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SCREENING OF *MORINGA OLEIFERA* SEED SOURCES FOR NUTRITIONAL VALUES AND MINERAL PROFILING - A POTENTIAL TREE FODDER IN NORTH-WESTERN INDIA

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SUMMARY

In the era of chemical revolution, livestock are totally dependent on synthetic supplements for their body growth, mental and physical health; and milk and meat production. *Moringa oleifera* is only plant which is considered as bowl of supplements and wide range of bioactive ingredients and minerals. In this connection, 14 seed sources were studied for nutritional values, fodder quality and mineral contents. North Indian seed source were observe prominent for dry matter (S6; 26.80 g/100g), ash content (S5; 11.53 g/100g DM), soluble sugars (S4; 23.17 g/100g DM), ether extract (S14; 4.69 g/100g DM), crude fibre (21.90 g/100g DM), phenolic compounds (S6; 10.24 g/100g DM), cellulose (S6; 26.90 g/100g DM), nitrate (806 µg/g DM) and saponins (S6; 24.40 µg/g DM). While, south Indian sources were best for crude protein (S9; 18.81 g/100g DM), flavonoids (S11; 1.90 g/100g DM), hemicellulose (20.30 g/100g DM) and tannins (S7; 55.88 µg/g DM). Besides, West Indian seed sources were found best for total carbohydrates (S2; 75.05 g/100g DM), total energy value (S2; 386.32 Kcal/100g DM), NFE (56.05 g/100g DM) and oxalate content (S10; 1.12%). In general, the highest concentration of essential minerals was found in north Indian sources, *i.e.* S6 and S14. Thus, there is sufficient scope for characterization of wild land races having high concentrations of nutrients and minerals to incorporate in future breeding programmes with high leaf biomass cultivars for forage nutritional security in lean period.

Key words : *Moringa oleifera*, seed sources, nutritional values, mineral profiling, tree fodder

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 in tropics (Lalas and Tsaknis, 2002). Commonly, it is well-known Sahjan (Hindi), drumstick tree, horseradish tree and west Indian ben tree (Ramachandran *et al.,* 1980). *Moringa oleifera* is an indigenous tree from north-western India and is often cultivated in hedges and home yards for household uses. Moringa can survive during 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 m amsl (Dalla, 1993).

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). Moreover, *M. oleifera* leaves are excellent resource of natural antioxidants like phenols and flavonoides; and consequently improve the timeframe of practical usability of food and feed (Dillard and Germany, 2000; Siddhuraju and Becker, 2003). *Moringa oleifera* leaves have adequate amount of mineral elements (Fuglie, 2005; Kasolo *et al.,* 2010; Mulyaningsih and Yusuf,

2018). Study carried out by Asiedu-Gyekye *et al.,* (2014) revealed 35 components (14 macroelements and 21 microelements) from leaves. 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 cattle and livestock to increase the weight and milk yield. The chemical composition and fibre components affect feed digestion, which directly or indirectly affects animal feed consumption and animal productivity (Arif *et al.,* 2020). Several studies carried out by Richter *et al.* (2003); Sanchez *et al.* (2006); Mendieta *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, either extract, detergent fibre, dry matter intake and digestibility, digestible nutrients and relative feed value (Sanchez *et al.,* 2006; Singh, 2021). The 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 animal diet 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 3 kg 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 (Anjorin *et al.,* 2010). The nutritional composition varies with genotype, cultural practices, environment, fertigation techniques, drying methods and storage conditions of plant parts (Dhakad *et al.,* 2019). 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*, thought genotypic evaluation is not so reported under subtropical climatic conditions of north-western Indian states. It is clear from the previous literatures 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 in north-western Indian conditions. 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 nutritive values followed by nutritional feed security in lean period. Keeping in view the above realities and facts, the current study has been planned with the aim to screen the diverse germplasm of *M. oleifera* for nutritional, fodder values and mineral profiling as potential tree fodder in north-western India.

MATERIALS AND METHODS

Climate and soil

The present study entitled was carried out in Department of Forestry & Natural Resources in collaboration with Forage & Millet Section, Department of Plant Breeding & Genetics, and Department of Animal Nutrition, GADVASU, Ludhiana, Punjab during the year 2019-20. 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 Fig. 1.

