 mg/g), S8 (1.37 mg/g) and S3 (1.34 mg/g) and the minimum mean value was seen in seed source S6 (0.47 mg/g).

4.3.3 Tannins

The recorded data for tannins of tender leaves, mature leaves and twigs of 14 seed sources of *M. oleifera* are included in Table 4.12 which showed significant difference among the seed sources. The mean value of tannins for tender leaves varied from 91.18-121.77 µg/g. The highest value was recorded in S2 (121.77 µg/g) which was at par with S11 (121.62 µg/g), whereas the lowest mean value was observed in S5 (91.18 µg/g). The average value for mature leaves lied between 114.12-154.71 µg/g in which the minimum value was seen in seed source S10 (114.12 µg/g) and the most in S2 (154.71 µg/g) and it was at par with seed source S7 (152.95 µg/g). The range for twigs recorded was 55.88-91.77 µg/g. The maximum value was observed in S9 (91.77) followed by S14 (87.06 µg/g), S1 (85.30 µg/g) and S12 (82.41 µg/g). However, minimum mean value (55.88 µg/g) was registered in S7 source.

4.3.4 Saponins

The saponin content for tender leaves ranged from 27.28-49.61 µg/g (Table 4.12). The highest mean value was registered in S3 (49.61 µg/g) which was at par with seed source S13 (49.51 µg/g). However the least mean value (27.28 µg/g) was possessed by S5. The mature leaves registered the largest mean value in seed source S2 (63.85 µg/g) followed by S13 (61.55 µg/g), S10 (59.10 µg/g) and S3 (54.63 µg/g). The mean values for mature leaves ranged from 44.07-63.85 µg/g. However, minimum mean value (44.07 µg/g) was observed in S11. The average value recorded for twigs ranged from 24.40-50.69 µg/g. The seed source S6 possessed minimum mean value (24.40 µg/g) and S10 had maximum mean value (50.69 µg/g) for twigs followed by S2 (48.99 µg/g), S3 (48.86 µg/g) and S12 (47.70 µg/g).

4.3.5 Nitrate

The recorded data for nitrate and oxalate of tender leaves, mature leaves and twigs of 14 seed sources of *M. oleifera* are included in Table 4.13 which showed significant difference among the seed sources. The mean values of nitrate for tender leaves ranged from 435.50-3198.00 µg/g. The seed source S9 registered maximum mean value (3198.00 µg/g) followed by S8 (2769.00 µg/g), S4 (2028.00 µg/g) and S7 (1261.00 µg/g). However, minimum mean value (435.50 µg/g) was recorded in S13. The mean value for mature leaves ranged from 910.00-3718.00 µg/g. The highest mean value was recorded in seed source S13 (3718.00 µg/g) succeeded by S10 (3042.00 µg/g), S8 (2866.50 µg/g) and S9 (2522.00 µg/g), where as minimum mean value was noticed in S5 (910.00 ppm). The average value for twigs varied from 793.00-2970.50 µg/g. The seed source S1 (2970.50 µg/g) showed largest mean value which was followed by S4 (2424.50 µg/g), S2 (2223.00 µg/g) and S3 (2125.50 µg/g) and the minimum mean value was showed by source S11 (793.00 µg/g).

4.3.6 Oxalate

The mean value for oxalate for tender leaves varied from 1.69-4.16% (Table 4.13). The highest value was recorded in S5 (4.16%) followed by S6 (3.66%), S14 (3.37%) and S10 (3.04%), whereas the lowest mean value was observed in S7 (1.69%). The average value for mature leaves lied between 1.29-3.38% in which the minimum value was seen in seed source S3 (1.29%) and the most in S7 (3.38%) which was followed by S14 (3.09%), S8 (2.98%) and S13 (2.53%). The norm value for twigs ranged from 1.12-2.42%. The maximum value was observed in S14 (2.42%), succeeded by S6 (2.08%), S12 (1.92%), S 4 (1.86%) and S13 (1.86%). However, minimum value was recorded in S10 (1.12%).

Antinutrients may be regarded as a class of compounds, which are generally not lethal and considered as anti-oxidents if they are within the limits. Most of antinutrients are used in the cure or control of diseases. They diminish animal productivity but may also cause toxicity during periods of scarcity or confinement when the feed rich in these substances is consumed

by animals in large quantities. It is important to note that the amounts of anti-nutrients in moringa are generally low and do not constitute any health risks to animal or human consumers (Nouman *et al* 2013). It would appear that the lower the quantities of these anti-nutrients, the better.

Phenolic compounds are important plant constituents with redox properties responsible for antioxidant activity. The hydroxyl groups in plant extracts are responsible for facilitating free radical scavenging. The total phenol content (mg/g) is lowest in twigs and highest in tender leaves. Mohammed and Manan (2015) reported values for the total phenol content which were identical to our finding. Flavonoids consist of a large group of polyphenolic secondary metabolic compounds, present in cell vacuoles of plants and their accumulation in plants is directly related to nutrient deficiency, reactive oxygen species (ROS) production and metal toxicity. The level of the flavonoids is least in twigs of moringa leaves and very low in tender and mature leaves. The flavonoids content in present results were less than the results recorded by Stevens *et al* (2015).

Tannins are water soluble phenolic compounds with molecular weight greater than 500. Tannins have a property of binding to protein to form reversible and irreversible complexes due to the existence of a number of phenolic hydroxyl groups. Feeding tannin rich forage, tannin protein complexes can reduce the digestion of forage protein. Tannins directly affect digestibility of cell wall by binding with microbial enzyme in the rumen. The reduced digestibility of cell wall compounds restricts the digestible energy that animal gain from forage plants (Kumar *et al* 2017). Tannin content was lowest in twigs. Dietary tannins are said to reduce feed efficiency and gain weight in chicks (Die *et al* 2007). Saponins are glycosides containing a polycyclic aglycone moiety of either C₂₇ steroid or C₃₀ triterpenoid (collectively termed as sapogenins) attached to a carbohydrate. Saponins are characterized by a bitter taste and foaming properties. Saponins for instance, confer bitter taste on moringa without any harmful effects (Makkar and Becker 1996). Saponins reduce the uptake of certain nutrients including glucose and cholesterol at the gut through intra-luminal physicochemical interaction (Kumar *et al* 2017). The content in tender leaves and twigs are low. These present results are identical to the results of Stevens *et al* 2015.

Nitrate is the form of nitrogen that the plant roots take up from the soil, and is transported to the leaves. When livestock consume forages, nitrate is normally converted in the rumen from nitrate - nitrite - ammonia - amino acid to protein. When forages have an unusually high concentration of nitrate, the animal cannot complete the conversion and nitrite accumulates. Nitrite is absorbed into the blood stream directly through the rumen wall and converts haemoglobin (the oxygen carrying molecule) in the blood to met haemoglobin, which cannot carry oxygen. The blood turns to a chocolate brown colour rather than the usual

bright red. An animal dying from nitrate (nitrite) poisoning actually dies from asphyxiation, or lack of oxygen. The nitrate content was least in tender leaves and highest in mature leaves. The nitrate level 0-1500 ppm was considered to be safe for feeding animals (Kumar *et al* 2017) which was good in tender leaves and twigs part.

Oxalate is an anti quality nutrient which under normal conditions is confined to separate places. However, when it is processed and/or digested, it comes into contact with the nutrients in the gastrointestinal tract. After released, oxalic acid binds with nutrients, rendering them inaccessible to the body. If feed with excessive amounts of oxalic acid is consumed regularly, nutritional deficiencies are likely to occur, as well as severe irritation to the lining of the gut (Kumar *et al* 2017). Oxalate salts normally result from a chemical combination between oxalic acid and a particular mineral such as Ca, Mg or Na (Noonan and Savage 1999). According to these authors (Noonan and Savage, 1999), soluble oxalates can cause kidney stones in humans and livestock. Noonan and Savage (1999) and Radek and Savage (2008) did a comparative study of the amount of oxalates present in moringa leaf and reported comparatively lower values of oxalates in the former, which were all in the insoluble form. The result were similar to their findings i.e < 3%. Stevens *et al* (2015) also recorded lowest content for oxalate content.

4.3 Mineral composition

4.3.1 Nitrogen (N)

The recorded data for Nitrogen of tender leaves and mature leaves of 14 seed sources of *M.oleifera* are presented in Table 4.14 which showed significant variability for all seed sources. The mean values of nitrogen for tender leaves ranged from 14272.00-35552.00 (mg/kg). Seed source S12 registered maximum mean value (35552.00 (mg/kg)) followed by S9 (31776.00 (mg/kg)), S10 (29816.00 (mg/kg)) and S7 (27856.00 (mg/kg)). However, minimum mean value (14272.00 (mg/kg)) was recorded in S5. The mean value for mature leaves ranged from 30656.00-45920.00 (mg/kg). Highest mean value was recorded in seed source S9 (45920.00 (mg/kg)) at par with S12 (44936.00 (mg/kg)), where as minimum mean value was noticed in S14 (30656.00 (mg/kg)).

4.3.2 Phosphorous (P)

The Phosphorous content for tender leaves ranged from 1040.00-2590.00 mg/kg (Table 4.14). The highest mean value was registered in S8 (2590.00 mg/kg) which was at par with seed source S3 (2534.00 mg/kg). However the least mean value (1040.00 mg/kg) was possessed by S14. The mature leaves registered the largest mean value in seed source S2 (2557.00 mg/kg) followed by S5 (2425.00 mg/kg), S12 (2378.00 mg/kg) and S3 (2279.00 mg/kg). The average values for mature leaves ranged from 1533.00-2557.00 mg/kg with lowest amount (1533.00 mg/kg) in S13.

Table 4.11: Variability for Total Phenols (mg/g) and Flavonoids (mg/g) for different phenophases of *Moringa oleifera* seed sources

<i>Moringa</i> Sources	Total Phenols			Flavonoids		
	Tender $\pm$ SE	Mature $\pm$ SE	Twigs $\pm$ SE	Tender $\pm$ SE	Mature $\pm$ SE	Twigs $\pm$ SE
S1	7.63 $\pm$ 0.01	6.71 $\pm$ 0.02	7.71 $\pm$ 0.01	1.07 $\pm$ 0.00	0.91 $\pm$ 0.00	0.64 $\pm$ 0.00
S2	12.76 $\pm$ 0.02	9.23 $\pm$ 0.01	7.29 $\pm$ 0.01	0.96 $\pm$ 0.00	1.21 $\pm$ 0.00	1.48 $\pm$ 0.01
S3	12.16 $\pm$ 0.02	9.28 $\pm$ 0.01	5.12 $\pm$ 0.01	3.05 $\pm$ 0.01	1.00 $\pm$ 0.00	1.34 $\pm$ 0.00
S4	9.81 $\pm$ 0.01	8.63 $\pm$ 0.01	9.03 $\pm$ 0.01	1.68 $\pm$ 0.01	0.92 $\pm$ 0.00	1.03 $\pm$ 0.00
S5	10.64 $\pm$ 0.01	9.62 $\pm$ 0.01	8.53 $\pm$ 0.01	0.71 $\pm$ 0.00	2.31 $\pm$ 0.00	0.54 $\pm$ 0.00
S6	9.77 $\pm$ 0.05	8.60 $\pm$ 0.02	10.24 $\pm$ 0.01	0.58 $\pm$ 0.00	2.47 $\pm$ 0.00	0.47 $\pm$ 0.00
S7	11.11 $\pm$ 0.01	6.60 $\pm$ 0.02	6.35 $\pm$ 0.01	3.56 $\pm$ 0.00	2.11 $\pm$ 0.00	1.31 $\pm$ 0.01
S8	8.21 $\pm$ 0.02	6.37 $\pm$ 0.09	7.02 $\pm$ 0.01	0.89 $\pm$ 0.00	1.73 $\pm$ 0.00	1.37 $\pm$ 0.00
S9	9.38 $\pm$ 0.01	7.66 $\pm$ 0.01	7.86 $\pm$ 0.01	2.33 $\pm$ 0.00	1.17 $\pm$ 0.00	0.81 $\pm$ 0.00
S10	9.96 $\pm$ 0.02	6.65 $\pm$ 0.02	7.99 $\pm$ 0.01	1.87 $\pm$ 0.01	1.05 $\pm$ 0.00	0.55 $\pm$ 0.01
S11	11.53 $\pm$ 0.01	11.05 $\pm$ 0.02	7.55 $\pm$ 0.01	2.48 $\pm$ 0.01	0.89 $\pm$ 0.00	1.90 $\pm$ 0.00
S12	10.18 $\pm$ 0.00	8.79 $\pm$ 0.01	7.88 $\pm$ 0.01	1.04 $\pm$ 0.00	0.60 $\pm$ 0.00	0.68 $\pm$ 0.00
S13	10.61 $\pm$ 0.01	9.23 $\pm$ 0.01	7.33 $\pm$ 0.01	1.08 $\pm$ 0.01	0.66 $\pm$ 0.00	0.58 $\pm$ 0.00
S14	9.50 $\pm$ 0.02	8.72 $\pm$ 0.01	6.79 $\pm$ 0.01	1.59 $\pm$ 0.00	0.98 $\pm$ 0.00	0.76 $\pm$ 0.00
Mean $\pm$ SE_m	10.23 $\pm$ 0.02	8.37 $\pm$ 0.03	7.62 $\pm$ 0.01	1.63 $\pm$ 0.00	1.28 $\pm$ 0.00	0.96 $\pm$ 0.00
LSD_{0.05}	0.05	0.08	0.04	0.01	0.01	0.01

Note: **S1** - Bhagya, UHS, Bhagalkot (Karnataka); **S2** - Konkan Ruchika, Dapoli (Maharashtra); **S3** – Dantiwara (Gujarat); **S4** - PAU-1, Ludhiana; **S5** - PAU-2, Ludhiana; **S6** - PAU-3, Ludhiana; **S7** - PKM-2, Tamil Nadu; **S8** - PKM-2, Tamil Nadu; **S9** - ODC-3, Tamil Nadu; **S10** - CAZRI, Jodhpur (Rajasthan); **S11** - Mandya, Karnataka; **S12** - Mysore, Karnataka; **S13** - PAU-4, Ludhiana; **S14** - PAU-5, Ludhiana (Punjab).

Table 4.12: Variability for Tannins (µg/g) and Saponins (µg/g) for different phenophases of *Moringa oleifera* seed sources

<i>Moringa</i> Sources	Tannins			Saponins		
	Tender ± SE	Mature ± SE	Twigs ± SE	Tender ± SE	Mature ± SE	Twigs ± SE
S1	111.18 ± 1.02	141.77 ± 1.02	85.30 ± 1.02	44.22 ± 0.10	50.89 ± 0.08	36.68 ± 0.06
S2	121.77 ± 1.02	154.71 ± 0.34	60.00 ± 0.68	37.02 ± 0.10	63.85 ± 0.07	48.99 ± 0.08
S3	100.59 ± 1.02	128.83 ± 1.02	65.30 ± 1.02	49.61 ± 0.08	54.63 ± 0.08	48.86 ± 0.08
S4	97.06 ± 1.02	132.36 ± 1.02	75.88 ± 1.02	38.04 ± 0.10	45.94 ± 0.08	24.90 ± 0.08
S5	91.18 ± 1.02	122.36 ± 0.68	73.53 ± 1.02	27.28 ± 0.12	47.50 ± 0.08	32.16 ± 0.04
S6	106.47 ± 1.02	136.48 ± 1.36	82.36 ± 0.68	29.52 ± 0.12	51.23 ± 0.07	24.40 ± 0.06
S7	108.83 ± 1.02	152.95 ± 0.68	55.88 ± 1.02	42.01 ± 0.08	53.21 ± 0.08	28.63 ± 0.04
S8	94.71 ± 1.02	125.30 ± 1.02	72.36 ± 1.02	38.92 ± 0.10	45.64 ± 0.10	36.50 ± 0.08
S9	111.77 ± 0.68	131.18 ± 1.02	91.77 ± 0.68	44.16 ± 0.33	44.62 ± 0.06	39.08 ± 0.08
S10	105.30 ± 1.02	114.12 ± 0.68	70.00 ± 1.02	37.36 ± 0.06	59.10 ± 0.09	50.69 ± 0.08
S11	121.62 ± 0.42	148.83 ± 1.02	67.65 ± 1.02	36.89 ± 0.10	44.07 ± 0.06	43.36 ± 0.08
S12	114.71 ± 1.02	142.36 ± 0.68	82.41 ± 1.33	42.42 ± 0.08	49.30 ± 0.10	47.70 ± 0.08
S13	118.82 ± 1.36	136.47 ± 0.68	81.18 ± 0.68	49.51 ± 0.06	61.55 ± 0.08	46.14 ± 0.04
S14	131.18 ± 1.02	146.47 ± 1.02	87.06 ± 0.68	47.27 ± 0.06	53.03 ± 0.09	47.41 ± 0.64
Mean ± SE_m	109.65 ± 1.00	136.72 ± 0.91	75.05 ± 0.94	40.30 ± 0.12	51.75 ± 0.08	39.68 ± 0.18
LSD_{0.05}	2.88	2.63	2.72	0.36	0.24	0.53

Note: **S1** - Bhagya, UHS, Bhagalkot (Karnataka); **S2** - Konkan Ruchika, Dapoli (Maharashtra); **S3** – Dantiwara (Gujarat); **S4** - PAU-1, Ludhiana; **S5** - PAU-2, Ludhiana; **S6** - PAU-3, Ludhiana; **S7** - PKM-2, Tamil Nadu; **S8** - PKM-2, Tamil Nadu; **S9** - ODC-3, Tamil Nadu; **S10** - CAZRI, Jodhpur (Rajasthan); **S11** - Mandya, Karnataka; **S12** - Mysore, Karnataka; **S13** - PAU-4, Ludhiana; **S14** - PAU-5, Ludhiana (Punjab).

Table 4.13: Variability for Nitrate ($\mu\text{g/g}$) and Oxalate (%) for different phenophases of *Moringa oleifera* seed sources

<i>Moringa</i> Sources	Nitrate			Oxalate		
	Tender $\pm$ SE	Mature $\pm$ SE	Twigs $\pm$ SE	Tender $\pm$ SE	Mature $\pm$ SE	Twigs $\pm$ SE
S1	942.50 $\pm$ 11.26	1105.00 $\pm$ 7.51	2970.50 $\pm$ 11.26	1.91 $\pm$ 0.06	1.86 $\pm$ 0.03	1.52 $\pm$ 0.03
S2	1222.00 $\pm$ 7.51	1950.00 $\pm$ 7.51	2223.00 $\pm$ 7.51	2.70 $\pm$ 0.13	1.52 $\pm$ 0.03	1.29 $\pm$ 0.03
S3	1209.00 $\pm$ 7.51	1942.50 $\pm$ 3.75	2125.50 $\pm$ 11.26	2.36 $\pm$ 0.13	1.29 $\pm$ 0.03	1.52 $\pm$ 0.03
S4	2028.00 $\pm$ 7.51	1547.00 $\pm$ 7.51	2424.50 $\pm$ 11.26	2.64 $\pm$ 0.16	1.35 $\pm$ 0.06	1.86 $\pm$ 0.03
S5	559.00 $\pm$ 15.01	910.00 $\pm$ 7.51	929.50 $\pm$ 11.26	4.16 $\pm$ 0.13	1.74 $\pm$ 0.03	1.41 $\pm$ 0.03
S6	721.50 $\pm$ 11.26	1521.00 $\pm$ 7.51	806.00 $\pm$ 7.51	3.66 $\pm$ 0.10	2.03 $\pm$ 0.07	2.08 $\pm$ 0.03
S7	1261.00 $\pm$ 7.51	2301.00 $\pm$ 7.51	1404.00 $\pm$ 7.51	1.69 $\pm$ 0.06	3.38 $\pm$ 0.07	1.41 $\pm$ 0.03
S8	2769.00 $\pm$ 7.51	2866.50 $\pm$ 3.75	1995.50 $\pm$ 3.75	2.02 $\pm$ 0.03	2.98 $\pm$ 0.06	1.63 $\pm$ 0.03
S9	3198.00 $\pm$ 7.51	2522.00 $\pm$ 7.51	1456.00 $\pm$ 7.51	1.91 $\pm$ 0.03	2.08 $\pm$ 0.06	1.24 $\pm$ 0.06
S10	1196.00 $\pm$ 7.51	3042.00 $\pm$ 7.51	1371.50 $\pm$ 11.26	3.04 $\pm$ 0.07	1.63 $\pm$ 0.03	1.12 $\pm$ 0.06
S11	552.50 $\pm$ 11.26	1501.50 $\pm$ 3.75	793.00 $\pm$ 7.51	2.65 $\pm$ 0.10	1.97 $\pm$ 0.03	1.52 $\pm$ 0.03
S12	1131.00 $\pm$ 7.51	1592.50 $\pm$ 11.26	1170.00 $\pm$ 7.51	2.47 $\pm$ 0.06	2.14 $\pm$ 0.07	1.92 $\pm$ 0.07
S13	435.50 $\pm$ 11.26	3718.00 $\pm$ 7.51	897.00 $\pm$ 7.51	2.76 $\pm$ 0.03	2.53 $\pm$ 0.03	1.86 $\pm$ 0.03
S14	1014.00 $\pm$ 7.51	1358.50 $\pm$ 11.26	1066.00 $\pm$ 7.51	3.37 $\pm$ 0.00	3.09 $\pm$ 0.03	2.42 $\pm$ 0.03
Mean $\pm$ SE_m	1302.79 $\pm$ 9.41	1991.25 $\pm$ 7.57	1545.14 $\pm$ 8.86	2.87 $\pm$ 0.09	1.91 $\pm$ 0.05	1.63 $\pm$ 0.04
LSD_{0.05}	27.26	21.94	25.66	0.26	0.14	0.12

Note: **S1** - Bhagya, UHS, Bhagalkot (Karnataka); **S2** - Konkan Ruchika, Dapoli (Maharashtra); **S3** – Dantiwara (Gujarat); **S4** - PAU-1, Ludhiana; **S5** - PAU-2, Ludhiana; **S6** - PAU-3, Ludhiana; **S7** - PKM-2, Tamil Nadu; **S8** - PKM-2, Tamil Nadu; **S9** - ODC-3, Tamil Nadu; **S10** - CAZRI, Jodhpur (Rajasthan); **S11** - Mandya, Karnataka; **S12** - Mysore, Karnataka; **S13** - PAU-4, Ludhiana; **S14** - PAU-5, Ludhiana (Punjab).