Study species and experimental details

Seed of five promising cultivars adopted at national level and four landraces of *M. oleifera* were procured from different states of India and simultaneously collected from 5 landraces maintained at PAU, Ludhiana campus. The details of seed sources are provided in Table 1. The seedlings were ready to transplant in field after 35-45 DAS and transplanted out during first week of August 2017 at spacing of 3.5m×2.0m in three replications with 5 plants per plot following the complete randomized block Design at teaching area of Department of Forestry and Natural

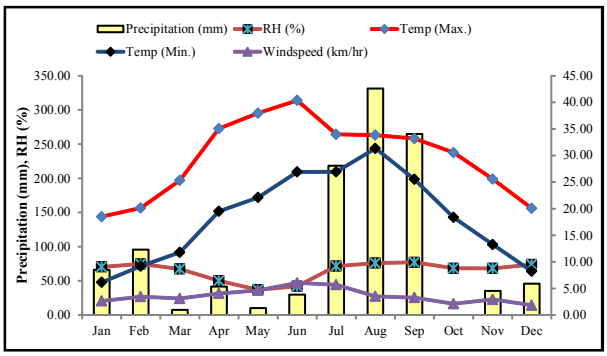

Fig. 1. Mean meteorological parameters of experimental site.

Resources, PAU, Ludhiana. The plants were irrigated and fertilized regularly as per the standard package of practices followed in *M. oleifera* (Anonymous, 2013). Plants were pollarded at the height of 6 feet during November 2018 for induction of more number of shoot to maximizing the fodder biomass. The plants were then frequently pollarded in every summer and winter.

Sample collection, preparation and nutritional analysis

The samples were taken for the present study was twigs containing tender green shoot, mature and tender leaves. 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 to estimate dry matter content. 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 CO_2 gas. The remainder is called ash, an inorganic component. Macro-Kjeldahl technique was used to quantify the N content (AOAC, 2005). The crude protein (%) content was then calculated by multiplying the nitrogen content with 6.25 factor. The AOAC's standard techniques were used to determine the pH, crude fibre and ether extract (AOAC 2005). Dubois *et al.* (1956) protocol was used to determine total soluble sugars. Total carbohydrate was calculated by using crude protein, ether extract and ash content as per the formulae given by Martin and Coolidge (1978). Similarly, the total energy value as Food was estimated using Martin and Coolidge's (1978) equations and given in Kcal/100g of DM. Neutral and acid detergent fibre, and acid detergent lignin (data not provided here) were determined by according to the method given by Van Soest *et al.* (1999) whose were used to estimate the hemicellulose and cellulose content (Goering and Vansoest, 1975). Nitrogen Free Extract (NFE) was calculated as per the formulae given by Detmann and Filho (2010). Swain and Hills' (1959) standard techniques were used to determine total phenols. Flavonoids were determined by using standard procedures of Chang e*t al.* (2002). Tannins were determined using Sadasivan and Manickam's (1992) conventional techniques. Saponins were determined by using standard procedures of Fenwick and Oakenfull (1983). The Nitrate-N content was determined by using standard procedures of Cotaldo *et al* (1975). The oxalate content was determined by using standard procedures of Abeza *et al.,* (1968).

Mineral profiling

The leaf samples for twigs were oven dried and grinded in a willy-mill containing stainless steel blade and passed through 0.5 mm sieve. About 1 g of powdered sample was taken and 10 ml of di-acid

TABLE 1
Geographical details of *Moringa oleifera* ecotypes procured and collected

Code	Ecotypes	Breeding history	Origin	Climatic conditions	Latitude (°N)	Longitude (°E)	Altitude (m)
S1	*Bhagya*	Cultivar	UHS Bagalkot, Karnataka	Semi-arid	16.18	75.69	542
S2	*Konkan Ruchira*	Cultivar	Dapoli, Maharastra	Semi-arid	17.75	73.18	164
S3	Dantiwara	Landrace	Gujarat	Arid	25.24	73.32	311
S4	PAU-1	Landrace	PAU Ludhiana, Punjab	Subtropical	30.90	75.81	249
S5	PAU-2	Landrace	PAU Ludhiana, Punjab	Subtropical	30.90	75.81	250
S6	PAU-3	Landrace	PAU Ludhiana, Punjab	Subtropical	30.90	75.81	248
S7	PKM-1	Cultivar	Tamil Nadu	Tropical	11.31	76.93	310
S8	PKM-2	Cultivar	Tamil Nadu	Tropical	11.31	76.93	310
S9	ODC-3	Cultivar	Tamil Nadu	Tropical	11.31	76.93	310
S10	CAZRI, Jodhpur	Landrace	Rajasthan	Arid	26.25	72.99	236
S11	Mandya	Landrace	Karnataka	Tropical	12.52	76.89	683
S12	Mysore	Landrace	Karnataka	Tropical	12.31	76.64	772
S13	PAU-4	Landrace	PAU Ludhiana, Punjab	Subtropical	30.90	75.81	250
S14	PAU-5	Landrace	PAU Ludhiana, Punjab	Subtropical	30.90	75.81	250

mixture (HNO_3: $HCLO_4$ @ 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 whatsman no. 1 filter paper. The volume was made to 50 ml with distilled water after filtration. The concentrations of elements were determined by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) as per the procedures described in APHA (2005). Besides, sulphur concentration was determined separately in samples using protocol given by Garrido (1964).

Statistical analysis

The data recorded on nutritional, bioactive ingredients, mineral concentrations 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). Duncan's multiple range test was performed to compare means on each of the significant ($P<0.01$) variables measured. Correlation analysis was carried out using the SPSS *version* 16 software.

RESULTS AND DISCUSSION

Nutritional variability

The mean nutritional for fourteen ecotypes of *M. oleifera* collected from different geographical regions of India showed significantly differences ($P\leq0.01$) for studied characteristics (Table 2). The S6 ecotype 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 ecotypes S13 (PAU-4) (11.60 g/100g), followed by S5 (11.53 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 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 seed source S2 registered highest mean value for total 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 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 average phenol content 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). The average flavonoids content 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).

It is clear from the present study that all 14

TABLE 2
Mean performance of fourteen ecotypes of *Moringa oleifera* for nutritional values

Moringa ecotypes	Dry Matter (g/100g)	Ash content (g/100g DM)	Crude Protein (g/100g DM)	Soluble Sugars (g/100g DM)	Carbohydrates (g/100g DM)	Total Energy (Kcal/100g DM)	Phenols (mg/g)	Flavonoids (mg/g)
S1	21.91 ± 0.35	10.41 ± 0.05	12.69 ± 0.15	18.88 ± 0.03	73.03 ± 0.21	377.73 ± 0.43	7.71± 0.01	0.64 ± 0.00
S2	23.29 ± 0.18	8.92 ± 0.07	11.64 ± 0.15	9.45 ± 0.03	75.05 ± 0.23	386.32 ± 0.51	7.29 ± 0.01	1.48 ± 0.01
S3	22.09 ± 0.29	9.47 ± 0.05	14.96 ± 0.15	13.27 ± 0.02	71.75 ± 0.20	381.24 ± 0.48	5.12 ± 0.01	1.34 ± 0.00
S4	23.41 ± 0.28	10.95 ± 0.06	14.09 ± 0.15	23.17 ± 0.03	71.37 ± 0.10	374.20 ± 0.07	9.03 ± 0.01	1.03 ± 0.00
S5	23.35 ± 0.33	11.53 ± 0.05	14.96 ± 0.25	9.81 ± 0.03	70.56 ± 0.19	368.63 ± 0.22	8.53 ± 0.01	0.54 ± 0.00
S6	26.80 ± 0.21	11.18 ± 0.03	16.54 ± 0.15	8.36 ± 0.03	69.11 ± 0.13	371.15 ± 0.06	10.24 ± 0.01	0.47 ± 0.00
S7	20.96 ± 0.34	9.56 ± 0.09	17.59 ± 0.25	21.06 ± 0.03	69.03 ± 0.15	380.88 ± 0.04	6.35 ± 0.01	1.31 ± 0.01
S8	21.85 ± 0.30	8.62 ± 0.05	18.02 ± 0.20	9.13 ± 0.03	69.37 ± 0.15	385.47 ± 0.15	7.02 ± 0.01	1.37 ± 0.00
S9	22.17 ± 0.25	9.77 ± 0.08	18.81 ± 0.15	13.11 ± 0.04	68.29 ± 0.08	376.55 ± 0.10	7.86 ± 0.01	0.81 ± 0.00
S10	22.73 ± 0.26	10.06 ± 0.07	17.67 ± 0.20	6.64 ± 0.02	69.19 ± 0.13	375.18 ± 0.04	7.99 ± 0.01	0.55 ± 0.01
S11	20.92 ± 0.30	9.69 ± 0.08	17.76 ± 0.25	14.59 ± 0.01	69.51 ± 0.33	376.46 ± 0.69	7.55 ± 0.01	1.90 ± 0.00
S12	22.15 ± 0.29	10.65 ± 0.12	18.64 ± 0.15	10.31 ± 0.03	67.17 ± 0.03	375.13 ± 0.24	7.88 ± 0.01	0.68 ± 0.00
S13	24.53 ± 0.38	11.60 ± 0.12	16.45 ± 0.20	9.00 ± 0.03	67.87 ± 0.32	374.02 ± 0.79	7.33 ± 0.01	0.58 ± 0.00
S14	25.34 ± 0.35	10.87 ± 0.06	16.89 ± 0.15	11.42 ± 0.03	67.55 ± 0.10	379.99 ± 0.06	6.79 ± 0.01	0.76 ± 0.00
Mean ± SEm	22.96 ± 0.30	10.23 ± 0.07	16.19 ± 0.19	12.73 ± 0.03	69.92 ± 0.19	377.35 ± 0.37	7.62 ± 0.01	0.96 ± 0.00
LSD0.05	0.86	0.21	0.55	0.08	0.54	1.08	0.04	0.01