4.3.3 Potassium (K)

The mean value of potassium for tender leaves ranged from 6588.00-21721.00 mg/kg (Table 4.14). The highest value was recorded in S6 (21721.00 mg/kg) followed by S8 (13501.00 mg/kg), S1 (13197.00 mg/kg) and S3 (11099.00 mg/kg), whereas the lowest mean value was observed in S14 (6588.00 mg/kg). The average value for mature leaves lied between 9859.00-16929.00 mg/kg in which the minimum value was seen in seed source S11 (9859.00 mg/kg) and the most in S14 (16929.00 mg/kg) which was followed by S1 (15050.00 mg/kg), S5 (13445.00 mg/kg) and S3 (13256.00 mg/kg).

4.3.4 Calcium (Ca)

The recorded data for calcium of tender leaves and mature leaves of 14 seed sources of *M. oleifera* are included in Table 4.15 which showed significant difference for all seed sources. The average value registered for tender leaves ranged from 964.00-3437.00 mg/kg. The maximum value was recorded in seed source S6 (3437.00 mg/kg) which was succeeded by S14 (2873.0 mg/kg), S1 (1698.00 mg/kg) and S7 (1659.00 mg/kg). S4 (964.00 mg/kg) showed the lowest amount of calcium. The mature leaves possessed largest mean value in S13 (3343.00 mg/kg) followed by S11 (2441.00 mg/kg), S14 (2184.00 mg/kg) and S1 (2067.00 mg/kg). The mean values varied from 1513.00-3343.00 mg/kg and the minimum value noticed in S7 seed source (1513.00 mg/kg).

4.3.5 Magnesium (Mg)

The mean values of magnesium for tender leaves ranged from 2241.00-6638.00 mg/kg (Table 4.15). Seed source S6 registered maximum mean value (6638.00 mg/kg) followed by S14 (5627.00 mg/kg), S3 (4151.00 mg/kg) and S3 (3914.00 mg/kg). However, minimum mean value (2241.00 mg/kg) was recorded in S4. The average value for mature leaves ranged from 3109.00-4903.00 mg/kg. The highest mean value was recorded in seed source S11 (4903.00 mg/kg) succeeded by S9 (4553.00 mg/kg), S3 (4326.00 mg/kg) and S13 (4261.00 mg/kg), where as minimum mean value was noticed in S7 (3109.00 mg/kg).

4.3.6 Sulphur (S)

The recorded data for sulphur of tender leaves and mature leaves of 14 seed sources of *M. oleifera* are included in Table 4.16 which showed significant variations for all seed sources. The mean value for sulphur for tender leaves varied from 3356.00-9675.00 (mg/kg). The highest value was recorded in S6 (9675.00 (mg/kg)) followed by S8 (8806.00 (mg/kg)), S3 (8615.00 (mg/kg)) and S12 (7660.00 (mg/kg)), whereas the lowest mean value was observed in S14 (3536.00 (mg/kg)). The average value for mature leaves lied between 5825.00-9716.00 (mg/kg) in which the minimum value was seen in seed source S13 (5825.00 (mg/kg)) and the most in S2 (9716.00 (mg/kg)) succeeded by S12 (9036.00 (mg/kg)), S3 (8660.00 (mg/kg)) and S6 (8504.00 (mg/kg)).

4.3.7 Iron (Fe)

The norm values of iron for tender leaves ranged from 201.00-778.00 mg/kg (Table 4.16). Seed source S6 recorded highest mean value (778.00 mg/kg) followed by S1 (452.00 mg/kg), S8 (356.00 mg/kg) and S11 (322.00 mg/kg). However, lowest mean value (201.00 mg/kg) was recorded in S4. The mean value for mature leaves ranged from 258.00-736.00 mg/kg. The maximum average value was recorded in seed source S11 (736.00 mg/kg) succeeded by S14 (561.00 mg/kg), S1 (528.00 mg/kg) and S4 (515.00 mg/kg), where as minimum mean value was observed in S7 (258.00 mg/kg).

4.3.8 Sodium (Na)

The recorded data for sodium of tender leaves and mature leaves of 14 seed sources of *M. oleifera* are included in Table 4.17 which showed significant difference among all the seed sources. The average value registered for tender leaves ranged from 331.00-892.00 mg/kg. The highest value was recorded in S14 (892.00 mg/kg) which was at par with S12 (859.00 mg/kg). The seed source S5 (331.00 mg/kg) showed the lowest amount of sodium content. The mature leaves possessed maximum mean value in S11 (1476.00 mg/kg) followed by S8 (1124.00 mg/kg), S2 (949.00 mg/kg) and S6 (941.00 mg/kg). The mean values varied from 373.00-1476.00 mg/kg and the minimum value noticed in S13 (373.00 mg/kg).

4.3.9 Boron (B)

The mean values of boron for tender leaves ranged from 21.21-63.99 mg/kg (Table 4.17). Seed source S6 recorded maximum mean value (63.99 mg/kg) followed by S11 (36.14 mg/kg), S1 (35.24 mg/kg) and S14 (34.73 mg/kg). However, minimum mean value (21.21 mg/kg) was recorded in S7. The average value for mature leaves ranged from 31.21-51.39 mg/kg. The highest mean value was registered in S8 (51.39 mg/kg) followed by S13 (49.15 mg/kg), S1 (48.33 mg/kg) and S2 (47.87 mg/kg), whereas least mean value was noticed in S3 (31.21 mg/kg).

4.3.10 Manganese (Mn)

The norm values of manganese for tender leaves ranged from 14.52-58.45 mg/kg (Table 4.17). The largest mean value (58.45 mg/kg) was observed in S6 followed by S14 (49.05 mg/kg), S3 (29.45 mg/kg) and S1 (29.43 mg/kg). However, minimum mean value (14.52 mg/kg) was recorded in S4. The mean value for mature leaves ranged from 20.94-44.18 mg/kg. The highest mean value was recorded in seed source S14 (44.18 mg/kg) succeeded by S11 (42.30 mg/kg), S2 (32.19 mg/kg) and S4 (31.32 mg/kg), whereas least mean value was noticed in S7 (20.94 mg/kg).

4.3.11 Nickel (Ni)

The recorded data for nickel of tender leaves and mature leaves of 14 seed sources of *M. oleifera* are included in Table 4.18 which showed significant variability among all the seed

sources. The norm values of nickel for tender leaves ranged from 0.67-3.16 mg/kg. Seed source S6 registered maximum mean value (3.16 mg/kg) followed by S2 (1.87 mg/kg), S1 (1.77 mg/kg) and S7 (1.56 mg/kg). However, minimum mean value (0.67 mg/kg) was recorded in S11. The average value for mature leaves varied from 0.67-1.97 mg/kg. The least value was observed in S10 (0.67 mg/kg) and the most value in S4 (1.97 mg/kg) succeeded by S1 (1.82 mg/kg), S14 (1.63 mg/kg) and S2 (1.61 mg/kg).

4.3.12 Copper (Cu)

The mean values of copper for tender leaves varied from 4.06-10.72 mg/kg (Table 4.18). The highest mean value (10.72 mg/kg) was noticed in S6 followed by S3 (8.01 mg/kg), S1 (6.97 mg/kg) and S8 (6.94 mg/kg), whereas, the least value was observed in S4 (4.06 mg/kg). The average value for mature leaves ranged from 4.63-7.55 mg/kg. The seed source S2 (7.55 mg/kg) showed largest mean value which was succeeded by S1 (9.37 mg/kg), S6 (7.36 mg/kg) and S10 (6.82 mg/kg) and the minimum mean value was noticed in seed source S7 (4.63 mg/kg).

4.3.13 Zinc (Zn)

The zinc content for tender leaves ranged from 16.65-89.87 mg/kg (Table 4.18). The maximum mean value was registered in S6 (89.87 mg/kg) which was followed by seed sources S5 (31.82 mg/kg), S13 (30.58 mg/kg) and S9 (28.45 mg/kg). However the minimum mean value (16.65 mg/kg) was possessed by S14. The mature leaves registered the largest mean value in seed source S11 (54.74 mg/kg) succeeded by S3 (34.68 mg/kg), S4 (33.37 mg/kg) and S14 (29.03 mg/kg). The mean values for mature leaves ranged from 17.03-54.74 mg/kg. Whereas, least mean value (17.03 mg/kg) was observed in S13.

4.3.14 Lead (Pb)

The recorded data for lead of tender leaves and mature leaves of 14 seed sources of *M. oleifera* are included in Table 4.19 which showed significant difference for all seed sources. The mean value lead content for tender leaves varied from 1.16-14.54 mg/kg. The largest value was possessed by S11 (14.54 mg/kg) followed by S9 (13.28 mg/kg), S1 (10.63 mg/kg) and S6 (3.29 mg/kg), whereas the lowest mean value was observed in S12 (1.16 mg/kg). The average value for mature leaves lied between 1.61-12.68 mg/kg in which the minimum value was seen in seed source S5 (1.61 mg/kg) and the most in S9 (12.68 mg/kg) which was succeeded by S11 (3.97 mg/kg), S1 (3.48 mg/kg) and S4 (2.83 mg/kg).

4.3.15 Cadmium (Cd)

The norm values of cadmium for tender leaves ranged from 0.07-0.28 mg/kg (Table 4.19). Seed source S2 registered maximum mean value (0.19 mg/kg) which was followed by S7 (0.12 mg/kg), S4 (0.11 mg/kg), S3 (0.10 mg/kg), S13 (0.10 mg/kg) and S14 (0.10 mg/kg). However, minimum mean value (0.07 mg/kg) was recorded in S12. The mean value for

mature leaves varied from 0.08-0.28 mg/kg. The highest mean value was recorded in seed source S1 (0.28 mg/kg) succeeded by S4 (0.24 mg/kg), S9 (0.12 mg/kg), S14 (0.12 mg/kg) and S7 (0.11 mg/kg), where as minimum mean value was noticed in three seed sources S5 (0.08 mg/kg), S10 (0.08 mg/kg) and S12 (0.08 mg/kg).

4.3.16 Chromium (Cr)

The average value registered for tender leaves ranged from 1.71-7.18 mg/kg (Table 4.19). The largest value was recorded in source S6 (7.18 mg/kg) which was followed by S1 (3.31 mg/kg), S12 (2.53 mg/kg) and S3 (2.46 mg/kg). S10 (1.71mg/kg) showed the lowest amount of chromium. The mature leaves possessed highest mean value in S1 (4.20 mg/kg) followed by S4 (3.88 mg/kg), S14 (3.79 mg/kg) and S11 (3.55 mg/kg). The mean values varied from 1.93-4.20 mg/kg and the minimum value noticed in S10 (1.93 mg/kg).

Minerals are required for normal growth, activities of muscles and skeletal development (such as calcium), cellular activity and oxygen transport (copper and iron), chemical reaction in the body and intestinal absorption (magnesium), fluid balance and nerve transmission (sodium and potassium), as well as the regulation of acid-base balance (phosphorus). Iron is useful in prevention of anemia disease (Oluyemi *et al* 2006). Manganese plays a role in energy production and in supporting the immune system (Muhammad *et al* 2011). Zinc is useful for protein synthesis, normal body development and recovery from illness (Muhammad *et al* 2011). The minerals determined are very essential macro minerals since they make the edible parts of moringa useful for food or feed (Dechassa *et al* 2003).

The comparative analysis of macro and micro nutrients showed that concentration of macro and micro nutrients differ significantly in tender leaves and mature leaves of *M. oleifera*. The highest value of nitrogen (39202.86 mg/kg) was recorded for the mature leaves. These findings are in close confirmation with Verma and Nigam (2014) who reported that moringa leaves contain higher values of crude protein as compared to stem and as per the standard procedure crude protein of sample was calculated by multiplying the N content with the factor 6.25. Arif *et al* 2020 reported the similar values for the nitrogen content in moringa leaves.

Mature leaves possessed maximum value of phosphorous (2147.36 ppm) and sulphur (7897.14 mg/kg) content. The present results confirm the findings of Moyo *et al* (2011) who reported that dried leaves of moringa contain 3,000 mg/kg and 6,300 mg/kg of phosphorus and sulphur along with this, familiar results were recorded by Arif *et al* (2020). Further, mature leaves had the highest potassium content. Makkar and Becker (1997); Newton *et al* (2010) reported the identical results for potassium in moringa.

Both calcium (2019.14 ppm) and magnesium (3926.00 mg/kg) content was observed highest in mature leaves of *M. oleifera*. Familiar result for magnesium was reported by Lopez

et al (2017) (3550-3620 mg/kg). Aslam *et al* (2005) observed that the samples of *M. oleifera* leaves from Sadiqabad were found to have similar calcium content. Sodium (710.29 mg/kg) was present in maximum quantity in mature leaves. Identical, sodium content was observed by Ajantha *et al* (2018).

Mature leaves had highest iron content (404.86 mg/kg). The similar finding had also been reported by Moyo *et al* (2011) who reported that dried leaves of moringa contain 490 ppm of iron. Arif *et al* 2020 recorded 488.75 ppm of iron in moringa leaves. Boron (41.17 mg/kg) and Manganese (30.49 mg/kg) was observed in mature leaves, which was the largest amount. The concentrations observed for Mn in this study is comparable to those reported (47.1 to 113.9 mg/kg) by Foidl *et al* (2001).

The maximum concentration of zinc (29.42 ppm) and copper (6.16ppm) was found in the tender leaves of the moringa plant. These results of the present investigation are in close agreement with Moyo *et al* (2011) who reported that dried leaves of moringa contain 31.03 & 8.25 of zinc and copper. The results were identical to the finding of Arif *et al* (2020). Zinc concentration of Foidl *et al* (2001); Newton *et al* (2010) were similar to amount present in tender leaves.

Heavy metals toxicity can have many health effects in the human as well as animal body. Heavy metals can damage and alter the functioning of organs such as kidney, brain, blood and liver. Heavy metal toxicity can either be acute or chronic effects. When body is exposed to heavy metals for longer time, it can lead to physical, muscular and neurological degenerative process. The lead content in tender leaves (4.38 ppm) and mature leaves (3.03 ppm) are quite less in moringa. In plants, the critical levels of the heavy metal Pb is 10-20 ppm and higher concentrations than these are very likely to be toxic (Sauerbeck 1982). The levels of nickel (1.29mg/kg), cadmium (0.10mg/kg) and chromium (2.59mg/kg) are quite low in the leaves of *M. oleifera* which does not have any high toxic effect in humans and animals. The similar results were recorded for chromium content <5 and 4.76 mg/kg by Freiburger *et al* (1998) and Mulyaningsih and Yusuf (2018). The <5 mg/kg nickel was considered as low by Freiburger *et al* (1998).

4.4 Genetic variability studies

A key to progress in tree improvement and breeding programme is the degree and the extent of variation present in a species germplasm. Planning of strategies for improvement and breeding of any species estimation of genetic variability is most importance (Zobel 1981). Therefore, for selection of promising *M. oleifera* Lam. and evaluation of genetic variations in the seed source is very crucial. Additive and non-additive are both the components of variation in variability traits.

Table 4.14: Variability for Nitrogen (mg/kg), Phosphorous (mg/kg) and Potassium (mg/kg) for different phenophases of *Moringa oleifera* seed sources

<i>Moringa</i> Sources	Nitrogen (N)		Posphorous (P)		Potassium (K)	
	Tender $\pm$ SE _m	Mature $\pm$ SE _m	Tender $\pm$ SE _m	Mature $\pm$ SE _m	Tender $\pm$ SE _m	Mature $\pm$ SE _m
S1	27016.00 $\pm$ 401.84	36256.00 $\pm$ 240.18	2180.00 $\pm$ 30.60	2260.00 $\pm$ 25.98	13197.00 $\pm$ 295.60	15050.00 $\pm$ 308.31
S2	16936.00 $\pm$ 244.80	34096.00 $\pm$ 308.45	1757.00 $\pm$ 26.56	2557.00 $\pm$ 31.18	9577.00 $\pm$ 216.51	11837.00 $\pm$ 312.35
S3	16656.00 $\pm$ 240.18	35136.00 $\pm$ 240.18	2534.00 $\pm$ 20.78	2279.00 $\pm$ 20.21	11099.00 $\pm$ 357.38	13256.00 $\pm$ 296.76
S4	15392.00 $\pm$ 323.32	43680.00 $\pm$ 323.32	1543.00 $\pm$ 22.52	1991.00 $\pm$ 21.36	9543.00 $\pm$ 153.00	12376.00 $\pm$ 305.42
S5	14272.00 $\pm$ 323.32	42976.00 $\pm$ 406.45	1979.00 $\pm$ 19.05	2425.00 $\pm$ 21.94	10812.00 $\pm$ 371.24	13445.00 $\pm$ 309.46
S6	15120.00 $\pm$ 323.32	38496.00 $\pm$ 240.18	3434.00 $\pm$ 24.83	2238.00 $\pm$ 23.09	21721.00 $\pm$ 424.35	11126.00 $\pm$ 260.38
S7	27856.00 $\pm$ 240.18	40880.00 $\pm$ 323.32	1610.00 $\pm$ 15.01	2022.00 $\pm$ 19.05	9920.00 $\pm$ 270.78	11075.00 $\pm$ 321.01
S8	24072.00 $\pm$ 161.66	42696.00 $\pm$ 244.80	2590.00 $\pm$ 29.44	1927.00 $\pm$ 18.48	13501.00 $\pm$ 347.56	11592.00 $\pm$ 295.03
S9	31776.00 $\pm$ 240.18	45920.00 $\pm$ 323.32	1850.00 $\pm$ 21.94	2111.00 $\pm$ 19.05	9503.00 $\pm$ 181.87	11042.00 $\pm$ 224.59
S10	29816.00 $\pm$ 401.84	40736.00 $\pm$ 406.45	1832.00 $\pm$ 19.05	2201.00 $\pm$ 15.59	8151.00 $\pm$ 176.67	10639.00 $\pm$ 333.71
S11	27712.00 $\pm$ 323.32	37936.00 $\pm$ 240.18	2081.00 $\pm$ 24.83	2204.00 $\pm$ 20.21	9266.00 $\pm$ 237.87	9859.00 $\pm$ 269.62
S12	35552.00 $\pm$ 323.32	44936.00 $\pm$ 401.84	2253.00 $\pm$ 21.94	2378.00 $\pm$ 19.05	9750.00 $\pm$ 35.80	13180.00 $\pm$ 275.97
S13	27432.00 $\pm$ 161.66	34440.00 $\pm$ 161.66	1846.00 $\pm$ 25.40	1533.00 $\pm$ 10.39	10101.00 $\pm$ 281.17	10428.00 $\pm$ 239.60
S14	23240.00 $\pm$ 161.66	30656.00 $\pm$ 240.18	1040.00 $\pm$ 17.90	1937.00 $\pm$ 17.90	6588.00 $\pm$ 188.22	16929.00 $\pm$ 370.66
Mean $\pm$ SE_m	23774.86 $\pm$ 296.20	39202.86 $\pm$ 568.62	2037.79 $\pm$ 24.07	2147.36 $\pm$ 21.54	10909.21 $\pm$ 274.28	12273.86 $\pm$ 306.94
LSD_{0.05}	832.78	1634.72	67.32	60.15	787.29	859.73

Note: **S1** - Bhagya, UHS, Bhagalkot (Karnataka); **S2** - Konkan Ruchika, Dapoli (Maharashtra); **S3** – Dantiwara (Gujarat); **S4** - PAU-1, Ludhiana; **S5** - PAU-2, Ludhiana; **S6** - PAU-3, Ludhiana; **S7** - PKM-2, Tamil Nadu; **S8** - PKM-2, Tamil Nadu; **S9** - ODC-3, Tamil Nadu; **S10** - CAZRI, Jodhpur (Rajasthan); **S11** - Mandya, Karnataka; **S12** - Mysore, Karnataka; **S13** - PAU-4, Ludhiana; **S14** - PAU-5, Ludhiana (Punjab).