seed sources of *M. oleifera* revealed significant variations for nutritional traits. These variations could be due to genetic source, environmental conditions, development stage or proportionate mixture of leaves and tender shoot. Dry matter content was observed high in local ecotypes irrespective to geographical origin. The crude protein 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 Elkhalifa *et al.,* (2007) and Oduro *et al.,* (2008). This makes the moringa as 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). Arif *et al* (2020) reported the high value of crude protein in moringa leaves. Total carbohydrate was observed highest in ecotype S2 showing the inverse proportionate to the protein content and for which, the total energy value was recorded highest in S2. 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. Phenols and flavonoids are within the limits as required for the animal feed requirement. Mohammed and Manan (2015) reported values for the total phenol content which were identical to our finding.

Forage characteristics

The genotypic variability for forage characteristics in fourteen ecotypes of *M. oleifera* collected from different geographical regions of India showed significantly differences (P≤0.01) for studies characteristics (Table 3). The pH value ranged 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). The highest content for the ether extract 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 content 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 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 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 was in S13 (47.17 g/100g DM).

TABLE 3
Variability for forage characteristics in *Moringa oleifera* ecotypes

Moringa ecotypes	pH value	Ether Extract (g/100g DM)	Crude Fibre (g/100g DM)	Hemicellulose (g/100g DM)	Cellulose (g/100g DM)	Nitrogen Free Extract (g/100g DM)
S1	6.24 ± 0.02	3.87 ± 0.01	21.90 ± 0.23	15.00 ± 0.95	25.10 ± 0.81	51.13 ± 0.44
S2	6.14 ± 0.02	4.40 ± 0.01	20.20 ± 0.29	8.90 ± 0.00	24.25 ± 0.14	54.85 ± 0.52
S3	5.98 ± 0.04	3.82 ± 0.01	15.70 ± 0.23	11.55 ± 0.09	23.25 ± 0.09	56.05 ± 0.03
S4	5.69 ± 0.02	3.60 ± 0.01	15.20 ± 0.35	16.75 ± 0.18	21.90 ± 1.04	56.17 ± 0.45
S5	5.88 ± 0.02	2.95 ± 0.01	16.80 ± 0.23	8.85 ± 0.12	23.70 ± 0.00	53.76 ± 0.04
S6	5.98 ± 0.03	3.17 ± 0.01	19.80 ± 0.35	4.90 ± 0.98	26.90 ± 0.17	49.31 ± 0.47
S7	6.11 ± 0.02	3.82 ± 0.01	14.50 ± 0.40	13.85 ± 0.18	24.80 ± 0.06	54.53 ± 0.25
S8	5.66 ± 0.02	3.99 ± 0.01	18.10 ± 0.35	17.85 ± 0.12	22.10 ± 0.17	51.27 ± 0.20
S9	6.10 ± 0.02	3.13 ± 0.01	19.80 ± 0.40	15.60 ± 0.12	23.05 ± 0.84	48.49 ± 0.48
S10	5.97 ± 0.01	3.08 ± 0.00	19.20 ± 0.35	15.55 ± 0.07	24.00 ± 0.23	49.99 ± 0.22
S11	6.12 ± 0.02	3.04 ± 0.01	20.40 ± 0.23	9.40 ± 1.15	24.60 ± 0.75	49.11 ± 0.57
S12	5.81 ± 0.02	3.55 ± 0.01	18.20 ± 0.23	20.30 ± 1.07	20.70 ± 0.75	48.97 ± 0.20
S13	5.90 ± 0.02	4.08 ± 0.00	20.70 ± 0.23	10.55 ± 1.16	26.40 ± 0.87	47.17 ± 0.09
S14	6.08 ± 0.03	4.69 ± 0.01	16.90 ± 0.23	14.85 ± 1.10	23.65 ± 0.72	50.65 ± 0.33
Mean ± SEm	5.98 ± 0.02	3.66 ± 0.01	18.39 ± 0.30	13.14 ± 0.71	23.89 ± 0.60	51.53 ± 0.35
LSD0.05	0.06	0.02	0.87	2.05	1.73	1.02

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 (Singh, 2021) 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). Among the different parts of moringa, twigs contain lower values of crude protein and ether extract than the leaves (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 and twigs contains the lesser crude fibre due to having tender shoots. Similar results were recorded in the studies conducted by Olugbemi *et al.* (2010) and Mutayoba *et al.* (2011). 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 (Singh, 2021). Mahima *et al* (2014) recorded similar results for the hemicellulose and cellulose content. In the analysis of foods and animal feeds, 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).

Antinutritional traits

The twigs of moringa possessed lower value of anti-nutritional factors which is best for considering *Moringa oleifera* as forage in animal feed. The genotypic variability for anti-nutritional parameters (Table 4) in fourteen ecotypes of *M. oleifera* collected from different geographical regions of India showed significantly differences (P≤0.01). The mean values of tannins were ranged from 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. The saponin content was found in between 24.40 to 50.69 µg/g among the ecotypes studied. 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). Similarly, the average value nitrate and oxalate content were varied from 793.00-2970.50 µg/g and 1.12-2.42%, respectively. Wide variations were observed for nitrate content, of which, minimum nitrate content was recorded in ecotypes S11. Very low amount of oxalate content was observed ranging from 1.12-2.42% with minimum value in S10 (CAZRI, Jodhpur, Rajasthan) seed source (1.12%).

TABLE 4
Variability for antinutritional parameters in *Moringa oleifera* ecotypes

Moringa ecotypes	Tannins (µg/g)	Saponins (µg/g)	Nitrate (µg/g)	Oxalate (%)
S1	85.30 ± 1.02	36.68 ± 0.06	2970.50 ± 11.26	1.52 ± 0.03
S2	60.00 ± 0.68	48.99 ± 0.08	2223.00 ± 7.51	1.29 ± 0.03
S3	65.30 ± 1.02	48.86 ± 0.08	2125.50 ± 11.26	1.52 ± 0.03
S4	75.88 ± 1.02	24.90 ± 0.08	2424.50 ± 11.26	1.86 ± 0.03
S5	73.53 ± 1.02	32.16 ± 0.04	929.50 ± 11.26	1.41 ± 0.03
S6	82.36 ± 0.68	24.40 ± 0.06	806.00 ± 7.51	2.08 ± 0.03
S7	55.88 ± 1.02	28.63 ± 0.04	1404.00 ± 7.51	1.41 ± 0.03
S8	72.36 ± 1.02	36.50 ± 0.08	1995.50 ± 3.75	1.63 ± 0.03
S9	91.77 ± 0.68	39.08 ± 0.08	1456.00 ± 7.51	1.24 ± 0.06
S10	70.00 ± 1.02	50.69 ± 0.08	1371.50 ± 11.26	1.12 ± 0.06
S11	67.65 ± 1.02	43.36 ± 0.08	793.00 ± 7.51	1.52 ± 0.03
S12	82.41 ± 1.33	47.70 ± 0.08	1170.00 ± 7.51	1.92 ± 0.07
S13	81.18 ± 0.68	46.14 ± 0.04	897.00 ± 7.51	1.86 ± 0.03
S14	87.06 ± 0.68	47.41 ± 0.64	1066.00 ± 7.51	2.42 ± 0.03
Mean ± SEm	75.05 ± 0.94	39.68 ± 0.18	1545.14 ± 8.86	1.63 ± 0.04
LSD0.05	2.72	0.53	25.66	0.12