Table 4.15: Variability for Calcium (mg/kg) and Magnesium (mg/kg) for different phenophases of *Moringa oleifera* seed sources

<i>Moringa</i> Sources	Calcium (Ca)		Magnesium (Mg)	
	Tender $\pm$ SE _m	Mature $\pm$ SE _m	Tender $\pm$ SE _m	Mature $\pm$ SE _m
S1	1698.00 $\pm$ 13.86	2067.00 $\pm$ 4.04	3688.00 $\pm$ 30.60	3516.00 $\pm$ 19.63
S2	1054.00 $\pm$ 12.12	1906.00 $\pm$ 10.39	2401.00 $\pm$ 17.90	4019.00 $\pm$ 21.36
S3	1511.00 $\pm$ 8.08	1617.00 $\pm$ 6.93	4151.00 $\pm$ 31.18	4326.00 $\pm$ 22.52
S4	964.00 $\pm$ 7.51	2053.00 $\pm$ 10.39	2241.00 $\pm$ 17.90	3728.00 $\pm$ 21.36
S5	1404.00 $\pm$ 8.66	1818.00 $\pm$ 8.08	3159.00 $\pm$ 21.36	3786.00 $\pm$ 19.05
S6	3437.00 $\pm$ 20.21	1882.00 $\pm$ 10.97	6638.00 $\pm$ 37.53	4168.00 $\pm$ 22.52
S7	1659.00 $\pm$ 8.08	1513.00 $\pm$ 8.66	3465.00 $\pm$ 17.32	3109.00 $\pm$ 20.21
S8	1307.00 $\pm$ 8.08	1895.00 $\pm$ 8.08	3773.00 $\pm$ 20.78	3536.00 $\pm$ 23.67
S9	1236.00 $\pm$ 8.66	1983.00 $\pm$ 9.24	3001.00 $\pm$ 18.48	4553.00 $\pm$ 29.44
S10	960.00 $\pm$ 7.51	1777.00 $\pm$ 9.24	2614.00 $\pm$ 18.48	3966.00 $\pm$ 22.52
S11	1376.00 $\pm$ 7.51	2441.00 $\pm$ 14.43	3914.00 $\pm$ 20.78	4903.00 $\pm$ 20.21
S12	1165.00 $\pm$ 7.51	1789.00 $\pm$ 8.66	3137.00 $\pm$ 10.39	3691.00 $\pm$ 21.94
S13	1331.00 $\pm$ 8.66	3343.00 $\pm$ 12.70	3008.00 $\pm$ 20.21	4261.00 $\pm$ 20.21
S14	2873.00 $\pm$ 12.70	2184.00 $\pm$ 8.08	5627.00 $\pm$ 35.80	3402.00 $\pm$ 15.59
Mean $\pm$ SE_m	1569.64 $\pm$ 10.91	2019.14 $\pm$ 9.93	3629.79 $\pm$ 24.85	3926.00 $\pm$ 22.24
LSD_{0.05}	30.53	27.60	69.50	62.70

Note: **S1** - Bhagya, UHS, Bhagalkot (Karnataka); **S2** - Konkan Ruchika, Dapoli (Maharashtra); **S3** – Dantiwara (Gujarat); **S4** - PAU-1, Ludhiana; **S5** - PAU-2, Ludhiana; **S6** - PAU-3, Ludhiana; **S7** - PKM-2, Tamil Nadu; **S8** - PKM-2, Tamil Nadu; **S9** - ODC-3, Tamil Nadu; **S10** - CAZRI, Jodhpur (Rajasthan); **S11** - Mandya, Karnataka; **S12** - Mysore, Karnataka; **S13** - PAU-4, Ludhiana; **S14** - PAU-5, Ludhiana (Punjab).

Table 4.16: Variability for Sulphur (mg/kg) and Iron (mg/kg) for different phenophases of *Moringa oleifera* seed sources

<i>Moringa</i> Sources	Sulphur (S)		Iron (Fe)	
	Tender $\pm$ SE _m	Mature $\pm$ SE _m	Tender $\pm$ SE _m	Mature $\pm$ SE _m
S1	7412.00 $\pm$ 238.45	7402.00 $\pm$ 226.90	452.00 $\pm$ 4.04	528.00 $\pm$ 6.35
S2	5973.00 $\pm$ 225.74	9716.00 $\pm$ 156.46	281.00 $\pm$ 4.04	422.00 $\pm$ 6.35
S3	8615.00 $\pm$ 190.53	8660.00 $\pm$ 150.69	295.00 $\pm$ 4.62	350.00 $\pm$ 5.20
S4	5246.00 $\pm$ 156.46	7565.00 $\pm$ 200.34	201.00 $\pm$ 5.20	515.00 $\pm$ 7.51
S5	6728.00 $\pm$ 229.79	6728.00 $\pm$ 172.63	287.00 $\pm$ 6.93	308.00 $\pm$ 5.20
S6	9675.00 $\pm$ 183.02	8504.00 $\pm$ 214.77	778.00 $\pm$ 5.20	317.00 $\pm$ 4.04
S7	5474.00 $\pm$ 181.29	7683.00 $\pm$ 140.87	278.00 $\pm$ 4.04	258.00 $\pm$ 4.62
S8	8806.00 $\pm$ 196.30	7322.00 $\pm$ 200.92	356.00 $\pm$ 4.62	345.00 $\pm$ 5.20
S9	6290.00 $\pm$ 186.48	8021.00 $\pm$ 174.94	269.00 $\pm$ 4.62	334.00 $\pm$ 4.04
S10	6228.00 $\pm$ 200.34	8363.00 $\pm$ 247.11	238.00 $\pm$ 4.04	300.00 $\pm$ 5.20
S11	7075.00 $\pm$ 198.03	8375.00 $\pm$ 206.11	322.00 $\pm$ 5.20	736.00 $\pm$ 5.20
S12	7660.00 $\pm$ 185.33	9036.00 $\pm$ 242.49	248.00 $\pm$ 5.20	309.00 $\pm$ 4.04
S13	6276.00 $\pm$ 225.21	5825.00 $\pm$ 146.65	262.00 $\pm$ 4.04	385.00 $\pm$ 6.93
S14	3536.00 $\pm$ 193.41	7360.00 $\pm$ 244.80	251.00 $\pm$ 4.04	561.00 $\pm$ 4.62
Mean $\pm$ SE_m	6784.62 $\pm$ 187.78	7897.14 $\pm$ 163.51	322.71 $\pm$ 4.64	404.86 $\pm$ 5.58
LSD_{0.05}	580.87	573.83	13.81	15.71

Note: **S1** - Bhagya, UHS, Bhagalkot (Karnataka); **S2** - Konkan Ruchika, Dapoli (Maharashtra); **S3** – Dantiwara (Gujarat); **S4** - PAU-1, Ludhiana; **S5** - PAU-2, Ludhiana; **S6** - PAU-3, Ludhiana; **S7** - PKM-2, Tamil Nadu; **S8** - PKM-2, Tamil Nadu; **S9** - ODC-3, Tamil Nadu; **S10** - CAZRI, Jodhpur (Rajasthan); **S11** - Mandya, Karnataka; **S12** - Mysore, Karnataka; **S13** - PAU-4, Ludhiana; **S14** - PAU-5, Ludhiana (Punjab).

Table 4.17: Variability for Sodium (mg/kg), Boron (mg/kg) and Manganese (mg/kg) for different phenophases of *Moringa oleifera* seed sources

<i>Moringa</i> Sources	Sodium (Na)		Boron (B)		Manganese (Mn)	
	Tender $\pm$ SE _m	Mature $\pm$ SE _m	Tender $\pm$ SE _m	Mature $\pm$ SE _m	Tender $\pm$ SE _m	Mature $\pm$ SE _m
S1	500.00 $\pm$ 24.25	615.00 $\pm$ 17.90	35.24 $\pm$ 0.12	48.33 $\pm$ 0.03	29.43 $\pm$ 0.18	29.62 $\pm$ 0.26
S2	501.00 $\pm$ 20.78	949.00 $\pm$ 19.63	22.94 $\pm$ 0.03	47.87 $\pm$ 0.09	20.62 $\pm$ 0.13	32.19 $\pm$ 0.26
S3	736.00 $\pm$ 21.36	798.00 $\pm$ 19.05	30.63 $\pm$ 0.07	31.21 $\pm$ 0.04	29.45 $\pm$ 0.27	28.16 $\pm$ 0.18
S4	383.00 $\pm$ 15.01	386.00 $\pm$ 19.05	26.27 $\pm$ 0.05	43.06 $\pm$ 0.06	14.52 $\pm$ 0.20	31.32 $\pm$ 0.21
S5	331.00 $\pm$ 16.74	487.00 $\pm$ 21.94	28.58 $\pm$ 0.06	40.05 $\pm$ 0.05	22.28 $\pm$ 0.23	25.19 $\pm$ 0.19
S6	579.00 $\pm$ 16.74	941.00 $\pm$ 22.52	63.99 $\pm$ 0.09	37.04 $\pm$ 0.07	58.45 $\pm$ 0.49	30.67 $\pm$ 0.22
S7	425.00 $\pm$ 19.05	397.00 $\pm$ 18.48	21.21 $\pm$ 0.09	35.12 $\pm$ 0.05	22.80 $\pm$ 0.22	20.94 $\pm$ 0.19
S8	821.00 $\pm$ 16.74	1124.00 $\pm$ 24.25	27.87 $\pm$ 0.09	51.39 $\pm$ 0.08	25.50 $\pm$ 0.24	29.42 $\pm$ 0.23
S9	486.00 $\pm$ 15.01	663.00 $\pm$ 23.67	31.98 $\pm$ 0.08	40.11 $\pm$ 0.07	21.94 $\pm$ 0.33	28.96 $\pm$ 0.24
S10	636.00 $\pm$ 25.98	895.00 $\pm$ 19.63	32.68 $\pm$ 0.05	34.41 $\pm$ 0.05	23.45 $\pm$ 0.27	29.56 $\pm$ 0.32
S11	826.00 $\pm$ 20.21	1476.00 $\pm$ 18.48	36.14 $\pm$ 0.09	43.19 $\pm$ 0.05	27.51 $\pm$ 0.31	42.30 $\pm$ 0.22
S12	859.00 $\pm$ 15.01	444.00 $\pm$ 18.48	28.58 $\pm$ 0.05	36.14 $\pm$ 0.08	26.99 $\pm$ 0.19	24.85 $\pm$ 0.20
S13	389.00 $\pm$ 15.01	373.00 $\pm$ 14.43	28.45 $\pm$ 0.06	49.15 $\pm$ 0.06	20.73 $\pm$ 0.27	29.46 $\pm$ 0.34
S14	892.00 $\pm$ 19.63	396.00 $\pm$ 18.48	34.73 $\pm$ 0.05	39.28 $\pm$ 0.05	49.05 $\pm$ 0.21	44.18 $\pm$ 0.21
Mean $\pm$ SE_m	597.43 $\pm$ 17.90	710.29 $\pm$ 19.99	32.09 $\pm$ 0.08	41.17 $\pm$ 0.06	28.05 $\pm$ 0.27	30.49 $\pm$ 0.25
LSD_{0.05}	55.02	57.56	0.21	0.17	0.77	0.69

Note: **S1** - Bhagya, UHS, Bhagalkot (Karnataka); **S2** - Konkan Ruchika, Dapoli (Maharashtra); **S3** – Dantiwara (Gujarat); **S4** - PAU-1, Ludhiana; **S5** - PAU-2, Ludhiana; **S6** - PAU-3, Ludhiana; **S7** - PKM-2, Tamil Nadu; **S8** - PKM-2, Tamil Nadu; **S9** - ODC-3, Tamil Nadu; **S10** - CAZRI, Jodhpur (Rajasthan); **S11** - Mandya, Karnataka; **S12** - Mysore, Karnataka; **S13** - PAU-4, Ludhiana; **S14** - PAU-5, Ludhiana (Punjab).

Table 4.18: Variability for Nickel (mg/kg), Copper (mg/kg) and Zinc (mg/kg) for different phenophases of *Moringa oleifera* seed sources

<i>Moringa</i> Sources	Nickel (Ni)		Copper (Cu)		Zinc (Zn)	
	Tender $\pm$ SE _m	Mature $\pm$ SE _m	Tender $\pm$ SE _m	Mature $\pm$ SE _m	Tender $\pm$ SE _m	Mature $\pm$ SE _m
S1	1.77 $\pm$ 0.05	1.82 $\pm$ 0.05	6.97 $\pm$ 0.02	7.37 $\pm$ 0.02	25.04 $\pm$ 0.09	23.23 $\pm$ 0.16
S2	1.87 $\pm$ 0.07	1.61 $\pm$ 0.03	6.02 $\pm$ 0.02	7.55 $\pm$ 0.02	23.98 $\pm$ 0.26	24.33 $\pm$ 0.20
S3	1.18 $\pm$ 0.08	1.12 $\pm$ 0.04	8.01 $\pm$ 0.02	6.00 $\pm$ 0.02	24.32 $\pm$ 0.20	34.68 $\pm$ 0.20
S4	1.26 $\pm$ 0.06	1.97 $\pm$ 0.05	4.06 $\pm$ 0.02	6.44 $\pm$ 0.02	24.24 $\pm$ 0.16	33.37 $\pm$ 0.20
S5	1.02 $\pm$ 0.05	1.24 $\pm$ 0.04	5.13 $\pm$ 0.02	5.70 $\pm$ 0.01	31.82 $\pm$ 0.20	26.02 $\pm$ 0.16
S6	3.16 $\pm$ 0.08	0.75 $\pm$ 0.03	10.72 $\pm$ 0.02	7.36 $\pm$ 0.02	89.87 $\pm$ 0.40	27.85 $\pm$ 0.16
S7	1.56 $\pm$ 0.05	0.87 $\pm$ 0.03	5.06 $\pm$ 0.02	4.63 $\pm$ 0.01	21.67 $\pm$ 0.22	19.64 $\pm$ 0.23
S8	1.13 $\pm$ 0.05	1.19 $\pm$ 0.04	6.94 $\pm$ 0.02	5.18 $\pm$ 0.02	27.80 $\pm$ 0.27	25.01 $\pm$ 0.16
S9	0.91 $\pm$ 0.04	1.13 $\pm$ 0.04	6.31 $\pm$ 0.02	5.53 $\pm$ 0.02	28.45 $\pm$ 0.25	23.98 $\pm$ 0.18
S10	0.86 $\pm$ 0.03	0.67 $\pm$ 0.04	4.91 $\pm$ 0.02	6.82 $\pm$ 0.02	21.76 $\pm$ 0.21	23.96 $\pm$ 0.15
S11	0.67 $\pm$ 0.04	1.57 $\pm$ 0.04	5.81 $\pm$ 0.02	6.77 $\pm$ 0.03	25.04 $\pm$ 0.16	54.74 $\pm$ 0.32
S12	0.78 $\pm$ 0.04	1.18 $\pm$ 0.04	6.44 $\pm$ 0.02	5.74 $\pm$ 0.02	20.67 $\pm$ 0.21	25.58 $\pm$ 0.23
S13	0.93 $\pm$ 0.02	1.39 $\pm$ 0.05	5.05 $\pm$ 0.02	4.73 $\pm$ 0.01	30.58 $\pm$ 0.23	17.03 $\pm$ 0.16
S14	0.94 $\pm$ 0.03	1.63 $\pm$ 0.04	4.77 $\pm$ 0.01	5.95 $\pm$ 0.02	16.65 $\pm$ 0.20	29.03 $\pm$ 0.17
Mean $\pm$ SE_m	1.29 $\pm$ 0.05	1.30 $\pm$ 0.03	6.16 $\pm$ 0.02	6.13 $\pm$ 0.02	29.42 $\pm$ 0.23	27.75 $\pm$ 0.20
LSD_{0.05}	0.15	0.12	0.06	0.05	0.67	0.57

Note: **S1** - Bhagya, UHS, Bhagalkot (Karnataka); **S2** - Konkan Ruchika, Dapoli (Maharashtra); **S3** – Dantiwara (Gujarat); **S4** - PAU-1, Ludhiana; **S5** - PAU-2, Ludhiana; **S6** - PAU-3, Ludhiana; **S7** - PKM-2, Tamil Nadu; **S8** - PKM-2, Tamil Nadu; **S9** - ODC-3, Tamil Nadu; **S10** - CAZRI, Jodhpur (Rajasthan); **S11** - Mandya, Karnataka; **S12** - Mysore, Karnataka; **S13** - PAU-4, Ludhiana; **S14** - PAU-5, Ludhiana (Punjab).

Table 4.19: Variability for Lead (mg/kg), Cadmium (mg/kg) and Chromium (mg/kg) for different phenophases of *Moringa oleifera* seed sources

Mor Sources	Lead (Pb)		Cadmium (Cd)		Chromium (Cr)	
	Tender $\pm$ SE_m	Mature $\pm$ SE_m	Tender $\pm$ SE_m	Mature $\pm$ SE_m	Tender $\pm$ SE_m	Mature $\pm$ SE_m
S1	10.63 $\pm$ 0.03	3.48 $\pm$ 0.02	0.08 $\pm$ 0.00	0.28 $\pm$ 0.02	3.31 $\pm$ 0.02	4.20 $\pm$ 0.02
S2	2.90 $\pm$ 0.02	2.17 $\pm$ 0.01	0.19 $\pm$ 0.02	0.09 $\pm$ 0.01	2.07 $\pm$ 0.02	3.17 $\pm$ 0.01
S3	1.66 $\pm$ 0.01	1.81 $\pm$ 0.01	0.10 $\pm$ 0.02	0.09 $\pm$ 0.01	2.46 $\pm$ 0.02	2.67 $\pm$ 0.02
S4	1.77 $\pm$ 0.01	2.83 $\pm$ 0.01	0.11 $\pm$ 0.01	0.24 $\pm$ 0.01	1.79 $\pm$ 0.02	3.88 $\pm$ 0.02
S5	1.90 $\pm$ 0.01	1.61 $\pm$ 0.02	0.08 $\pm$ 0.01	0.08 $\pm$ 0.01	2.27 $\pm$ 0.01	2.73 $\pm$ 0.01
S6	3.29 $\pm$ 0.02	2.17 $\pm$ 0.01	0.09 $\pm$ 0.01	0.10 $\pm$ 0.01	7.18 $\pm$ 0.02	2.00 $\pm$ 0.01
S7	1.85 $\pm$ 0.01	2.09 $\pm$ 0.02	0.12 $\pm$ 0.01	0.11 $\pm$ 0.01	2.10 $\pm$ 0.02	2.22 $\pm$ 0.01
S8	2.41 $\pm$ 0.02	1.92 $\pm$ 0.01	0.08 $\pm$ 0.01	0.09 $\pm$ 0.01	1.99 $\pm$ 0.02	3.05 $\pm$ 0.02
S9	13.28 $\pm$ 0.05	12.68 $\pm$ 0.05	0.09 $\pm$ 0.01	0.12 $\pm$ 0.01	2.27 $\pm$ 0.02	2.57 $\pm$ 0.02
S10	1.23 $\pm$ 0.01	1.66 $\pm$ 0.01	0.08 $\pm$ 0.00	0.08 $\pm$ 0.01	1.71 $\pm$ 0.01	1.93 $\pm$ 0.01
S11	14.54 $\pm$ 0.04	3.97 $\pm$ 0.02	0.08 $\pm$ 0.01	0.09 $\pm$ 0.01	2.03 $\pm$ 0.02	3.55 $\pm$ 0.02
S12	1.16 $\pm$ 0.01	2.23 $\pm$ 0.01	0.07 $\pm$ 0.01	0.08 $\pm$ 0.01	2.53 $\pm$ 0.01	2.71 $\pm$ 0.01
S13	2.47 $\pm$ 0.02	1.84 $\pm$ 0.01	0.10 $\pm$ 0.01	0.10 $\pm$ 0.01	2.12 $\pm$ 0.02	3.32 $\pm$ 0.02
S14	2.20 $\pm$ 0.01	2.00 $\pm$ 0.02	0.10 $\pm$ 0.01	0.12 $\pm$ 0.01	2.09 $\pm$ 0.01	3.79 $\pm$ 0.03
Mean $\pm$ SE_m	4.38 $\pm$ 0.02	3.03 $\pm$ 0.02	0.10 $\pm$ 0.01	0.12 $\pm$ 0.01	2.57 $\pm$ 0.01	2.99 $\pm$ 0.02
LSD_{0.05}	0.07	0.06	0.03	0.03	0.05	0.05

Note: **S1** - Bhagya, UHS, Bhagalkot (Karnataka); **S2** - Konkan Ruchika, Dapoli (Maharashtra); **S3** – Dantiwara (Gujarat); **S4** - PAU-1, Ludhiana; **S5** - PAU-2, Ludhiana; **S6** - PAU-3, Ludhiana; **S7** - PKM-2, Tamil Nadu; **S8** - PKM-2, Tamil Nadu; **S9** - ODC-3, Tamil Nadu; **S10** - CAZRI, Jodhpur (Rajasthan); **S11** - Mandya, Karnataka; **S12** - Mysore, Karnataka; **S13** - PAU-4, Ludhiana; **S14** - PAU-5, Ludhiana (Punjab).

Heritability and genetic advance give information of total variation present in planting material as well as environmental influences on the traits under study. The heritable additive component of variance is the parameters with high genetic gain and high heritability can be undertaken for further improvement programmes.

4.4.1 Tender leaves

Variability and genetic parameters estimated for nutritional, fodder and antinutritional traits of 14 *M. oleifera* seed sources in terms of average, range, genotypic phenotypic and genotypic coefficient of variation (%), heritability, genetic advance and genetic advance as percent of mean are presented in Table 4.20. All the studied parameters of tender leaves showed a broad range of values signifying the amount of variation present in the seed sources. Environmental factors has very less influence on dry matter, ash content, crude protein, crude fat, carbohydrate, total soluble sugar, nitrogen free extract, NDF, IVDMD, DDM, RFV, pH, total phenols, flavonoid, tanin, saponin, nitrate and oxalate because of less difference between phenotypic and genotypic coefficient of variation, thus the phenotype acts as true representative of their genotype and selection based on phenotypic performance might be used for further breeding programmes. Moderate estimate of environmental coefficient was recorded for organic matter, crude fibre, ADF, ADL, hemicelluloses and cellulose and DMI traits and thus these traits are more affected by environmental conditions.

Heritability is useful for the ranking importance of each trait in cross-breeding programmes. The maximum heritability was recorded in flavonoid (99.99%) and least was recorded for hemicellulose (84.42%). Flavonoid (99.99%), crude fat (99.98%), nitrate (99.96%), total phenols (99.95%), total soluble sugar (99.92%), saponin (99.91%), carbohydrate (99.53%), crude protein (99.45%) and tannin (99.25%) has very high heritability indicating that the variability existing in these traits are tightly linked with their genetic constitution. Hemicellulose (84.42%) has low heritability, while remaining traits have moderate to high heritability. In the present study, genetic advance was found highest for nitrate (1689.12%) which was followed by RFV (68.81%). Lowest value 0.87% for genetic advance was observed for DMI. Genetic gain was maximum registered 129.65% for nitrate and followed by 115.71% for flavonoid, 91.96% ADL and 80.41% for crude fat, whereas, minimum was recorded 12.78% for hemicellulose. Very high heritability coupled with high genetic advance as per cent of mean was observed for the characters viz., flavonoids (99.99% with 115.71%), crude fat (99.98% with 80.41%) and nitrate (99.96% with 129.66%) which indicated that the predominance of additive gene action in the expression of these characters which could be utilized for the development of high nutrient yielding drumstick genotypes.