Antinutrients may be regarded as a class of compounds, which are generally not lethal and considered as anti-oxidants 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. Tannins have a property of binding to protein to form reversible and irreversible complexes and 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). Lower tannin content was may increase the suitability of *Moringa* as feed efficiency and gain weight in chicks (Die *et al.,* 2007).

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; Stevens *et al.,* 2015; Kumar *et al.,* 2017). When forages have an unusually high concentration of nitrate, the animal cannot complete the conversion and nitrite accumulates. The nitrate level 0-1500 ppm was considered to be safe for feeding animals (Kumar *et al.,* 2017) which was good in *Moringa* twigs. 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). 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, which were all in the insoluble form. The result were similar to their findings i.e. < 3%.

Mineral elements concentration

The genotypic variability for elemental concentrations in fourteen ecotypes of *M. oleifera* collected from different geographical regions of India showed significantly differences (P≤0.01) (Fig. 2). The range of N content is directly correlated with the range of crude protein content as CP is estimated by -N method. The largest content of P was observed in S3 (5899 mg/kg) followed by S2 (4704 mg/kg) and S10 (4664 mg/kg). The average K content was ranged from 13927-27014 mg/kg. The maximum value for Ca was recorded in local seed source S143 (PAU-5) (26120 mg/kg) followed by S13 (24680 mg/kg) and S4 (21208 mg/kg). The norm values of Mg ranged from 2456-5021 mg/kg with highest value in seed source S14 (5021 mg/kg) and lowest content in S11 (2456 mg/kg). The highest value for S and Fe was observed in seed source S3 (13818 mg/kg) and S13 (276 mg/kg). The maximum value for Na and B was noticed in seed source S14 (739 mg/kg) and S7 (51.10 mg/kg), whereas, the norm values for Mn ranged from 19.35-61.50 mg/kg. The seed source S3 (8.95 mg/