4.4.2 Mature leaves

All the nutritional, fodder and antinutritional parameters of mature leaves showed a

broad range of values signifying the amount of variation present in the seed sources (Table 4.21). Environmental factors has very less influence on dry matter, ash content, crude protein, crude fat, crude fibre, carbohydrate, total soluble sugar, nitrogen free extract, NDF, DMI, DDM, RFV, pH, total phenols, flavonoid, tanin, saponin, nitrate and oxalate because of less difference between phenotypic and genotypic coefficient of variation, thus the phenotype acts as true representative of their genotype and selection based on phenotypic performance might be used for further breeding programmes. Moderate estimate of environmental coefficient was recorded for organic matter, ADF, ADL, IVDMD, hemicelluloses and cellulose and DMI traits and thus these traits are more affected by environmental conditions.

The maximum heritability was recorded in flavonoid (99.99%) and least was recorded for hemicellulose (53.70%). Flavonoid (99.99%), nitrate (99.97%), crude fat (99.96%), saponin (99.95%), total phenols (99.89%), total soluble sugars (99.85%) and crude fibre (99.15%) has very high heritability indicating that the variability existing in these traits are tightly linked with their genetic constitution. Hemicellulose (53.70%) has low heritability, while remaining traits have moderate to high heritability. In the present study, genetic advance was found highest for nitrate (1656.16%) which was followed by RFV (32.08%). Lowest value 0.42% for genetic advance was observed for DMI. Genetic gain was maximum registered 98.26% for flavonoid and followed by 83.17% for nitrate, 49.46% oalate and 43.86% for non-fibrous carbohydrate, whereas, minimum was recorded 8.02% for ash content. Very high heritability coupled with high genetic advance as per cent of mean was observed for the characters viz., flavonoid (99.99% with 98.26%), nitrate (99.97% with 83.17%) which indicated that the predominance of additive gene action in the expression of these characters which could be utilized for the development of high nutrient yielding drumstick genotypes.

4.4.3 Twigs

All the characteristics studied for twigs showed a broad range of values signifying the amount of variation present in the seed sources (Table 4.22). Environmental factors has very less influence on ash content, crude protein, crude fat, crude fibre, carbohydrate, total soluble sugar, nitrogen free extract, ADF, IVDMD, DMI, DDM, pH, total phenols, flavonoid, tanin, saponin and nitrate because of less difference between phenotypic and genotypic coefficient of variation, thus the phenotype acts as true representative of their genotype and selection based on phenotypic performance might be used for further breeding programmes. Moderate estimate of environmental coefficient was recorded for dry matter, organic matter, NDF, ADL, hemicelluloses and cellulose and RFV traits and thus these traits are more affected by environmental conditions.

The maximum heritability was recorded in total soluble sugars (99.99%) and least was

recorded for cellulose (68.10%). Total soluble sugars (99.99%), flavonoid (99.98%), crude fat (99.96%), total phenols (99.96%) nitrate (99.95%), saponin (99.89%) has very high heritability indicating that the variability existing in these traits are tightly linked with their genetic constitution. Cellulose (68.10%) has low heritability, while remaining traits have moderate to high heritability. In the present study, genetic advance was found highest for nitrate (1415.69%) which was followed by RFV (28.15%). Lowest value 0.47% for genetic advance was observed for DMI. Genetic gain was maximum registered 95.21% for flavonoid and followed by 91.62% for nitrate, 81.53% total soluble sugar and hemicelluloses (62.64%), whereas, minimum was recorded 6.45% for carbohydrate. Very high heritability coupled with high genetic advance as per cent of mean was observed for the characters viz., TSS (99.99% with 81.53%), flavonoid (99.98% with 95.21%), nitrate (99.95% with 91.62%) which indicated that the predominance of additive gene action in the expression of these characters which could be utilized for the development of high nutrient yielding drumstick genotypes.

4.4.4 Mineral traits in tender leaves

Variability and genetic parameters estimated for minerals for 14 *M. oleifera* seed sources in terms of average, range, genotypic phenotypic and genotypic coefficient of variation (%), heritability, genetic advance and genetic gain as percent of mean are presented Table 4.23. All the mineral parameters of tender leaves showed a broad range of values signifying the amount of variation present in the seed sources. Environmental factors has very less influence on nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulphur (S), iron (Fe), zinc (Zn), copper (Cu), boron (B), manganese (Mn), nickel (Ni), lead (Pb) and chromium (Cr) because of less difference between phenotypic and genotypic coefficient of variation, thus the phenotype acts as true representative of their genotype and selection based on phenotypic performance might be used for further breeding programmes. Moderate estimate of environmental coefficient was recorded for sodium (Na) and cadmium (Cd) traits and thus these traits are more affected by environmental conditions.

The maximum heritability was recorded in lead (99.99%) and least was recorded for cadmium (70.62%). Boron (99.98%), chromium (99.96%), copper (99.96%), zinc (99.95%), calcium (99.93%), magnesium (99.87%), manganese (99.84%), phosphorus (99.46%) and nitrogen (99.45%) has very high heritability indicating that the variability existing in these traits are tightly linked with their genetic constitution. Cadmium (70.62%) has low heritability, while remaining traits have moderate to high heritability. In the present study, genetic advance was found highest for nitrogen (14272.25%) which was followed by potassium (7285.57%), sulphur (3200.53%), magnesium (2498.70%), calcium (1476.42%) and phosphorus (1165.18%). Lowest value 0.04% for genetic advance was observed for cadmium. Genetic gain was maximum registered 220.00% for lead and followed by 124.96%

for zinc, 111.03% chromium, nickel 102.37%, calcium 94.06% and iron (91.83%), whereas, minimum was recorded 47.17% for sulphur. Very high heritability coupled with high genetic advance as per cent of mean was observed for the characters viz., lead (99.99% with 220.00%), chromium (99.96% with 111.03%) and calcium (99.93% with 94.06%) which indicated that the predominance of additive gene action in the expression of these characters which could be utilized for the development of high mineral yielding drumstick genotypes.

4.4.4 Mineral traits in mature leaves

Mineral traits for mature leaves showed a broad range of values signifying the amount of variation present in the seed sources (Table 4.24). Environmental factors has very less influence on nitrogen (N), calcium (Ca), magnesium (Mg), sulphur (S), iron (Fe), zinc (Zn), copper (Cu), boron (B), manganese (Mn), nickel (Ni), sodium (Na), lead (Pb) and chromium (Cr) because of less difference between phenotypic and genotypic coefficient of variation, thus the phenotype acts as true representative of their genotype and selection based on phenotypic performance might be used for further breeding programmes. Moderate estimate of environmental coefficient was recorded for phosphorus (P), potassium (K) and cadmium (Cd) traits and thus these traits are more affected by environmental conditions.

The maximum heritability was recorded in lead (99.98%) and least was recorded for sulphur (92.21%). Among the nutrients studied lead (99.98%), boron (99.97%), copper (99.88%), calcium (99.85%), zinc (99.84%) and chromium (99.81%) has very high heritability indicating that the variability existing in these traits are tightly linked with their genetic constitution. Sulphur (92.214%) has low heritability, while remaining traits have moderate to high heritability. In the present study, genetic advance was found highest for nitrogen (9257.10%) which was followed by potassium (3821.84%), sulphur (1928.08%), magnesium (996.06%), and calcium (916.71%). Lowest value 0.12% for genetic advance was observed for cadmium. Genetic gain was maximum registered 194.25% for lead followed by 100.12% for cadmium, 96.41% sodium, iron (67.80%), whereas, minimum was recorded 23.61% for nitrogen. Very high heritability coupled with high genetic advance as per cent of mean was observed for the characters viz., lead (99.98% with 194.25%), zinc (99.84% with 67.17%) and iron (99.47% with 67.80%) which indicated that the predominance of additive gene action in the expression of these characters which could be utilized for the development of high mineral yielding drumstick genotypes.

4.5. Correlation studies

Correlation provides an insight to the deep complexity and the amount of inter-relationship existing between different traits. Some characters are strongly inter-linked with each other therefore knowledge of association of these characters is most important during the selection of one or more characters.

Table 4.20: Genetic variability estimates for tender leaves of *Moringa oleifera* seed sources

Parameter	Mean	Range	Coefficient of variation		Heritability (%)	Genetic Advance	Genetic gain (% of mean)
			Genotypic (%)	Enviornmental (%)			
DM	20.103	17.12-25.71	12.07	0.61	90.56	4.75	23.67
ASH	10.159	7.75-11.27	9.45	0.05	98.84	1.96	19.35
OM	9.986	6.39-15.56	24.47	1.04	92.04	4.82	48.35
CP	14.86	8.92-22.22	29.22	0.08	99.45	8.92	60.03
FAT	3.522	1.20-5.73	39.04	0.00	99.98	2.83	80.41
CF	17.811	15.05-20.95	7.94	0.40	90.76	2.77	15.59
CARB	71.46	63.94-79.19	7.27	0.02	99.53	10.67	14.93
TSS	9.688	7.45-11.49	14.16	0.00	99.92	2.82	29.15
NFE	53.649	42.99-61.31	10.16	0.07	98.68	11.15	20.79
NDF	36.036	30.30-47.65	14.55	0.16	97.81	10.68	29.63
ADF	24.615	18.70-37.55	23.78	0.26	97.83	11.92	48.45
ADL	6.379	2.95-12.55	45.35	0.72	96.90	5.86	91.96
IVDMD	72.571	65.30-78.50	7.00	0.20	94.52	10.17	14.02
HEMI	11.421	10.10-12.75	6.75	0.60	84.42	1.46	12.78
CELL	18.237	13.10-28.75	25.83	0.53	96.05	9.51	52.15
DMI	3.39	2.52-3.96	12.78	0.23	96.49	0.87	25.87
DDM	69.725	59.65-74.33	6.54	0.07	97.83	9.29	13.32
RFV	184.685	116.50-228.3	18.41	0.32	96.59	68.81	37.25
pH	5.57	5.08-6.27	5.63	0.03	98.72	0.60	11.52
PHE	10.231	7.63-12.76	13.68	0.00	99.95	2.88	28.18
FLA	1.633	0.58-3.56	56.18	0.00	99.99	1.89	115.72
TAN	109.655	91.18-121.77	10.43	0.04	99.25	23.47	21.41
SAP	40.3	27.28-49.61	16.59	0.01	99.91	13.76	34.16
NIT	103.79	435.5-3198.0	62.95	0.01	99.96	1689.12	129.65
OXA	2.866	1.69-4.16	21.27	0.67	93.95	1.22	42.47

Table 4.21: Genetic variability estimates for mature leaves of *Moringa oleifera* seed sources

Parameter	Mean	Range	Coefficient of variation		Heritability (%)	Genetic Advance	Genetic gain (% of mean)
			Genotypic (%)	Environmental (%)			
DM	19.762	16.92-24.69	9.18	0.37	92.37	3.59	18.18
ASH	11.29	10.74-12.08	4.02	0.14	93.34	0.90	8.02
OM	8.472	5.55-12.61	20.9	1.06	90.60	3.48	41.08
CP	24.502	19.16-28.70	11.72	0.27	95.61	5.78	23.61
FAT	5.015	3.93-5.87	12.65	0.00	99.96	1.30	26.06
CF	24.721	21.10-28.15	10.08	0.04	99.15	5.11	20.69
CARB	59.193	55.93-64.22	4.37	0.11	95.31	5.20	8.79
TSS	6.433	4.85-9.48	20.73	0.02	99.85	2.74	42.68
NFE	34.472	27.86-41.02	12.38	0.17	97.37	8.67	25.17
NDF	41.096	37.00-51.05	8.20	0.15	96.56	6.82	16.60
ADF	28.305	22.85-34.18	10.81	0.94	84.58	5.80	20.49
ADL	9.8	6.25-13.95	19.97	0.92	91.36	3.85	39.33
IVDMD	75.996	65.90-81.90	6.89	0.24	93.31	10.42	13.71
HEMI	12.791	10.65-16.88	11.11	4.05	53.70	2.14	16.77
CELL	18.505	12.10-24.93	20.89	1.35	88.27	7.48	40.44
DMI	2.936	2.35-3.24	7.23	0.18	95.33	0.42	14.55
DDM	66.851	62.28-71.10	3.56	0.31	84.57	4.51	6.75
RFV	152.55	113.46-178.8	10.47	0.27	95.02	32.08	21.03
pH	6.23	5.93-6.63	2.89	0.06	96.07	0.40	5.84
PHE	8.366	6.37-11.05	16.50	0.01	99.89	2.84	33.99
FLA	1.285	0.60-2.47	47.70	0.00	99.99	1.26	98.26
TAN	136.725	114.12-154.7	8.69	0.07	98.48	24.29	17.77
SAP	51.752	44.07-63.85	12.15	0.00	99.95	12.95	25.0
NIT	1991.25	910.0-3718.0	40.38	0.01	99.97	1656.16	83.17
OXA	1911	1.29-3.38	24.44	0.44	96.52	0.94	49.46

Note: **DM** - Dry matter; **ASH** - Ash content; **OM** - Organic matter; **CP** - Crude protein; **FAT** - Crude fat; **CF** - Crude fibre; **CARB** - Total Carbohydrates; **TSS** - Total soluble sugar; **NFE** - Nitrogen free extract; **NDF** -Neutral detergent fibre; **ADF** - Acid detergent fibre; **ADL** - Acid detergent lignin; **IVDMD** - *In vitro* dry matter digestibility; **HEMI** - Hemicellulose; **CELL** - Cellulose; **DMI** - Dry matter intake; **DDM** - Digestible dry matter; **RFV** - Relative feed value; **pH**; **PHE** - Total phenols; **FLA** - Flavonoids; **TAN** - Tannins; **SAP** - Saponins; **NIT** - Nitrate; **OXA** - Oxalate

Table 4.22: Genetic variability estimates for twigs of *Moringa oleifera* seed sources

Parameter	Mean	Range	Coefficient of variation		Heritability (%)	Genetic Advance	Genetic gain (% of mean)
			Genotypic (%)	Enviornmental (%)			
DM	22.678	19.91-26.80	7.68	0.35	91.52	3.43	15.13
ASH	10.234	8.62-11.60	9.15	0.08	98.17	1.91	18.67
OM	12.444	9.50-15.62	12.66	0.60	91.10	3.1	24.91
CP	16.192	11.64-18.81	13.64	0.15	97.78	4.50	27.79
FAT	3.658	2.95-4.69	14.69	0.00	99.96	1.10	30.26
CF	18.386	14.50-21.90	12.32	0.09	98.58	4.63	25.19
CARB	69.917	67.17-75.05	3.17	0.04	97.74	4.51	6.45
TSS	12.729	6.64-23.17	39.58	0.00	99.99	10.37	81.53
NFE	51.531	47.17-56.17	5.77	0.07	97.70	6.05	11.57
NDF	46.387	38.80-52.20	8.82	0.21	95.49	8.24	17.76
ADF	33.25	28.15-38.35	9.12	0.40	91.77	5.98	18.00
ADL	9.364	6.05-13.55	22.98	0.82	93.20	4.28	45.71
IVDMD	72.757	58.50-81.00	8.41	0.28	93.71	12.21	16.78
HEMI	13.137	4.90-20.30	31.74	1.39	91.79	8.23	62.64
CELL	23.886	20.70-26.90	6.55	1.39	68.10	2.66	11.14
DMI	2.607	2.30-3.09	9.13	0.22	95.39	0.47	18.38
DDM	62.998	59.03-66.97	3.75	0.16	91.78	4.66	7.40
RFV	127.465	105.21-157.3	10.97	0.25	95.51	28.15	22.08
pH	5.98	5.63-6.27	2.86	0.07	95.80	0.30	5.78
PHE	7.619	5.12-10.24	15.88	0.00	99.96	2.49	32.72
FLA	0.96	0.47-1.90	46.22	0.00	99.98	0.91	95.21
TAN	75.047	55.88-91.77	14.03	0.16	97.72	21.44	28.58
SAP	39.677	24.40-50.69	23.40	0.01	99.89	19.12	48.18
NIT	1545.14	793.0-2970.5	44.48	0.01	99.95	1415.69	91.6
OXA	1.627	1.12-2.42	21.91	0.47	95.86	0.71	44.19

Note: **DM** - Dry matter; **ASH** - Ash content; **OM** - Organic matter; **CP** - Crude protein; **FAT** - Crude fat; **CF** - Crude fibre; **CARB** - Total Carbohydrates; **TSS** - Total soluble sugar; **NFE** - Nitrogen free extract; **NDF** -Neutral detergent fibre; **ADF** - Acid detergent fibre; **ADL** - Acid detergent lignin; **IVDMD** - *In vitro* dry matter digestibility; **HEMI** - Hemicellulose; **CELL** - Cellulose; **DMI** - Dry matter intake; **DDM** - Digestible dry matter; **RFV** - Relative feed value; **pH**; **PHE** - Total phenols; **FLA** - Flavonoids; **TAN** - Tannins; **SAP** - Saponins; **NIT** - Nitrate; **OXA** - Oxalate

Table 4.23: Genetic variability estimates for minerals traits in tender leaves of *Moringa oleifera* seed sources

Parameter	Mean	Range	Coefficient of variation		Heritability (%)	Genetic Advance	Genetic gain (% of mean)
			Genotypic (%)	Enviornmental (%)			
N	23,774.86	14272.00-35552.00	29.22	0.08	99.45	14,272.25	60.03
P	2,307.79	1040.00-2590.00	27.83	0.07	99.46	1,165.18	57.17
K	10,909.21	6588.00-21721.00	32.70	0.29	98.25	7,285.57	66.78
Ca	1,569.64	964.00-3437.00	45.67	0.02	99.93	1,476.42	94.06
Mg	3,629.79	2241.00-6638.00	33.43	0.02	99.87	2,498.70	68.83
S	6,784.62	3356.00-9675.00	23.37	0.49	95.96	3,200.53	47.17
Fe	322.714	201.00-778.00	44.64	0.07	99.69	296.36	91.83
Zn	29.422	16.65-89.87	60.67	0.02	99.95	36.76	124.96
Cu	6.157	4.06-10.72	27.44	0.01	99.96	3.48	56.53
B	32.091	21.21-63.99	31.69	0.00	99.98	20.95	65.28
Mn	28.052	14.52-58.45	41.80	0.03	99.84	24.13	86.04
Ni	1.288	0.67-3.16	50.13	0.44	98.26	1.31	102.37
Na	597.429	331.00-892.00	32.68	0.41	97.54	397.25	66.49
Pb	4.378	1.16-14.54	106.80	0.00	99.99	9.63	220.00
Cd	0.099	0.07-0.28	27.73	5.27	70.62	0.04	48.02
Cr	2.566	1.71-7.18	53.90	0.01	99.96	2.84	111.03

Table 4.24: Genetic variability estimates for minerals traits in mature leaves of *Moringa oleifera* seed sources

Parameter	Mean	Range	Coefficient of variation		Heritability (%)	Genetic Advance	Genetic gain (% of mean)
			Genotypic (%)	Enviornmental (%)			
N	39202.86	30656.00-45920.00	11.72	0.27	95.60	9257.10	23.61
P	2147.357	1533.00-2557.00	11.89	0.13	97.91	520.63	24.24
K	12273.86	9859.00-16929.00	15.68	0.59	92.91	3821.84	31.13
Ca	2019.143	1513.00-3343.00	22.05	0.02	99.85	916.71	45.40
Mg	3926	3109.00-4903.00	12.35	0.04	99.37	996.06	25.37
S	7897.143	5825.00-9716.00	12.34	0.51	92.21	1928.08	24.41
Fe	404.857	258.00-736.00	33.00	0.09	99.47	274.52	67.80
Zn	27.747	17.03-54.74	32.63	0.02	99.84	18.63	67.17
Cu	6.127	4.63-7.55	15.62	0.01	99.88	1.97	32.16
B	41.168	31.21-51.39	15.09	0.00	99.97	12.79	31.08
Mn	30.488	20.94-44.18	20.18	0.05	99.52	12.64	41.49
Ni	1.297	0.67-1.97	30.03	0.24	98.42	0.79	61.37
Na	710.286	373.00-1476.00	47.05	0.25	98.93	684.85	96.41
Pb	3.033	1.61-12.68	94.30	0.01	99.98	5.89	194.25
Cd	0.12	0.08-0.28	50.23	1.68	93.63	0.12	100.12
Cr	2.985	1.93-4.20	23.64	0.02	99.81	1.45	48.66

It provides a good baseline for indirect selection especially for those below ground or biomass characters which requires destructive sampling. The amount of genetic gain obtained from indirect selection i.e. correlated response gives a better understanding of degree and magnitude of genetic association and must be given the due weightage while formulating the selection criteria in any tree improvement programme.

4.5.1 Correlation analysis for tender leaves

The genotypic and phenotypic correlations in all possible combinations among all the parameters viz., nutritional, fodder and antinutritional under study are provided in Table 4.25 and 4.26, respectively. In general, genotypic correlation coefficients were higher than corresponding phenotypic correlation coefficients for most of the traits studied. Dry matter showed positive significant, correlation with organic matter, crude fat, tannins and saponin while significant negatively correlated with cellulose both at genotypic and phenotypic level. Crude protein had positive correlation with crude fat, dry matter intake and relative feed value at genotypic level and with crude fat at phenotypic level. Carbohydrate and nitrogen free extract were negatively correlated with crude protein at phenotypic level. At both genotypic and phenotypic level crude fibre had high correlation with ADL, phenols and tannins whereas; carbohydrate showed positive correlation with nitrogen free extract and cellulose. NDF had high correlation with ADF, cellulose and oxalate and very low correlation with dry matter intake, digestible dry matter and relative feed value at both levels. However, ADF had positive correlation with ADL, cellulose and oxalate and negative correlation with dry matter intake, digestible dry matter and oxalate at genotypic and phenotypic levels. IVDMD had low correlation with cellulose and high correlation with dry matter intake, digestible dry matter and relative feed value. Nitrate had negative correlation with oxalate at both levels. Crude protein had very low correlation with antinutritional traits like nitrate and oxalate.

4.5.2 Correlation analysis for mature leaves

The genotypic and phenotypic correlations in all possible combinations among all the parameters viz., nutritional, fodder and antinutritional under study are presented in Table 4.27 and 4.28, respectively. In general, genotypic correlation coefficients were higher than corresponding phenotypic correlation coefficients for most of the traits. Dry matter had positive significant, correlation with organic matter, phenols and oxalate while significant negatively correlated with NDF, hemicelluloses and nitrate both at genotypic and phenotypic level. Crude protein had positive correlation with NDF and hemicelluloses, whereas, negatively correlated with carbohydrate, non-fibrous carbohydrate and nitrate at genotypic level and phenotypic level. At both genotypic and phenotypic level crude fibre had high correlation with cellulose and tannins and very low correlation with nitrogen free extract

whereas carbohydrate exhibited positive correlation with non-fibrous carbohydrates, nitrogen free extract and nitrate. NDF had high correlation with ADL and cellulose and very low correlation with dry matter intake and relative feed value at both levels. However, ADF had positive correlation with ADL and cellulose and negative correlation with digestible dry matter and relative feed value at genotypic and phenotypic levels. IVDMD had low correlation with saponin and high correlation with digestible dry matter and phenols. Crude protein had very low correlation with antinutritional traits like nitrate and oxalate.

There was a negative correlation between acid detergent fiber content and dry matter digestibility, which is in agreement with Mokoboki *et al* (2019) and Kamalak *et al* (2005). Minson (1990) also observed the negative correlation between ADF and digestibility. In contrast to this, the results reported by Repetto *et al* (2003) showed that ADF has the closest relationship with DMD. Negative correlation coefficient values in these browse species might be due to indigestible material such as cellulose and lignin that might have restricted DM digestibility. Substrate degradability can be reduced due to more lignifications of the plant cell wall (Du *et al* 2016).

4.5.3 Correlation analysis for twigs

The genotypic and phenotypic correlations in all possible combinations among all the parameters viz., nutritional, fodder and antinutritional under study are given in Table 4.29 and 4.30, respectively. In general, genotypic correlation coefficients were higher than corresponding phenotypic correlation coefficients for most of the traits. Dry matter had positive significant, correlation with organic matter and nitrate while significant negatively correlated with IVDMD both at genotypic and phenotypic level. Crude protein had positive correlation with crude fibre and ADL whereas negatively correlated with carbohydrates and nitrogen free extract at genotypic level and phenotypic level. At both genotypic and phenotypic level crude fibre exhibited high correlation with ADL and dry matter intake and very low correlation with nitrogen free extract, whereas, carbohydrate had positive correlation with non-fibrous carbohydrates, total soluble sugars and nitrogen free extract. NDF has high correlation with ADF, cellulose and flavonoids and very low correlation with dry matter intake, digestible dry matter and relative feed value at both levels. However, ADF had positive correlation with cellulose and flavonoid and negative correlation with dry matter intake, digestible dry matter and relative feed value at genotypic and phenotypic levels. IVDMD showed low correlation with nitrate and high correlation with hemicelluloses and flavonoids. Nitrate had positive correlation with oxalate at both levels. Crude protein had very low correlation with antinutritional traits however, had moderate negative with nitrate.

4.5.4 Correlation analysis for minerals in tender leaves

The genotypic and phenotypic correlations in all possible combinations among all the parameters under study are given in Table 4.31 and 4.32, respectively. In general, genotypic correlation coefficients were higher than corresponding phenotypic correlation coefficients for most of the traits. Nitrogen has positive significant, correlation with sodium and lead while significant negatively correlated with zinc, nickel and cadmium both at genotypic and phenotypic level. Phosphorus had positive correlation with potassium, sulphur and copper whereas negatively correlated with cadmium at genotypic level and phenotypic level. At both genotypic and phenotypic level potassium has high correlation with iron, zinc and chromium. Calcium has positive correlation with magnesium, boron and manganese. Magnesium has high correlation with boron and manganese and low correlation with cadmium at both levels. However, sulphur has positive correlation with iron and copper and negative correlation with cadmium at genotypic and phenotypic levels. Iron has high correlation with zinc, boron and chromium. Zinc and copper has positive correlation with boron and chromium. Manganese has low correlation with cadmium and high correlation with nickel and chromium at both levels.

4.5.5 Correlation analysis for minerals in mature leaves

The genotypic and phenotypic correlations in all possible combinations among all the parameters under study are given in Table 4.33 and 4.34, respectively. In general, genotypic correlation coefficients were higher than corresponding phenotypic correlation coefficients for most of the traits. Nitrogen has positive significant, correlation with phosphorus and lead while significant negatively correlated with iron and manganese both at genotypic and phenotypic level. Phosphorus had positive correlation with sulphur and copper whereas negatively correlated with calcium at genotypic level and phenotypic level. Potassium has high correlation with nickel, cadmium and chromium and low correlation with magnesium and sodium. Calcium has positive correlation with iron, boron and chromium and negative with sulphur. Magnesium has high correlation with zinc, sodium and lead. However, sulphur has positive correlation with copper and sodium and negative correlation with chromium at genotypic and phenotypic levels. Iron has high correlation with manganese and chromium. Zinc and copper has positive correlation with manganese and sodium. Manganese has high correlation with nickel and chromium at both levels. Cadmium has positive correlation with chromium.

Table 4.25: Genotypic correlations coefficients for tender leaves of *Moringa oleifera* seed sources

	DM	Ash	OM	CP	Fat	CF	Carb	TSS	NFE	NDF	ADF	ADL	IVDMD	Hemi	Cellu	DMI	DDM	RFV	pH	Phenoles	Flavonoid	Tannis	Saponin	Nitrate
Ash	0.195 ^{NS}																							
OM	0.921 ^{**}	-0.198 ^{NS}																						
CP	0.212 ^{NS}	-0.350 [*]	0.329 [*]																					
Fat	0.647 ^{**}	0.089 ^{NS}	0.592 ^{**}	0.669 ^{**}																				
CF	0.115 ^{NS}	-0.208 ^{NS}	0.207 ^{NS}	0.140 ^{NS}	-0.107 ^{NS}																			
Carb	-0.385 [*]	0.085 ^{NS}	-0.395 ^{**}	-0.949 ^{**}	-0.841 ^{**}	-0.050 ^{NS}																		
TSS	-0.373 [*]	-0.223 ^{NS}	-0.260 ^{NS}	-0.364 [*]	-0.649 ^{**}	0.157 ^{NS}	0.517 ^{**}																	
NFE	-0.396 ^{**}	0.134 ^{NS}	-0.431 ^{**}	-0.940 ^{**}	-0.773 ^{**}	-0.307 [*]	0.966 ^{**}	0.452 ^{**}																
NDF	-0.296 ^{NS}	0.442 ^{**}	-0.477 ^{**}	-0.545 ^{**}	-0.490 ^{**}	-0.033 ^{NS}	0.503 ^{**}	-0.073 ^{NS}	0.488 ^{**}															
ADF	-0.296 ^{NS}	0.437 ^{**}	-0.474 ^{**}	-0.561 ^{**}	-0.506 ^{**}	-0.012 ^{NS}	0.522 ^{**}	-0.025 ^{NS}	0.500 ^{**}	0.996 ^{**}														
ADL	0.103 ^{NS}	0.190 ^{NS}	0.007 ^{NS}	0.082 ^{NS}	0.027 ^{NS}	0.328 [*]	-0.111 ^{NS}	-0.318 [*]	-0.191 ^{NS}	0.613 ^{**}	0.603 ^{**}													
IVDMD	0.358 [*]	0.044 ^{NS}	0.354 [*]	0.302 ^{NS}	0.585 ^{**}	0.281 ^{NS}	-0.415 ^{**}	-0.390 [*]	-0.469 ^{**}	-0.541 ^{**}	-0.555 ^{**}	-0.311 [*]												
Hemi	0.232 ^{NS}	-0.309 [*]	0.356 [*]	0.555 ^{**}	0.508 ^{**}	-0.134 ^{NS}	-0.542 ^{**}	-0.309 [*]	-0.481 ^{**}	-0.766 ^{**}	-0.818 ^{**}	-0.414 ^{**}	0.534 ^{**}											
Cellu	-0.431 ^{**}	0.426 ^{**}	-0.593 ^{**}	-0.747 ^{**}	-0.645 ^{**}	-0.216 ^{NS}	0.717 ^{**}	0.164 ^{NS}	0.739 ^{**}	0.862 ^{**}	0.872 ^{**}	0.136 ^{NS}	-0.499 ^{**}	-0.762 ^{**}										
DMI	0.315 [*]	-0.445 ^{**}	0.496 ^{**}	0.577 ^{**}	0.490 ^{**}	0.081 ^{NS}	-0.529 ^{**}	0.060 ^{NS}	-0.525 ^{**}	-0.994 ^{**}	-0.991 ^{**}	-0.588 ^{**}	0.535 ^{**}	0.763 ^{**}	-0.870 ^{**}									
DDM	0.296 ^{NS}	-0.437 ^{**}	0.474 ^{**}	0.561 ^{**}	0.506 ^{**}	0.012 ^{NS}	-0.522 ^{**}	0.025 ^{NS}	-0.500 ^{**}	-0.996 ^{**}	-1.000 ^{**}	-0.603 ^{**}	0.555 ^{**}	0.818 ^{**}	-0.872 ^{**}	0.991 ^{**}								
RFV	0.314 [*]	-0.443 ^{**}	0.494 ^{**}	0.583 ^{**}	0.497 ^{**}	0.072 ^{NS}	-0.537 ^{**}	0.041 ^{NS}	-0.530 ^{**}	-0.993 ^{**}	-0.993 ^{**}	-0.586 ^{**}	0.541 ^{**}	0.783 ^{**}	-0.874 ^{**}	1.000 ^{**}	0.993 ^{**}							
pH	0.604 ^{**}	0.121 ^{NS}	0.549 ^{**}	0.177 ^{NS}	0.598 ^{**}	-0.337 [*]	-0.328 [*]	-0.335 [*]	-0.226 ^{NS}	-0.134 ^{NS}	-0.164 ^{NS}	0.151 ^{NS}	0.096 ^{NS}	0.335 [*]	-0.297 ^{NS}	0.130 ^{NS}	0.164 ^{NS}	0.142 ^{NS}						
Phenoles	0.182 ^{NS}	-0.054 ^{NS}	0.236 ^{NS}	-0.277 ^{NS}	-0.391 [*]	0.500 ^{**}	0.345 [*]	0.225 ^{NS}	0.199 ^{NS}	0.106 ^{NS}	0.110 ^{NS}	0.106 ^{NS}	-0.109 ^{NS}	-0.117 ^{NS}	0.072 ^{NS}	-0.084 ^{NS}	-0.110 ^{NS}	-0.088 ^{NS}	-0.124 ^{NS}					
Flavonoid	0.016 ^{NS}	-0.146 ^{NS}	0.060 ^{NS}	0.231 ^{NS}	-0.043 ^{NS}	0.078 ^{NS}	-0.155 ^{NS}	0.155 ^{NS}	-0.168 ^{NS}	0.027 ^{NS}	0.012 ^{NS}	0.322 [*]	-0.399 ^{**}	0.094 ^{NS}	-0.183 ^{NS}	-0.010 ^{NS}	-0.012 ^{NS}	-0.006 ^{NS}	0.348 [*]	0.364 [*]				
Tannis	0.734 ^{**}	0.028 ^{NS}	0.738 ^{**}	0.394 ^{**}	0.646 ^{**}	0.298 ^{NS}	-0.506 ^{**}	-0.060 ^{NS}	-0.559 ^{**}	-0.610 ^{**}	-0.583 ^{**}	-0.206 ^{NS}	0.560 ^{**}	0.275 ^{NS}	-0.597 ^{**}	0.628 ^{**}	0.583 ^{**}	0.618 ^{**}	0.418 ^{**}	0.193 ^{NS}	0.066 ^{NS}			
Saponin	0.536 ^{**}	-0.045 ^{NS}	0.541 ^{**}	0.440 ^{**}	0.519 ^{**}	-0.125 ^{NS}	-0.497 ^{**}	-0.058 ^{NS}	-0.442 ^{**}	-0.508 ^{**}	-0.538 ^{**}	-0.121 ^{NS}	0.205 ^{NS}	0.633 ^{**}	-0.594 ^{**}	0.477 ^{**}	0.538 ^{**}	0.488 ^{**}	0.522 ^{**}	-0.035 ^{NS}	0.417 ^{**}	0.432 ^{**}		
Nitrate	-0.376 [*]	-0.318 [*]	-0.251 ^{NS}	0.173 ^{NS}	0.041 ^{NS}	-0.197 ^{NS}	-0.097 ^{NS}	0.002 ^{NS}	-0.041 ^{NS}	-0.182 ^{NS}	-0.233 ^{NS}	-0.044 ^{NS}	0.075 ^{NS}	0.531 ^{**}	-0.263 ^{NS}	0.168 ^{NS}	0.233 ^{NS}	0.188 ^{NS}	0.308 [*]	-0.366 [*]	0.157 ^{NS}	-0.292 ^{NS}	0.141 ^{NS}	
Oxalate	0.071 ^{NS}	0.188 ^{NS}	-0.010 ^{NS}	-0.455 ^{**}	-0.157 ^{NS}	-0.020 ^{NS}	0.387 [*]	-0.388 [*]	0.374 [*]	0.691 ^{**}	0.700 ^{**}	0.392 [*]	-0.192 ^{NS}	-0.615 ^{**}	0.629 ^{**}	-0.672 ^{**}	-0.700 ^{**}	-0.675 ^{**}	0.041 ^{NS}	0.138 ^{NS}	-0.225 ^{NS}	-0.241 ^{NS}	-0.626 ^{**}	-0.364 [*]

Table 4.26: Phenotypic correlations coefficients for tender leaves of *Moringa oleifera* seed sources

	DM	Ash	OM	CP	Fat	CF	Carb	TSS	NFE	NDF	ADF	ADL	IVDMD	Hemi	Cellu	DMI	DDM	RFV	pH	Phenoles	Flavonoid	Tannis	Saponin	Nitrate
Ash	0.206 ^{NS}																							
OM	0.926 ^{**}	-0.171 ^{NS}																						
CP	0.214 ^{NS}	-0.346 [*]	0.329 [*]																					
Fat	0.616 ^{**}	0.089 ^{NS}	0.569 ^{**}	0.667 ^{**}																				
CF	0.110 ^{NS}	-0.193 ^{NS}	0.197 ^{NS}	0.137 ^{NS}	-0.101 ^{NS}																			
Carb	-0.380 [*]	0.080 ^{NS}	-0.394 ^{**}	-0.949 ^{**}	-0.839 ^{**}	-0.052 ^{NS}																		
TSS	-0.356 [*]	-0.223 ^{NS}	-0.250 ^{NS}	-0.361 [*]	-0.649 ^{**}	0.154 ^{NS}	0.515 ^{**}																	
NFE	-0.390 [*]	0.129 ^{NS}	-0.427 ^{**}	-0.937 ^{**}	-0.768 ^{**}	-0.320 [*]	0.963 ^{**}	0.447 ^{**}																
NDF	-0.292 ^{NS}	0.428 ^{**}	-0.466 ^{**}	-0.541 ^{**}	-0.484 ^{**}	-0.031 ^{NS}	0.501 ^{**}	-0.073 ^{NS}	0.483 ^{**}															
ADF	-0.299 ^{NS}	0.421 ^{**}	-0.470 ^{**}	-0.557 ^{**}	-0.500 ^{**}	-0.005 ^{NS}	0.520 ^{**}	-0.024 ^{NS}	0.494 ^{**}	0.995 ^{**}														
ADL	0.109 ^{NS}	0.188 ^{NS}	0.021 ^{NS}	0.085 ^{NS}	0.027 ^{NS}	0.334 [*]	-0.113 ^{NS}	-0.311 [*]	-0.198 ^{NS}	0.600 ^{**}	0.591 ^{**}													
IVDMD	0.346 [*]	0.054 ^{NS}	0.347 [*]	0.300 ^{NS}	0.569 ^{**}	0.282 ^{NS}	-0.411 ^{**}	-0.376 [*]	-0.466 ^{**}	-0.543 ^{**}	-0.553 ^{**}	-0.286 ^{NS}												
Hemi	0.269 ^{NS}	-0.264 ^{NS}	0.368 [*]	0.512 ^{**}	0.467 ^{**}	-0.156 ^{NS}	-0.502 ^{**}	-0.290 ^{NS}	-0.434 ^{**}	-0.700 ^{**}	-0.769 ^{**}	-0.376 [*]	0.467 ^{**}											
Cellu	-0.435 ^{**}	0.403 ^{**}	-0.591 ^{**}	-0.737 ^{**}	-0.632 ^{**}	-0.211 ^{NS}	0.709 ^{**}	0.160 ^{NS}	0.730 ^{**}	0.858 ^{**}	0.870 ^{**}	0.116 ^{NS}	-0.505 ^{**}	-0.717 ^{**}										
DMI	0.312 [*]	-0.426 ^{**}	0.486 ^{**}	0.569 ^{**}	0.480 ^{**}	0.072 ^{NS}	-0.524 ^{**}	0.059 ^{NS}	-0.516 ^{**}	-0.993 ^{**}	-0.988 ^{**}	-0.571 ^{**}	0.539 ^{**}	0.695 ^{**}	-0.867 ^{**}									
DDM	0.300 ^{NS}	-0.421 ^{**}	0.470 ^{**}	0.557 ^{**}	0.500 ^{**}	0.005 ^{NS}	-0.520 ^{**}	0.024 ^{NS}	-0.494 ^{**}	-0.995 ^{**}	-1.000 ^{**}	-0.591 ^{**}	0.553 ^{**}	0.769 ^{**}	-0.870 ^{**}	0.988 ^{**}								
RFV	0.315 [*]	-0.423 ^{**}	0.487 ^{**}	0.576 ^{**}	0.488 ^{**}	0.062 ^{NS}	-0.532 ^{**}	0.040 ^{NS}	-0.521 ^{**}	-0.992 ^{**}	-0.991 ^{**}	-0.569 ^{**}	0.544 ^{**}	0.721 ^{**}	-0.872 ^{**}	0.999 ^{**}	0.991 ^{**}							
pH	0.566 ^{**}	0.115 ^{NS}	0.521 ^{**}	0.175 ^{NS}	0.594 ^{**}	-0.326 [*]	-0.324 [*]	-0.333 [*]	-0.220 ^{NS}	-0.130 ^{NS}	-0.159 ^{NS}	0.148 ^{NS}	0.095 ^{NS}	0.295 ^{NS}	-0.286 ^{NS}	0.126 ^{NS}	0.159 ^{NS}	0.136 ^{NS}						
Phenoles	0.171 ^{NS}	-0.054 ^{NS}	0.224 ^{NS}	-0.277 ^{NS}	-0.391 [*]	0.474 ^{**}	0.345 [*]	0.225 ^{NS}	0.199 ^{NS}	0.105 ^{NS}	0.109 ^{NS}	0.103 ^{NS}	-0.108 ^{NS}	-0.106 ^{NS}	0.072 ^{NS}	-0.083 ^{NS}	-0.109 ^{NS}	-0.087 ^{NS}	-0.123 ^{NS}					
Flavonoid	0.017 ^{NS}	-0.145 ^{NS}	0.059 ^{NS}	0.231 ^{NS}	-0.043 ^{NS}	0.074 ^{NS}	-0.155 ^{NS}	0.155 ^{NS}	-0.167 ^{NS}	0.026 ^{NS}	0.011 ^{NS}	0.317 [*]	-0.388 [*]	0.088 ^{NS}	-0.180 ^{NS}	-0.010 ^{NS}	-0.011 ^{NS}	-0.006 ^{NS}	0.346 [*]	0.364 [*]				
Tannis	0.696 ^{**}	0.031 ^{NS}	0.705 ^{**}	0.391 [*]	0.643 ^{**}	0.281 ^{NS}	-0.503 ^{**}	-0.060 ^{NS}	-0.553 ^{**}	-0.607 ^{**}	-0.579 ^{**}	-0.210 ^{NS}	0.544 ^{**}	0.253 ^{NS}	-0.584 ^{**}	0.621 ^{**}	0.579 ^{**}	0.612 ^{**}	0.412 ^{**}	0.193 ^{NS}	0.066 ^{NS}			
Saponin	0.511 ^{**}	-0.044 ^{NS}	0.520 ^{**}	0.439 ^{**}	0.519 ^{**}	-0.124 ^{NS}	-0.496 ^{**}	-0.058 ^{NS}	-0.437 ^{**}	-0.503 ^{**}	-0.534 ^{**}	-0.121 ^{NS}	0.201 ^{NS}	0.584 ^{**}	-0.583 ^{**}	0.470 ^{**}	0.534 ^{**}	0.481 ^{**}	0.520 ^{**}	-0.035 ^{NS}	0.417 ^{**}	0.431 ^{**}		
Nitrate	-0.358 [*]	-0.316 [*]	-0.241 ^{NS}	0.173 ^{NS}	0.041 ^{NS}	-0.186 ^{NS}	-0.097 ^{NS}	0.002 ^{NS}	-0.042 ^{NS}	-0.180 ^{NS}	-0.231 ^{NS}	-0.043 ^{NS}	0.073 ^{NS}	0.487 ^{**}	-0.258 ^{NS}	0.165 ^{NS}	0.231 ^{NS}	0.184 ^{NS}	0.305 [*]	-0.366 [*]	0.157 ^{NS}	-0.291 ^{NS}	0.140 ^{NS}	
Oxalate	0.056 ^{NS}	0.181 ^{NS}	-0.014 ^{NS}	-0.437 ^{**}	-0.150 ^{NS}	-0.038 ^{NS}	0.372 [*]	-0.375 [*]	0.363 [*]	0.666 ^{**}	0.675 ^{**}	0.375 [*]	-0.181 ^{NS}	-0.557 ^{**}	0.602 ^{**}	-0.640 ^{**}	-0.675 ^{**}	-0.645 ^{**}	0.046 ^{NS}	0.133 ^{NS}	-0.219 ^{NS}	-0.232 ^{NS}	-0.608 ^{**}	-0.354 [*]

Table 4.27: Genotypic correlations coefficients for mature leaves of *Moringa oleifera* seed sources

	DM	Ash	OM	CP	Fat	CF	Carb	TSS	NFE	NDF	ADF	ADL	IVDMD	Hemi	Cellu	DMI	DDM	RFV	pH	Phenoles	Flavonoid	Tannis	Saponin	Nitrate
Ash	0.213 ^{NS}																							
OM	0.968**	-0.038 ^{NS}																						
CP	0.056 ^{NS}	0.018 ^{NS}	0.052 ^{NS}																					
Fat	0.284 ^{NS}	-0.177 ^{NS}	0.336*	-0.577**																				
CF	0.375*	-0.313*	0.464**	0.342*	0.352*																			
Carb	-0.169 ^{NS}	-0.153 ^{NS}	-0.134 ^{NS}	-0.971**	0.426**	-0.411**																		
TSS	-0.074 ^{NS}	-0.641**	0.088 ^{NS}	-0.430**	0.258 ^{NS}	0.195 ^{NS}	0.526**																	
NFE	-0.321*	0.090 ^{NS}	-0.352*	-0.789**	0.053 ^{NS}	-0.833**	0.846**	0.205 ^{NS}																
NDF	-0.072 ^{NS}	-0.314*	0.007 ^{NS}	-0.029 ^{NS}	-0.233 ^{NS}	-0.340*	0.144 ^{NS}	0.238 ^{NS}	0.286 ^{NS}															
ADF	0.083 ^{NS}	-0.299 ^{NS}	0.162 ^{NS}	0.067 ^{NS}	-0.123 ^{NS}	-0.109 ^{NS}	0.008 ^{NS}	0.284 ^{NS}	0.069 ^{NS}	0.907**														
ADL	0.234 ^{NS}	0.259 ^{NS}	0.173 ^{NS}	0.263 ^{NS}	-0.051 ^{NS}	0.312*	-0.325*	-0.334*	-0.379*	-0.207 ^{NS}	-0.146 ^{NS}													
IVDMD	-0.397**	0.192 ^{NS}	-0.455**	-0.218 ^{NS}	-0.212 ^{NS}	-0.379*	0.260 ^{NS}	0.070 ^{NS}	0.379*	0.057 ^{NS}	-0.152 ^{NS}	0.450**												
Hemi	-0.349*	-0.100 ^{NS}	-0.332*	-0.213 ^{NS}	-0.286 ^{NS}	-0.572**	0.324*	-0.047 ^{NS}	0.530**	0.419**	-0.002 ^{NS}	-0.177 ^{NS}	0.464**											
Cellu	-0.053 ^{NS}	-0.368*	0.040 ^{NS}	-0.080 ^{NS}	-0.072 ^{NS}	-0.244 ^{NS}	0.171 ^{NS}	0.394**	0.246 ^{NS}	0.823**	0.866**	-0.622**	-0.348*	0.088 ^{NS}										
DMI	0.067 ^{NS}	0.325*	-0.015 ^{NS}	0.044 ^{NS}	0.207 ^{NS}	0.338*	-0.156 ^{NS}	-0.262 ^{NS}	-0.292 ^{NS}	-0.995**	-0.940**	0.222 ^{NS}	-0.028 ^{NS}	-0.335*	-0.857**									
DDM	-0.083 ^{NS}	0.299 ^{NS}	-0.162 ^{NS}	-0.067 ^{NS}	0.123 ^{NS}	0.109 ^{NS}	-0.008 ^{NS}	-0.284 ^{NS}	-0.069 ^{NS}	-0.907**	-1.000**	0.146 ^{NS}	0.152 ^{NS}	0.002 ^{NS}	-0.866**	0.940**								
RFV	0.018 ^{NS}	0.315*	-0.062 ^{NS}	0.015 ^{NS}	0.173 ^{NS}	0.268 ^{NS}	-0.114 ^{NS}	-0.276 ^{NS}	-0.225 ^{NS}	-0.972**	-0.980**	0.203 ^{NS}	0.038 ^{NS}	-0.195 ^{NS}	-0.879**	0.989**	0.980**							
pH	-0.373*	-0.135 ^{NS}	-0.347*	-0.124 ^{NS}	0.167 ^{NS}	0.098 ^{NS}	0.120 ^{NS}	0.123 ^{NS}	0.016 ^{NS}	0.001 ^{NS}	0.199 ^{NS}	-0.143 ^{NS}	-0.234 ^{NS}	-0.426**	0.230 ^{NS}	-0.035 ^{NS}	-0.199 ^{NS}	-0.101 ^{NS}						
Phenoles	0.121 ^{NS}	-0.091 ^{NS}	0.147 ^{NS}	-0.277 ^{NS}	-0.128 ^{NS}	-0.021 ^{NS}	0.355*	0.177 ^{NS}	0.227 ^{NS}	-0.124 ^{NS}	-0.211 ^{NS}	0.289 ^{NS}	0.248 ^{NS}	0.161 ^{NS}	-0.314*	0.145 ^{NS}	0.212 ^{NS}	0.177 ^{NS}	-0.128 ^{NS}					
Flavonoid	-0.320*	-0.012 ^{NS}	-0.324*	0.218 ^{NS}	-0.431**	-0.479**	-0.135 ^{NS}	-0.167 ^{NS}	0.198 ^{NS}	0.649**	0.616**	0.089 ^{NS}	0.361*	0.213 ^{NS}	0.443**	-0.649**	-0.616**	-0.643**	0.230 ^{NS}	-0.191 ^{NS}				
Tannis	-0.008 ^{NS}	-0.207 ^{NS}	0.045 ^{NS}	-0.420**	0.442**	0.245 ^{NS}	0.394**	0.494**	0.096 ^{NS}	-0.133 ^{NS}	-0.166 ^{NS}	0.124 ^{NS}	0.279 ^{NS}	0.043 ^{NS}	-0.194 ^{NS}	0.154 ^{NS}	0.166 ^{NS}	0.166 ^{NS}	0.387*	0.261 ^{NS}	-0.123 ^{NS}			
Saponin	0.139 ^{NS}	0.302 ^{NS}	0.065 ^{NS}	-0.613**	0.486**	-0.141 ^{NS}	0.508**	0.142 ^{NS}	0.391*	-0.046 ^{NS}	-0.003 ^{NS}	0.062 ^{NS}	0.214 ^{NS}	-0.103 ^{NS}	-0.034 ^{NS}	0.035 ^{NS}	0.003 ^{NS}	0.021 ^{NS}	0.013 ^{NS}	-0.029 ^{NS}	-0.170 ^{NS}	0.151 ^{NS}		
Nitrate	0.454**	0.365*	0.371*	0.033 ^{NS}	0.350*	0.243 ^{NS}	-0.187 ^{NS}	-0.380*	-0.255 ^{NS}	-0.058 ^{NS}	0.168 ^{NS}	-0.048 ^{NS}	-0.637**	-0.501**	0.157 ^{NS}	0.040 ^{NS}	-0.168 ^{NS}	-0.035 ^{NS}	0.236 ^{NS}	-0.338*	-0.193 ^{NS}	-0.271 ^{NS}	0.417**	
Oxalate	0.258 ^{NS}	-0.275 ^{NS}	0.335*	-0.387*	0.394**	-0.071 ^{NS}	0.381*	0.016 ^{NS}	0.273 ^{NS}	0.023 ^{NS}	-0.153 ^{NS}	-0.105 ^{NS}	-0.290 ^{NS}	0.383*	-0.067 ^{NS}	-0.010 ^{NS}	0.152 ^{NS}	0.049 ^{NS}	0.089 ^{NS}	0.085 ^{NS}	-0.161 ^{NS}	0.235 ^{NS}	0.025 ^{NS}	0.084 ^{NS}

Table 4.28: Phenotypic correlations coefficients for mature leaves of *Moringa oleifera* seed sources

	DM	Ash	OM	CP	Fat	CF	Carb	TSS	NFE	NDF	ADF	ADL	IVDMD	Hemi	Cellu	DMI	DDM	RFV	pH	Phenoles	Flavonoid	Tannis	Saponin	Nitrate
Ash	0.176 ^{NS}																							
OM	0.969**	-0.075 ^{NS}																						
CP	0.066 ^{NS}	-0.003 ^{NS}	0.068 ^{NS}																					
Fat	0.273 ^{NS}	-0.168 ^{NS}	0.319*	-0.566**																				
CF	0.368*	-0.305*	0.449**	0.341*	0.350*																			
Carb	-0.170 ^{NS}	-0.134 ^{NS}	-0.138 ^{NS}	-0.972**	0.418**	-0.408**																		
TSS	-0.068 ^{NS}	-0.623**	0.089 ^{NS}	-0.419**	0.257 ^{NS}	0.195 ^{NS}	0.513**																	
NFE	-0.317*	0.095 ^{NS}	-0.345*	-0.793**	0.054 ^{NS}	-0.829**	0.849**	0.202 ^{NS}																
NDF	-0.065 ^{NS}	-0.301 ^{NS}	0.010 ^{NS}	-0.027 ^{NS}	-0.228 ^{NS}	-0.327*	0.138 ^{NS}	0.234 ^{NS}	0.274 ^{NS}															
ADF	0.041 ^{NS}	-0.249 ^{NS}	0.104 ^{NS}	0.086 ^{NS}	-0.115 ^{NS}	-0.084 ^{NS}	-0.023 ^{NS}	0.259 ^{NS}	0.034 ^{NS}	0.836**														
ADL	0.256 ^{NS}	0.225 ^{NS}	0.203 ^{NS}	0.260 ^{NS}	-0.049 ^{NS}	0.308*	-0.316*	-0.319*	-0.372*	-0.175 ^{NS}	-0.122 ^{NS}													
IVDMD	-0.379*	0.188 ^{NS}	-0.431**	-0.194 ^{NS}	-0.205 ^{NS}	-0.366*	0.231 ^{NS}	0.065 ^{NS}	0.354*	0.066 ^{NS}	-0.107 ^{NS}	0.440**												
Hemi	-0.185 ^{NS}	-0.105 ^{NS}	-0.161 ^{NS}	-0.195 ^{NS}	-0.207 ^{NS}	-0.435**	0.285 ^{NS}	-0.030 ^{NS}	0.426**	0.335*	-0.237 ^{NS}	-0.099 ^{NS}	0.301 ^{NS}											
Cellu	-0.095 ^{NS}	-0.313*	-0.017 ^{NS}	-0.060 ^{NS}	-0.069 ^{NS}	-0.221 ^{NS}	0.139 ^{NS}	0.368*	0.213 ^{NS}	0.763**	0.870**	-0.596**	-0.305*	-0.142 ^{NS}										
DMI	0.064 ^{NS}	0.309*	-0.013 ^{NS}	0.042 ^{NS}	0.202 ^{NS}	0.324*	-0.150 ^{NS}	-0.256 ^{NS}	-0.279 ^{NS}	-0.994**	-0.867**	0.187 ^{NS}	-0.039 ^{NS}	-0.271 ^{NS}	-0.794**									
DDM	-0.041 ^{NS}	0.249 ^{NS}	-0.104 ^{NS}	-0.086 ^{NS}	0.115 ^{NS}	0.084 ^{NS}	0.023 ^{NS}	-0.259 ^{NS}	-0.034 ^{NS}	-0.836**	-1.000**	0.122 ^{NS}	0.107 ^{NS}	0.237 ^{NS}	-0.870**	0.867**								
RFV	0.029 ^{NS}	0.293 ^{NS}	-0.044 ^{NS}	0.007 ^{NS}	0.168 ^{NS}	0.252 ^{NS}	-0.100 ^{NS}	-0.268 ^{NS}	-0.207 ^{NS}	-0.965**	-0.942**	0.174 ^{NS}	0.019 ^{NS}	-0.092 ^{NS}	-0.848**	0.983**	0.942**							
pH	-0.334*	-0.155 ^{NS}	-0.299 ^{NS}	-0.099 ^{NS}	0.162 ^{NS}	0.102 ^{NS}	0.099 ^{NS}	0.123 ^{NS}	0.001 ^{NS}	0.012 ^{NS}	0.201 ^{NS}	-0.111 ^{NS}	-0.213 ^{NS}	-0.324*	0.218 ^{NS}	-0.045 ^{NS}	-0.201 ^{NS}	-0.110 ^{NS}						
Phenoles	0.114 ^{NS}	-0.091 ^{NS}	0.139 ^{NS}	-0.271 ^{NS}	-0.128 ^{NS}	-0.021 ^{NS}	0.346*	0.177 ^{NS}	0.224 ^{NS}	-0.123 ^{NS}	-0.195 ^{NS}	0.272 ^{NS}	0.238 ^{NS}	0.116 ^{NS}	-0.293 ^{NS}	0.143 ^{NS}	0.195 ^{NS}	0.173 ^{NS}	-0.125 ^{NS}					
Flavonoid	-0.307*	-0.012 ^{NS}	-0.308*	0.214 ^{NS}	-0.431**	-0.477**	-0.132 ^{NS}	-0.167 ^{NS}	0.195 ^{NS}	0.637**	0.566**	0.086 ^{NS}	0.349*	0.157 ^{NS}	0.415**	-0.634**	-0.566**	-0.627**	0.226 ^{NS}	-0.190 ^{NS}				
Tannis	-0.006 ^{NS}	-0.197 ^{NS}	0.043 ^{NS}	-0.406**	0.439**	0.242 ^{NS}	0.379*	0.490**	0.092 ^{NS}	-0.118 ^{NS}	-0.167 ^{NS}	0.131 ^{NS}	0.267 ^{NS}	0.078 ^{NS}	-0.200 ^{NS}	0.136 ^{NS}	0.166 ^{NS}	0.155 ^{NS}	0.378*	0.258 ^{NS}	-0.122 ^{NS}			
Saponin	0.133 ^{NS}	0.288 ^{NS}	0.062 ^{NS}	-0.597**	0.485**	-0.141 ^{NS}	0.494**	0.142 ^{NS}	0.385*	-0.045 ^{NS}	-0.005 ^{NS}	0.058 ^{NS}	0.206 ^{NS}	-0.072 ^{NS}	-0.033 ^{NS}	0.034 ^{NS}	0.005 ^{NS}	0.021 ^{NS}	0.013 ^{NS}	-0.028 ^{NS}	-0.170 ^{NS}	0.151 ^{NS}		
Nitrate	0.435**	0.354*	0.352*	0.030 ^{NS}	0.350*	0.242 ^{NS}	-0.180 ^{NS}	-0.380*	-0.250 ^{NS}	-0.056 ^{NS}	0.154 ^{NS}	-0.044 ^{NS}	-0.614**	-0.363*	0.146 ^{NS}	0.038 ^{NS}	-0.154 ^{NS}	-0.034 ^{NS}	0.230 ^{NS}	-0.338*	-0.193 ^{NS}	-0.269 ^{NS}	0.417**	
Oxalate	0.255 ^{NS}	-0.272 ^{NS}	0.327*	-0.370*	0.387*	-0.064 ^{NS}	0.366*	0.017 ^{NS}	0.261 ^{NS}	0.029 ^{NS}	-0.157 ^{NS}	-0.099 ^{NS}	-0.302 ^{NS}	0.320*	-0.078 ^{NS}	-0.016 ^{NS}	0.156 ^{NS}	0.049 ^{NS}	0.097 ^{NS}	0.082 ^{NS}	-0.158 ^{NS}	0.238 ^{NS}	0.024 ^{NS}	0.082 ^{NS}

Table 4.29: Genotypic correlations coefficients for twigs of *Moringa oleifera* seed sources

	DM	Ash	OM	CP	Fat	CF	Carb	TSS	NFE	NDF	ADF	ADL	IVDMD	Hemi	Cellu	DMI	DDM	RFV	pH	Phenoles	Flavonoid	Tannis	Saponin	Nitrate
Ash	0.437**																							
OM	0.845**	-0.111 ^{NS}																						
CP	-0.017 ^{NS}	-0.031 ^{NS}	0.000 ^{NS}																					
Fat	0.062 ^{NS}	-0.191 ^{NS}	0.182 ^{NS}	-0.344*																				
CF	-0.123 ^{NS}	0.023 ^{NS}	-0.150 ^{NS}	-0.107 ^{NS}	-0.092 ^{NS}																			
Carb	-0.183 ^{NS}	-0.345*	0.003 ^{NS}	-0.901**	0.181 ^{NS}	0.119 ^{NS}																		
TSS	-0.424**	-0.038 ^{NS}	-0.446**	-0.242 ^{NS}	0.063 ^{NS}	-0.397**	0.242 ^{NS}																	
NFE	-0.042 ^{NS}	-0.275 ^{NS}	0.116 ^{NS}	-0.590**	0.205 ^{NS}	-0.673**	0.654**	0.483**																
NDF	-0.472**	-0.061 ^{NS}	-0.485**	0.338*	0.182 ^{NS}	-0.119 ^{NS}	-0.355*	0.395**	-0.174 ^{NS}															
ADF	-0.068 ^{NS}	0.195 ^{NS}	-0.191 ^{NS}	-0.021 ^{NS}	0.009 ^{NS}	0.176 ^{NS}	-0.063 ^{NS}	0.187 ^{NS}	-0.181 ^{NS}	0.345*														
ADL	-0.242 ^{NS}	0.078 ^{NS}	-0.314*	0.131 ^{NS}	0.020 ^{NS}	-0.103 ^{NS}	-0.168 ^{NS}	0.365*	-0.047 ^{NS}	0.670**	0.872**													
IVDMD	-0.148 ^{NS}	0.258 ^{NS}	-0.317*	0.021 ^{NS}	-0.425**	-0.203 ^{NS}	-0.027 ^{NS}	0.312*	0.135 ^{NS}	-0.005 ^{NS}	-0.342*	-0.306*												
Hemi	-0.414**	-0.202 ^{NS}	-0.337*	0.347*	0.172 ^{NS}	-0.245 ^{NS}	-0.303 ^{NS}	0.252 ^{NS}	-0.039 ^{NS}	0.730**	-0.389*	0.024 ^{NS}	0.244 ^{NS}											
Cellu	0.201 ^{NS}	0.270 ^{NS}	0.062 ^{NS}	-0.221 ^{NS}	-0.011 ^{NS}	0.482**	0.108 ^{NS}	-0.140 ^{NS}	-0.287 ^{NS}	-0.253 ^{NS}	0.739**	0.315*	-0.243 ^{NS}	-0.786**										
DMI	0.472**	0.088 ^{NS}	0.469**	-0.347*	-0.211 ^{NS}	0.098 ^{NS}	0.359*	-0.395**	0.193 ^{NS}	-0.996**	-0.331*	-0.652**	0.015 ^{NS}	-0.737**	0.254 ^{NS}									
DDM	0.068 ^{NS}	-0.194 ^{NS}	0.191 ^{NS}	0.021 ^{NS}	-0.009 ^{NS}	-0.176 ^{NS}	0.063 ^{NS}	-0.187 ^{NS}	0.181 ^{NS}	-0.345*	-1.000**	-0.872**	0.342*	0.389*	-0.739**	0.331*								
RFV	0.405**	0.005 ^{NS}	0.445**	-0.284 ^{NS}	-0.179 ^{NS}	0.010 ^{NS}	0.324*	-0.387*	0.234 ^{NS}	-0.947**	-0.616**	-0.840**	0.133 ^{NS}	-0.481**	-0.039 ^{NS}	0.947**	0.616**							
pH	-0.207 ^{NS}	-0.157 ^{NS}	-0.135 ^{NS}	-0.232 ^{NS}	0.106 ^{NS}	0.402**	0.272 ^{NS}	0.136 ^{NS}	-0.103 ^{NS}	0.018 ^{NS}	0.500**	0.305*	-0.454**	-0.346*	0.550**	-0.014 ^{NS}	-0.500**	-0.177 ^{NS}						
Phenoles	0.505**	0.536**	0.240 ^{NS}	-0.021 ^{NS}	-0.514**	0.290 ^{NS}	-0.081 ^{NS}	-0.105 ^{NS}	-0.281 ^{NS}	-0.241 ^{NS}	0.002 ^{NS}	-0.139 ^{NS}	0.294 ^{NS}	-0.238 ^{NS}	0.194 ^{NS}	0.265 ^{NS}	-0.002 ^{NS}	0.208 ^{NS}	-0.221 ^{NS}					
Flavonoid	-0.413**	-0.744**	-0.015 ^{NS}	-0.057 ^{NS}	0.161 ^{NS}	-0.161 ^{NS}	0.333*	0.296 ^{NS}	0.370*	-0.051 ^{NS}	0.009 ^{NS}	0.147 ^{NS}	-0.285 ^{NS}	-0.057 ^{NS}	-0.183 ^{NS}	0.017 ^{NS}	-0.010 ^{NS}	0.013 ^{NS}	0.114 ^{NS}	-0.496**				
Tannis	0.270 ^{NS}	0.527**	-0.014 ^{NS}	0.228 ^{NS}	-0.057 ^{NS}	0.388*	-0.436**	-0.137 ^{NS}	-0.620**	0.034 ^{NS}	-0.285 ^{NS}	-0.357*	0.282 ^{NS}	0.241 ^{NS}	-0.061 ^{NS}	-0.056 ^{NS}	0.285 ^{NS}	0.038 ^{NS}	-0.039 ^{NS}	0.409**	-0.654**			
Saponin	-0.183 ^{NS}	-0.253 ^{NS}	-0.053 ^{NS}	0.067 ^{NS}	0.309*	0.295 ^{NS}	-0.035 ^{NS}	-0.500**	-0.251 ^{NS}	0.144 ^{NS}	-0.046 ^{NS}	0.062 ^{NS}	-0.591**	0.175 ^{NS}	-0.175 ^{NS}	-0.168 ^{NS}	0.046 ^{NS}	-0.126 ^{NS}	0.222 ^{NS}	-0.551**	0.123 ^{NS}	-0.043 ^{NS}		
Nitrate	-0.414**	-0.412**	-0.213 ^{NS}	-0.638**	0.344*	-0.014 ^{NS}	0.727**	0.485**	0.552**	0.173 ^{NS}	-0.249 ^{NS}	-0.144 ^{NS}	0.256 ^{NS}	0.351*	-0.284 ^{NS}	-0.189 ^{NS}	0.249 ^{NS}	-0.072 ^{NS}	0.050 ^{NS}	-0.226 ^{NS}	0.192 ^{NS}	-0.118 ^{NS}	-0.061 ^{NS}	
Oxalate	0.582**	0.515**	0.337*	0.104 ^{NS}	0.421**	-0.142 ^{NS}	-0.423**	-0.011 ^{NS}	-0.208 ^{NS}	0.067 ^{NS}	0.070 ^{NS}	0.064 ^{NS}	0.011 ^{NS}	0.014 ^{NS}	0.048 ^{NS}	-0.088 ^{NS}	-0.070 ^{NS}	-0.112 ^{NS}	-0.256 ^{NS}	0.185 ^{NS}	-0.263 ^{NS}	0.472**	-0.135 ^{NS}	-0.264 ^{NS}

Table 4.30: Phenotypic correlations coefficients for twigs of *Moringa oleifera* seed sources

	DM	Ash	OM	CP	Fat	CF	Carb	TSS	NFE	NDF	ADF	ADL	IVDMD	Hemi	Cellu	DMI	DDM	RFV	pH	Phenoles	Flavonoid	Tannis	Saponin	Nitrate
Ash	0.430**																							
OM	0.856**	-0.098 ^{NS}																						
CP	-0.008 ^{NS}	-0.034 ^{NS}	0.010 ^{NS}																					
Fat	0.061 ^{NS}	-0.189 ^{NS}	0.175 ^{NS}	-0.339*																				
CF	-0.104 ^{NS}	0.020 ^{NS}	-0.126 ^{NS}	-0.102 ^{NS}	-0.089 ^{NS}																			
Carb	-0.188 ^{NS}	-0.342*	-0.011 ^{NS}	-0.901**	0.178 ^{NS}	0.115 ^{NS}																		
TSS	-0.406**	-0.038 ^{NS}	-0.426**	-0.239 ^{NS}	0.063 ^{NS}	-0.394**	0.240 ^{NS}																	
NFE	-0.061 ^{NS}	-0.270 ^{NS}	0.087 ^{NS}	-0.594**	0.201 ^{NS}	-0.673**	0.658**	0.477**																
NDF	-0.455**	-0.069 ^{NS}	-0.462**	0.321*	0.178 ^{NS}	-0.112 ^{NS}	-0.333*	0.388*	-0.163 ^{NS}															
ADF	-0.063 ^{NS}	0.209 ^{NS}	-0.190 ^{NS}	-0.021 ^{NS}	0.008 ^{NS}	0.149 ^{NS}	-0.069 ^{NS}	0.179 ^{NS}	-0.164 ^{NS}	0.325*														
ADL	-0.267 ^{NS}	0.058 ^{NS}	-0.327*	0.121 ^{NS}	0.020 ^{NS}	-0.096 ^{NS}	-0.149 ^{NS}	0.354*	-0.039 ^{NS}	0.665**	0.807**													
IVDMD	-0.152 ^{NS}	0.257 ^{NS}	-0.315*	0.025 ^{NS}	-0.413**	-0.213 ^{NS}	-0.035 ^{NS}	0.302 ^{NS}	0.136 ^{NS}	-0.001 ^{NS}	-0.285 ^{NS}	-0.279 ^{NS}												
Hemi	-0.392*	-0.219 ^{NS}	-0.307*	0.324*	0.166 ^{NS}	-0.217 ^{NS}	-0.270 ^{NS}	0.243 ^{NS}	-0.037 ^{NS}	0.726**	-0.415**	0.052 ^{NS}	0.206 ^{NS}											
Cellu	0.208 ^{NS}	0.281 ^{NS}	0.068 ^{NS}	-0.177 ^{NS}	-0.010 ^{NS}	0.361*	0.061 ^{NS}	-0.117 ^{NS}	-0.228 ^{NS}	-0.238 ^{NS}	0.721**	0.173 ^{NS}	-0.147 ^{NS}	-0.753**										
DMI	0.454**	0.093 ^{NS}	0.447**	-0.328*	-0.206 ^{NS}	0.092 ^{NS}	0.337*	-0.388*	0.181 ^{NS}	-0.996**	-0.312*	-0.644**	0.009 ^{NS}	-0.731**	0.236 ^{NS}									
DDM	0.063 ^{NS}	-0.209 ^{NS}	0.190 ^{NS}	0.021 ^{NS}	-0.008 ^{NS}	-0.149 ^{NS}	0.069 ^{NS}	-0.179 ^{NS}	0.164 ^{NS}	-0.325*	-1.000**	-0.807**	0.285 ^{NS}	0.415**	-0.720**	0.312*								
RFV	0.389*	0.002 ^{NS}	0.428**	-0.268 ^{NS}	-0.175 ^{NS}	0.014 ^{NS}	0.308*	-0.380*	0.219 ^{NS}	-0.943**	-0.609**	-0.819**	0.110 ^{NS}	-0.464**	-0.055 ^{NS}	0.943**	0.609**							
pH	-0.191 ^{NS}	-0.140 ^{NS}	-0.131 ^{NS}	-0.231 ^{NS}	0.102 ^{NS}	0.384*	0.265 ^{NS}	0.133 ^{NS}	-0.094 ^{NS}	0.007 ^{NS}	0.485**	0.282 ^{NS}	-0.424**	-0.346*	0.479**	-0.003 ^{NS}	-0.485**	-0.168 ^{NS}						
Phenoles	0.483**	0.532**	0.229 ^{NS}	-0.020 ^{NS}	-0.514**	0.287 ^{NS}	-0.081 ^{NS}	-0.105 ^{NS}	-0.278 ^{NS}	-0.236 ^{NS}	0.003 ^{NS}	-0.136 ^{NS}	0.287 ^{NS}	-0.229 ^{NS}	0.166 ^{NS}	0.259 ^{NS}	-0.004 ^{NS}	0.203 ^{NS}	-0.216 ^{NS}					
Flavonoid	-0.395**	-0.737**	-0.013 ^{NS}	-0.057 ^{NS}	0.161 ^{NS}	-0.160 ^{NS}	0.329*	0.296 ^{NS}	0.366*	-0.050 ^{NS}	0.008 ^{NS}	0.141 ^{NS}	-0.277 ^{NS}	-0.054 ^{NS}	-0.152 ^{NS}	0.018 ^{NS}	-0.009 ^{NS}	0.013 ^{NS}	0.111 ^{NS}	-0.496**				
Tannis	0.255 ^{NS}	0.527**	-0.021 ^{NS}	0.216 ^{NS}	-0.057 ^{NS}	0.377*	-0.424**	-0.136 ^{NS}	-0.602**	0.032 ^{NS}	-0.255 ^{NS}	-0.354*	0.275 ^{NS}	0.216 ^{NS}	-0.009 ^{NS}	-0.055 ^{NS}	0.255 ^{NS}	0.031 ^{NS}	-0.040 ^{NS}	0.406**	-0.646**			
Saponin	-0.179 ^{NS}	-0.250 ^{NS}	-0.054 ^{NS}	0.065 ^{NS}	0.309*	0.290 ^{NS}	-0.034 ^{NS}	-0.500**	-0.245 ^{NS}	0.139 ^{NS}	-0.043 ^{NS}	0.057 ^{NS}	-0.567**	0.164 ^{NS}	-0.138 ^{NS}	-0.163 ^{NS}	0.043 ^{NS}	-0.122 ^{NS}	0.218 ^{NS}	-0.550**	0.123 ^{NS}	-0.041 ^{NS}		
Nitrate	-0.395**	-0.408**	-0.202 ^{NS}	-0.632**	0.344*	-0.013 ^{NS}	0.720**	0.485**	0.546**	0.172 ^{NS}	-0.239 ^{NS}	-0.138 ^{NS}	0.246 ^{NS}	0.339*	-0.237 ^{NS}	-0.186 ^{NS}	0.239 ^{NS}	-0.071 ^{NS}	0.048 ^{NS}	-0.226 ^{NS}	0.192 ^{NS}	-0.115 ^{NS}	-0.062 ^{NS}	
Oxalate	0.544**	0.492**	0.319*	0.101 ^{NS}	0.412**	-0.133 ^{NS}	-0.407**	-0.011 ^{NS}	-0.202 ^{NS}	0.061 ^{NS}	0.043 ^{NS}	0.066 ^{NS}	-0.009 ^{NS}	0.028 ^{NS}	-0.006 ^{NS}	-0.081 ^{NS}	-0.043 ^{NS}	-0.096 ^{NS}	-0.233 ^{NS}	0.179 ^{NS}	-0.257 ^{NS}	0.456**	-0.134 ^{NS}	-0.256 ^{NS}

Table 4.31: Genotypic correlations coefficients for mineral for tender leaves of *Moringa oleifera* seed sources

	N	P	K	Ca	Mg	S	Fe	Zn	Cu	B	Mn	Ni	Na	Pb	Cd
P	-0.202 ^{NS}														
K	-0.368 [*]	0.890 ^{**}													
Ca	-0.283 ^{NS}	0.322 [*]	0.564 ^{**}												
Mg	-0.227 ^{NS}	0.451 ^{**}	0.578 ^{**}	0.956 ^{**}											
S	-0.124 ^{NS}	0.977 ^{**}	0.788 ^{**}	0.140 ^{NS}	0.307 [*]										
Fe	-0.297 ^{NS}	0.797 ^{**}	0.945 ^{**}	0.728 ^{**}	0.731 ^{**}	0.661 ^{**}									
Zn	-0.396 ^{**}	0.758 ^{**}	0.910 ^{**}	0.663 ^{**}	0.632 ^{**}	0.593 ^{**}	0.908 ^{**}								
Cu	-0.220 ^{NS}	0.908 ^{**}	0.869 ^{**}	0.561 ^{**}	0.654 ^{**}	0.843 ^{**}	0.868 ^{**}	0.775 ^{**}							
B	-0.211 ^{NS}	0.662 ^{**}	0.762 ^{**}	0.777 ^{**}	0.794 ^{**}	0.501 ^{**}	0.881 ^{**}	0.871 ^{**}	0.753 ^{**}						
Mn	-0.190 ^{NS}	0.412 ^{**}	0.548 ^{**}	0.957 ^{**}	0.966 ^{**}	0.251 ^{NS}	0.730 ^{**}	0.640 ^{**}	0.641 ^{**}	0.831 ^{**}					
Ni	-0.497 ^{**}	0.574 ^{**}	0.836 ^{**}	0.620 ^{**}	0.516 ^{**}	0.416 ^{**}	0.851 ^{**}	0.806 ^{**}	0.704 ^{**}	0.636 ^{**}	0.554 ^{**}				
Na	0.318 [*]	0.140 ^{NS}	-0.100 ^{NS}	0.215 ^{NS}	0.422 ^{**}	0.183 ^{NS}	0.014 ^{NS}	-0.152 ^{NS}	0.220 ^{NS}	0.174 ^{NS}	0.430 ^{**}	-0.261 ^{NS}			
Pb	0.337 [*]	0.033 ^{NS}	-0.003 ^{NS}	-0.049 ^{NS}	0.018 ^{NS}	0.063 ^{NS}	0.137 ^{NS}	-0.015 ^{NS}	0.102 ^{NS}	0.183 ^{NS}	-0.032 ^{NS}	-0.113 ^{NS}	0.044 ^{NS}		
Cd	-0.413 ^{**}	-0.352 [*]	-0.190 ^{NS}	-0.121 ^{NS}	-0.269 ^{NS}	-0.384 [*]	-0.168 ^{NS}	-0.122 ^{NS}	-0.171 ^{NS}	-0.356 [*]	-0.204 ^{NS}	0.301 ^{NS}	-0.321 [*]	-0.206 ^{NS}	
Cr	-0.301 ^{NS}	0.753 ^{**}	0.910 ^{**}	0.762 ^{**}	0.730 ^{**}	0.592 ^{**}	0.957 ^{**}	0.940 ^{**}	0.851 ^{**}	0.903 ^{**}	0.760 ^{**}	0.855 ^{**}	-0.031 ^{NS}	0.028 ^{NS}	-0.161 ^{NS}

Table 4.32: Phenotypic correlations coefficients for mineral for tender leaves of *Moringa oleifera* seed sources

	N	P	K	Ca	Mg	S	Fe	Zn	Cu	B	Mn	Ni	Na	Pb	Cd
P	-0.199 ^{NS}														
K	-0.359*	0.879**													
Ca	-0.282 ^{NS}	0.322*	0.557**												
Mg	-0.226 ^{NS}	0.450**	0.573**	0.955**											
S	-0.122 ^{NS}	0.960**	0.765**	0.137 ^{NS}	0.304 ^{NS}										
Fe	-0.295 ^{NS}	0.794**	0.939**	0.726**	0.730**	0.652**									
Zn	-0.395**	0.756**	0.903**	0.663**	0.631**	0.582**	0.907**								
Cu	-0.220 ^{NS}	0.905**	0.862**	0.561**	0.654**	0.825**	0.866**	0.775**							
B	-0.210 ^{NS}	0.660**	0.756**	0.776**	0.793**	0.490**	0.879**	0.870**	0.753**						
Mn	-0.189 ^{NS}	0.410**	0.544**	0.955**	0.965**	0.241 ^{NS}	0.728**	0.640**	0.641**	0.831**					
Ni	-0.496**	0.567**	0.819**	0.615**	0.512**	0.405**	0.841**	0.798**	0.698**	0.630**	0.547**				
Na	0.313*	0.135 ^{NS}	-0.105 ^{NS}	0.214 ^{NS}	0.415**	0.166 ^{NS}	0.009 ^{NS}	-0.150 ^{NS}	0.219 ^{NS}	0.171 ^{NS}	0.425**	-0.258 ^{NS}			
Pb	0.336*	0.033 ^{NS}	-0.003 ^{NS}	-0.049 ^{NS}	0.018 ^{NS}	0.061 ^{NS}	0.137 ^{NS}	-0.015 ^{NS}	0.102 ^{NS}	0.183 ^{NS}	-0.032 ^{NS}	-0.112 ^{NS}	0.042 ^{NS}		
Cd	-0.341*	-0.289 ^{NS}	-0.162 ^{NS}	-0.102 ^{NS}	-0.220 ^{NS}	-0.337*	-0.151 ^{NS}	-0.111 ^{NS}	-0.149 ^{NS}	-0.303 ^{NS}	-0.177 ^{NS}	0.278 ^{NS}	-0.300 ^{NS}	-0.173 ^{NS}	
Cr	-0.300 ^{NS}	0.751**	0.902**	0.762**	0.730**	0.579**	0.955**	0.940**	0.851**	0.903**	0.760**	0.847**	-0.030 ^{NS}	0.028 ^{NS}	-0.135 ^{NS}

Table 4.33: Genotypic correlations coefficients for mineral for mature leaves of *Moringa oleifera* seed sources

	N	P	K	Ca	Mg	S	Fe	Zn	Cu	B	Mn	Ni	Na	Pb	Cd
P	0.147 ^{NS}														
K	-0.360*	0.152 ^{NS}													
Ca	-0.373*	-0.653**	-0.185 ^{NS}												
Mg	-0.022 ^{NS}	0.082 ^{NS}	-0.532**	0.374*											
S	0.040 ^{NS}	0.745**	-0.108 ^{NS}	-0.573**	0.215 ^{NS}										
Fe	-0.421**	-0.076 ^{NS}	0.192 ^{NS}	0.429**	0.299 ^{NS}	-0.019 ^{NS}									
Zn	-0.075 ^{NS}	0.219 ^{NS}	-0.108 ^{NS}	0.025 ^{NS}	0.547**	0.301 ^{NS}	0.722**								
Cu	-0.265 ^{NS}	0.613**	0.114 ^{NS}	-0.164 ^{NS}	0.242 ^{NS}	0.576**	0.391*	0.343*							
B	-0.142 ^{NS}	-0.296 ^{NS}	-0.062 ^{NS}	0.561**	-0.017 ^{NS}	-0.367*	0.369*	-0.115 ^{NS}	0.045 ^{NS}						
Mn	-0.557**	-0.133 ^{NS}	0.236 ^{NS}	0.399**	0.328*	0.050 ^{NS}	0.834**	0.614**	0.376*	0.217 ^{NS}					
Ni	-0.291 ^{NS}	-0.076 ^{NS}	0.432**	0.390*	-0.042 ^{NS}	-0.176 ^{NS}	0.748**	0.284 ^{NS}	0.229 ^{NS}	0.583**	0.471**				
Na	-0.057 ^{NS}	0.292 ^{NS}	-0.469**	-0.059 ^{NS}	0.560**	0.444**	0.335*	0.614**	0.444**	0.165 ^{NS}	0.385*	-0.143 ^{NS}			
Pb	0.400**	-0.016 ^{NS}	-0.191 ^{NS}	0.026 ^{NS}	0.428**	0.067 ^{NS}	0.043 ^{NS}	0.035 ^{NS}	-0.071 ^{NS}	0.026 ^{NS}	0.033 ^{NS}	0.019 ^{NS}	0.049 ^{NS}		
Cd	-0.004 ^{NS}	-0.115 ^{NS}	0.391*	0.067 ^{NS}	-0.297 ^{NS}	-0.228 ^{NS}	0.380*	-0.048 ^{NS}	0.296 ^{NS}	0.324*	0.035 ^{NS}	0.642**	-0.308*	0.146 ^{NS}	
Cr	-0.375*	-0.212 ^{NS}	0.486**	0.467**	-0.087 ^{NS}	-0.301 ^{NS}	0.784**	0.264 ^{NS}	0.165 ^{NS}	0.626**	0.526**	0.963**	-0.108 ^{NS}	-0.023 ^{NS}	0.654**

Table 4.34: Phenotypic correlations coefficients for mineral for mature leaves of *Moringa oleifera* seed sources

	N	P	K	Ca	Mg	S	Fe	Zn	Cu	B	Mn	Ni	Na	Pb	Cd
P	0.125 ^{NS}														
K	-0.358 [*]	0.137 ^{NS}													
Ca	-0.363 [*]	-0.646 ^{**}	-0.177 ^{NS}												
Mg	-0.021 ^{NS}	0.080 ^{NS}	-0.514 ^{**}	0.372 [*]											
S	0.036 ^{NS}	0.718 ^{**}	-0.095 ^{NS}	-0.546 ^{**}	0.212 ^{NS}										
Fe	-0.403 ^{**}	-0.076 ^{NS}	0.176 ^{NS}	0.428 ^{**}	0.297 ^{NS}	-0.021 ^{NS}									
Zn	-0.069 ^{NS}	0.214 ^{NS}	-0.107 ^{NS}	0.025 ^{NS}	0.546 ^{**}	0.290 ^{NS}	0.720 ^{**}								
Cu	-0.257 ^{NS}	0.607 ^{**}	0.107 ^{NS}	-0.164 ^{NS}	0.242 ^{NS}	0.555 ^{**}	0.389 [*]	0.343 [*]							
B	-0.140 ^{NS}	-0.293 ^{NS}	-0.058 ^{NS}	0.560 ^{**}	-0.017 ^{NS}	-0.354 [*]	0.368 [*]	-0.115 ^{NS}	0.044 ^{NS}						
Mn	-0.537 ^{**}	-0.133 ^{NS}	0.217 ^{NS}	0.396 ^{**}	0.328 [*]	0.045 ^{NS}	0.830 ^{**}	0.613 ^{**}	0.375 [*]	0.217 ^{NS}					
Ni	-0.272 ^{NS}	-0.074 ^{NS}	0.409 ^{**}	0.389 [*]	-0.037 ^{NS}	-0.157 ^{NS}	0.742 ^{**}	0.281 ^{NS}	0.229 ^{NS}	0.578 ^{**}	0.467 ^{**}				
Na	-0.046 ^{NS}	0.284 ^{NS}	-0.449 ^{**}	-0.058 ^{NS}	0.559 ^{**}	0.436 ^{**}	0.336 [*]	0.611 ^{**}	0.442 ^{**}	0.163 ^{NS}	0.381 [*]	-0.134 ^{NS}			
Pb	0.391 [*]	-0.015 ^{NS}	-0.184 ^{NS}	0.027 ^{NS}	0.427 ^{**}	0.066 ^{NS}	0.043 ^{NS}	0.035 ^{NS}	-0.071 ^{NS}	0.026 ^{NS}	0.033 ^{NS}	0.020 ^{NS}	0.049 ^{NS}		
Cd	-0.008 ^{NS}	-0.108 ^{NS}	0.334 [*]	0.062 ^{NS}	-0.288 ^{NS}	-0.216 ^{NS}	0.366 [*]	-0.044 ^{NS}	0.284 ^{NS}	0.314 [*]	0.044 ^{NS}	0.610 ^{**}	-0.305 [*]	0.142 ^{NS}	
Cr	-0.363 [*]	-0.209 ^{NS}	0.462 ^{**}	0.466 ^{**}	-0.085 ^{NS}	-0.288 ^{NS}	0.782 ^{**}	0.264 ^{NS}	0.165 ^{NS}	0.625 ^{**}	0.525 ^{**}	0.956 ^{**}	-0.105 ^{NS}	-0.023 ^{NS}	0.631 ^{**}

CHAPTER V

SUMMARY

In the era of chemical revolution, human being and livestock are totally dependent on junk foods and synthetic supplements for their body growth, mental and physical health; and milk and meat production. However, because of arising adverse effect of synthetic foods on body development and arising resistance against the standard medicines, human consideration has been moved towards the incorporation of natural plant products and herbal medications. *Moringa oleifera* is only plant which is considered as bowl of supplements and wide range of phytochemical ingredients and minerals. *Moringa oleifera* Lam. is marvel tree have a place with monogeneric genera of family Moringaceae and native to north-western India and widely cultivated plant due to its vary fast growth, wider adoptability, having tolerance against droughts and moderately tolerance against frost. *Moringa oleifera* is a multi-purpose plant with an enormous assortment of potential uses which improves human and cattle health alongside has ecological significance in various manners. Each and every plant part is utilized in, for example, human food, medicines, fodder, manure, therapeutic properties, bio-sorbent, coagulant specialist, biodiesel, and other uses. It is striking for high amount of supplements and mineral enhancements, for instance, proteins, dietary strands, essential amino acids, Ca, Fe, and so on with a quality comparable to that of meat, milk, eggs, beats, and so on. It is an established fact that nutritional composition of *M. oleifera* plant parts varies with the geographical location due to varying factors of locality. Besides, the nutritional composition varies with genotypes, phenophases, agronomic practices, environment, fertigation techniques and drying methods and storage conditions of plant parts. Apart from these factors, level of nutrients and mineral concentration are also influenced by the seasons. Keeping in view all these facts, present study entitled, “Evaluation of *Moringa oleifera* Lam. seed sources for nutritional value and mineral content” was conducted with following objectives:

- 1) To study variations among seed sources of *Moringa oleifera* for nutritional value and mineral content
- 2) To study variations among seed sources of *Moringa oleifera* for fodder and antinutritional characteristics

In the present study, a total of 14 seed sources were studied for nutritional values, fodder quality and mineral contents. Out of 14 seed sources, 5 were national varieties, 5 local genotypes from PAU, Ludhiana and rest from different states of the country. Samples of 12 seed sources were collected from the evaluation trial established since August 2017 at spacing of 3.5×2.0 m in three replications with plot size of 5 plants following Complete Randomized Block Design (CRBD). Samples of S13 was collected from plant growing at Forestry Research Farm of Department of Forestry and Natural Resources at Ludhiana, while S14 was

collected from the plant grown in PAU residential area. The samples of all three phenophases viz., tender leaves, mature leaves and twigs, were collected in last week of August 2020 for analysis. Samples were dried in shade for 6-7 days followed by in oven at 105⁰C for 7 days or until achieved constant dry matter weight. Studies on dry matter, ash content, organic matter, nutritional characterisation (crude protein, crude fats, crude fibres, carbohydrates, non-fibrous carbohydrates, NFE, total energy for food), fodder traits (NDF, ADF, ADL, IVDMD, DMI, DDM and RFV) and antinutritional traits (total phenols, flavonoides, tannin, saponin, nitrate and oxalate) were carried out in Forage and Millet Section, PBG, while mineral elements (N, P, K, Ca, Mg, S, Fe, Na, B, Mn, Ni, Cu, Zn, Pb, Cd and Cr) were determined by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) in Department of Soil Science, PAU Ludhiana. All nutritional, mineral, fodder and antinutritional characteristics were then subjected to Analysis of variance, genetic variability and correlation studies using CPCS1 and OPSTAT softwares.

The tender leaves of seed source S13 (PAU-4) registered maximum mean value (21.12 g/100g) for dry matter which was statistically at par with S14 (20.71 g/100g) (PAU- 5) and S12 (Mysore, Karnataka) (20.04 g/100g). The highest mean value for ash content was registered in S7 (PKM-2, Tamil Nadu) (11.27 g/100g), followed by S1 (11.24 g/100g) and S13 (11.13 g/100g). The maximum value for organic matter was recorded in local seed sources S10 (10.75 g/100g) (CAZRI, Jodhpur, Rajasthan) which was at par S12 (12.70 g/100g), S14 (10.56 g/100g), S13 (9.99 g/100g) and S9 (9.70 g/100g). For crude protein the maximum value was recorded in S12 (Mysore, Karnataka) (22.22 g/100g DM) which was followed by S9 (19.86 g/100g DM) and S10 (18.64 g/100g DM). Highest content for the crude fat was observed in local seed source S14 (5.73 g/100g DM) followed by S13 (5.63 g/100g DM), S12 (4.50 g/100g DM) and S8 (4.20 g/100g DM). The largest value for crude fibre was observed in S12 (20.95 g/100g DM) followed by S4 (19.10 g/100g DM), S11 (19.05 g/100g DM) and S2 (18.80 g/100g DM). Local variety S5 (PAU-2) had highest mean value for total carbohydrate content (79.19 g/100g DM) and followed by S3 (78.56 g/100g DM), S4 (77.60 g/100g DM) and S2 (76.82 g/100g DM). The maximum content for total Soluble Sugar was registered in Gujarat seed source S3 (Dantiwara) (11.49 g/100g DM) trailed by S2 (11.33 g/100g DM), S1 (11.27 g/100g DM) and S4 (11.12 g/100g DM). The highest value for nitrogen free extract was recorded in seed source S3 (61.31 g/100g DM) which was at par with S5 (61.04 g/100g DM), whereas the lowest mean value was observed in S12 (42.99 g/100g DM). The average value of total energy ranged in between 363.24 to 388.07 kcal/100g. The local seed source S14 (PAU-5) possessed the extreme value (388.07 kcal/100g) followed by S12 (385.14 kcal/100g), S10 (384.67 kcal/100g) and S9 (384.23 kcal/100g).

The mature leaves of seed source S13 (PAU-4) registered maximum mean value (22.69 g/100g) for dry matter and it was followed by S14 (21.81 g/100g), S8 (20.84 g/100g) and S12 (20.49 g/100g). The highest mean value for ash content was registered in S13 (12.08 g/100g) followed by S7 (11.93 g/100g). The highest value of organic matter was recorded in local seed sources S14 (11.06 g/100g) which was at par with S13 (10.61 g/100g). For crude protein the maximum value was observed in S9 (ODC-3, Tamil Nadu) (28.70 g/100g DM) which was followed by S12 (28.09 g/100g DM). Highest content for the crude fat was observed in two seed source S2 and S14 (5.87 g/100g DM) and they were followed by S13 (5.83 g/100g DM), S8 (5.70 g/100g DM) and S1 (5.17 g/100g DM). The highest value for crude fibre was recorded in S12 (28.15 g/100g DM) followed by S2 (27.80 g/100g DM), S8 (27.50 g/100g DM) and S4 (27.15 g/100g DM). Local variety S14 (PAU-5) registered highest mean value for carbohydrate content (64.22 g/100g DM) followed by S2 (62.00 g/100g DM), S3 (61.57 g/100g DM) and S1 (60.85 g/100g DM). The maximal content for total soluble sugar was registered in S2 (Konkan Ruchika, Dapoli) (9.48 g/100g DM) succeeded by S1 (8.38 g/100g DM), S11 (7.46 g/100g DM) and S14 (6.99 g/100g DM). The highest value for nitrogen free extract was recorded in seed source S14 (41.02 g/100g DM) which was at par with S3 (39.72 g/100g DM) and S6 (39.43 g/100g DM), whereas the lowest mean value was observed in S12 (27.86 g/100g DM). The mean values of total energy ranged from 374.11-386.33 kcal/100g. The local seed source S14 (PAU-5) possessed the extreme value (386.33 kcal/100g) which was at par with S2 (386.05 kcal/100g) and S8 (385.54 kcal/100g).

The twigs of *M. oleifera* leaves of seed source S6 registered maximum mean value (26.80 g/100g) for dry matter followed by S14 (25.34 g/100g), S13 (24.53 g/100g) and S4 (23.41 g/100g). The highest mean value for ash content was registered in local varieties S13 (PAU-4) (11.60 g/100g), followed by S5 (11.53 g/100g). The largest value of organic matter was recorded in local seed sources S6 (15.62 g/100g) followed by S14 (14.47 g/100g), S2 (14.37 g/100g) and S8 (13.23 g/100g). The maximum value for crude protein was observed in S9 ODC-3, Tamil Nadu (18.81 g/100g DM) which was followed by S12 (18.64 g/100g DM). The highest content for the crude fat was observed in local seed source S14 (4.69 g/100g DM) followed by S2 (4.40 g/100g DM), S13 (4.08 g/100g DM) and S8 (3.99 g/100g DM). The largest value for crude fibre was recorded in S12 (20.95 g/100g DM) followed by S1 (21.90 g/100g DM), followed by S13 (20.70 g/100g DM) and S11 (20.40 g/100g DM). The seed source S2 registered highest mean value for carbohydrate content (75.05 g/100g DM) succeeded by S1 (73.03 g/100g DM), S3 (71.75 g/100g DM) and S4 (71.37 g/100g DM). The maximal content for total soluble sugar was registered in local seed source S4 (PAU-1) (23.17 g/100g DM) followed S7 (21.06 g/100g DM), S1 (18.88 g/100g DM) and S11 (14.59 g/100g DM). The highest value for nitrogen free extract was recorded in seed source S4 (56.17

g/100g DM) which was statistically at par with S3 (56.05 g/100g DM), whereas the least value was observed in S13 (47.17 g/100g DM). The average total energy value ranged in between of 371.15 and 386.32 kcal/100g. The local seed source S2 possessed the extreme value (386.32 kcal/100g) which was at par with S8 (385.47 kcal/100g).

The leaves of *M. oleifera* can be a good fodder substitute as it possesses good quality fodder characteristics. The tender leaves possessed fair amount of fodder parameters. The seed source S5 registered maximum mean value of NDF content (47.65 g/100g DM) followed by S7 (44.95 g/100g DM), S4 (40.95 g/100g DM) and S6 (39.95 g/100g DM). The average value for ADF and ADL content ranged from 18.70-37.55 g/100g DM and 2.95-12.55 g/100g DM. The highest mean value for IVDMD content was registered in local source S14 (78.50 %) which was at par with two seed sources S2 (77.30 %) and S8 (77.30 %). The largest value of hemicelluloses was recorded in S8 (12.75 g/100g DM) which was at par with S9 (12.55 g/100g DM) and S13 (12.09 g/100g DM), whereas the lowest mean value was observed in S5 (10.10 g/100g DM). The seed source S5 registered maximum mean value (28.75 g/100g DM) for cellulose content followed by S6 (25.55 g/100g DM), S7 (21.60 g/100g DM) and S3 (20.55 g/100g DM). The maximum value for DMI, DDM and RFV was noticed in source S11 (Mandya, Karnataka) (3.96 g/100g DM), (74.33 g/100g DM) and (228.30 g/100g DM). The tender leaves of moringa possessed lower concentration of anti-nutritional factors which is best for fodder characteristics. Tender leaves had more phenol concentration than mature and twig. Flavonoid content ranged from 0.58-3.56 mg/g. The lowest content for tannin and saponin was noticed in local seed source S5 (PAU-3) (91.18 µg/g) and (27.28 µg/g). The average content of nitrate ranged from 435.50-3198.00 µg/g with least amount in S13 (435.50 µg/g). Very low amount of oxalate content was observed in tender leaves ranging from 1.69-4.16%.

The mature leaves have good amount of fodder parameters. The local seed source S6 (PAU-3) registered maximum mean value of NDF content (51.05 g/100g DM) followed by S8 (43.55 g/100g DM), S9 (43.20 g/100g DM) and S2 (42.40 g/100g DM). The average value for ADF and ADL content ranged from 22.85-34.18 g/100g DM and 6.25-13.95 g/100g DM. The highest mean value for IVDMD content was registered in local source S5 (PAU-2) (81.90 %) followed by S4 (81.50 %), S6 (81.35 %), S2 (81.10 %) and S7 (80.40 %). The maximum value of hemicelluloses was recorded in S6 (16.88 g/100g DM) followed by S14 (14.70 g/100g DM), whereas the lowest mean value was observed in S2 (10.65 g/100g DM). The seed source S6 registered maximum mean value (24.93 g/100g DM) for cellulose content followed by S8 (24.10 g/100g DM) and S9 (23.15 g/100g DM). The highest value for DMI, DDM and RFV was noticed in variety S12 (Mysore, Karnataka) (3.24 g/100g DM), (71.10 g/100g DM) and (178.84 g/100g DM). The mature leaves of moringa contained low amount of anti-nutritional factors which is good for fodder characteristics. The flavonoid content

ranged from 0.60-2.47 mg/g. The minimum content for tannin and saponin was observed in seed source S10 (114.12 µg/g) and S11 (44.07 µg/g). The nitrate content ranged from 910.00-3718.00 µg/g with least amount was found in S5 (910.00 µg/g). Oxalate was observed in very low content ranging from 1.29-3.38% with minimum value was seen in Gujarat seed source S3 (1.29%).

The twigs showed good amount of fodder characteristics. The seed source S7 registered maximum mean value of NDF content (52.20 g/100g DM) followed by S12 (51.80 g/100g DM). The average value for ADF and ADL content ranged from 28.15-38.35 g/100g DM and 6.05-13.55 g/100g DM. The highest mean value for IVDMD content was registered in seed source S5 (81.00 %) which was followed by S4 (80.60 %), S1 (80.10 %) and S8 (79.60 %). The highest value of hemicellulose was recorded in S6 (26.90 g/100g DM) succeeded by S8 (17.85 g/100g DM), S4 (16.75 g/100g DM) and S9 (15.60 g/100g DM), whereas the lowest mean value was observed in S6 (4.90 g/100g DM). The local seed source S6 registered maximum mean value (26.90 g/100g DM) and minimum content in S12 (20.70 g/100g DM) for cellulose content. The highest value for DMI, DDM and RFV was noticed in variety S5 (3.09 g/100g DM), S8 (66.97 g/100g DM) and S7 (105.21 g/100g DM). The twigs of moringa possessed lower value of anti-nutritional factors which is best for fodder characteristics. The flavonoid content ranged from 0.47-1.90 mg/g. The lowest content for tannin and saponin was noticed in local seed source S7 (55.88 µg/g) and S6 (24.40 µg/g). The average content of nitrate ranged from 793.00-2970.50 µg/g with least amount in S11 (793.00 µg/g). Very low amount of oxalate content was observed in twigs of *M. oleifera* ranging from 1.12-2.42% with minimum value in S10 (CAZRI, Jodhpur, Rajasthan) seed source (1.12%).

The good amount of mineral content was present in the tender leaves of moringa leaves. The mean values of N ranged from 14272.00-35552.00 mg/kg with highest amount in seed source S12 (35552.00 mg/kg) followed by S9 (31776.00 mg/kg), S10 (29816.00 mg/kg) and S7 (27856.00 mg/kg). The largest content of P was observed in S8 (2590.00 mg/kg) which was at par with seed source S3 (2534.00 mg/kg). The average K content for tender leaves ranged from 6588.00-21721.00 mg/kg. The maximum value for Ca was recorded in local seed source S6 (3437.00 mg/kg) which was followed by S14 (2873.0 mg/kg), S1 (1698.00 mg/kg) and S7 (1659.00 mg/kg). The norm values of Mg ranged from 2241.00-6638.00 mg/kg with highest value in local source S6 (6638.00 mg/kg) and lowest content in S4 (2241.00 mg/kg). The maximum value for the S and Fe was observed in local seed source S6 (PAU-3) (9675.00 mg/kg) and (778.00 mg/kg). The maximum value for Na and B was noticed in local seed source S14 (PAU-5) (892.00 mg/kg) and (S6 PAU-3), whereas the norm values for Mn ranged from 14.52-58.45 mg/kg. The local seed source S6 (PAU-3) possessed more content of Ni, Cu and Zn. In general, the Ni, Cu and heavy metal (i.e. Pb, Cd and Cr) content was quite low in tender and mature leaves (< 10 mg/kg). The lowest value for Cd was

observed in source S12 (0.07 mg/kg) and Cr in S10 (CAZRI, Jodhpur, Rajasthan) (1.71mg/kg).

The mature leaves of moringa leaves possessed significant amount of mineral content. The mean values of N ranged from 30656.00-45920.00 mg/kg with highest amount in seed source S9 (45920.00 mg/kg) followed by S12 (44936.00 mg/kg). The largest content of P was observed in S2 (2557.00 mg/kg) followed by S5 (2425.00 mg/kg), S12 (2378.00 mg/kg) and S3 (2279.00 mg/kg). The average K content was for tender leaves ranged from 9859.00-16929.00 mg/kg. The maximum value for Ca was recorded in local seed source S13 (PAU-4) (3343.00 mg/kg) followed by S11 (2441.00 mg/kg), S14 (2184.00 mg/kg) and S1 (2067.00 mg/kg). The norm values of Mg ranged from 3109.00-4903.00 mg/kg with highest value in seed source S11 (4903.00 mg/kg) and lowest content in S7 (3109.00 mg/kg). The highest value for the S and Fe was observed in seed source S2 (Konkan Ruchika, Dapoli) (9716.00 ppm) and S11 (736.00 mg/kg). The maximum value for Na and B was noticed in seed source S11 (1476.00 mg/kg) and S8 (51.39 mg/kg), whereas the norm values for Mn ranged from 20.94-44.18 mg/kg. The seed source S4 (1.97 mg/kg) possessed the most value of Ni followed by S1 (1.82 mg/kg), S14 (1.63 mg/kg) and S2 (1.61 mg/kg). The average value content for Cu and Zn ranged from 4.63-7.55 mg/kg and 17.03-54.74 mg/kg. Mature leaves had very low content of heavy metals i.e. Pb, Cd, Cr and the lowest value for Cd was observed in source S5 (0.08 mg/kg) and Cr in S10 (CAZRI, Jodhpur, Rajasthan) (1.93 mg/kg).

All the studied parameters of tender leaves, mature leaves and twigs showed a broad range of values signifying the amount of variation present in the seed sources. Environmental factors has very less influence on almost most of the traits studied because of less difference between phenotypic and genotypic coefficient of variation, thus the phenotype acts as true representative of their genotype and selection based on phenotypic performance might be used for further breeding programme. High heritability was observed for all traits studied. All characteristics were strongly genetically controlled as environmental coefficient of variation was very low. Dry matter showed positive correlation with OM, CP, fats and fibre, while negative with carbohydrates, TSS and NEF, however, negative with CP in twigs. Crude protein was negatively correlated with total carbohydrates, TSS and NEF.

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Plate 1: General overview of research trial at field and sample collection



Plate 2: Sample preparation and shade drying

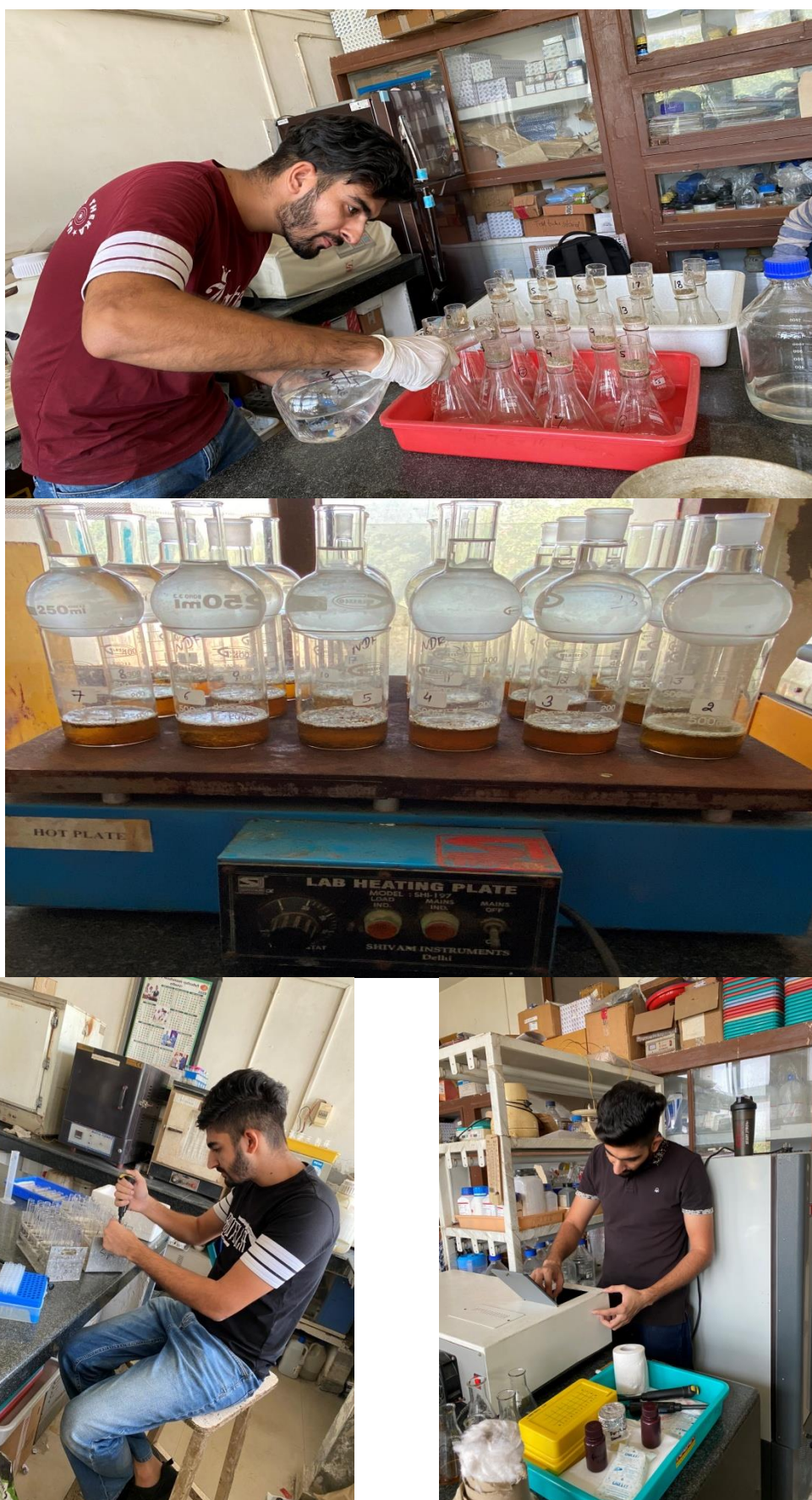


Plate 3: Glimpses of laboratory work for estimating nutritional and fodder values



Plate 4: Digestion of samples for mineral analysis

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