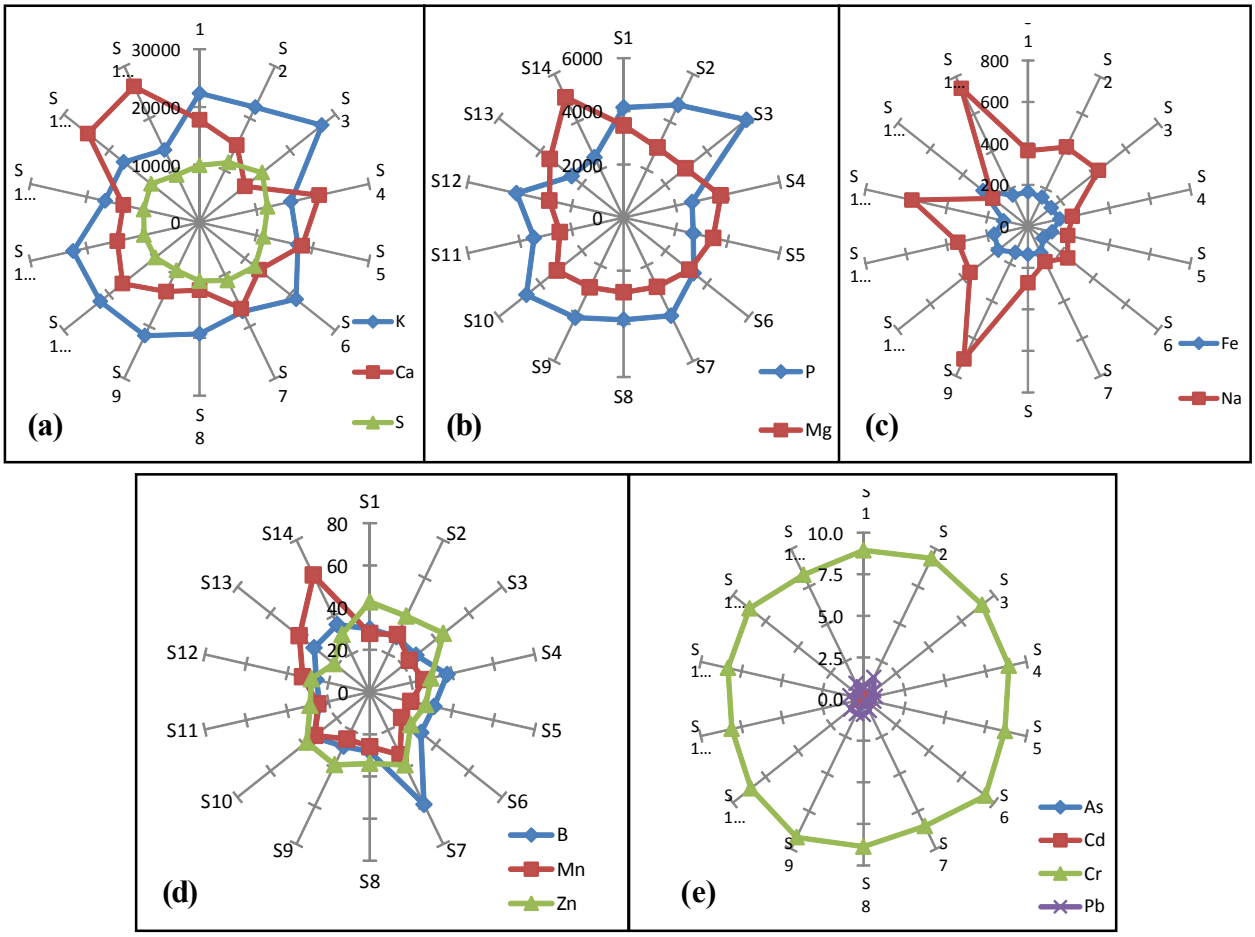

Fig. 2. Variability for mineral profiling in (a-b) major elements, (c-d) trace elements and (e) heavy metals in *Moringa oleifera* ecotypes collected from different geographical regions of India.

kg) possessed the highest value of Ni followed by S2 (2.60 mg/kg). The average value for Cu and Zn ranged from 5.35-10.20 mg/kg and 21.60-44.50 mg/kg. Twigs had very low content of heavy metals, *i.e.* As, Pb and Cd, however, Cd was observed high but within permissible limits (8.10-9.38 mg/kg). Varying and high levels of these elements present in *M. oleifera* ecotypes have either a direct or an indirect role in the control of some ailments in animals (Gowrishankar *et al.,* 2010). Studies have revealed that commonly available feeds and fodders contain the micronutrients far below the required daily needs (Anonymous, 2012). This emphasizes the fact the nutritional role of essential elements should further be studied in *Moringa* as a proportionate feed mixtures.

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. The genotypic and phenotypic correlations in all possible combinations among all the parameters *viz.,* nutritional, fodder and antinutritional under study are given in Table 5. In general, genotypic correlation coefficients were higher than corresponding phenotypic correlation coefficients for most of the traits. In general, significantly high positive correlations were observed among DM and ash with phenols, tannins and oxalates at genotypic level, while DM with oxalate and ash with phenols and tannins at phenotypic level; carbohydrate with NFE and nitrate at genotypic and phenotypic levels; NFE with nitrate at genotypic and phenotypic levels. Besides, significantly high negative correlations were observed among CP with carbohydrates, NFE and nitrate content; EE with phenols; crude fibre with NFE; TSS with saponins, phenols with saponins at genotypic and phenotypic levels. Dry matter had positive significant, correlation with ash, phenols and oxalate, while significant negatively correlated with TSS, flavonoids and nitrates both at genotypic and phenotypic level. Ash content showed positive correlation with phenols, tannins and oxalate content, however, significant negatively correlated with carbohydrates, flavonoids and nitrate content. Crude protein had positive correlation only with hemicellulose, while, negatively correlated with crude fat, carbohydrates, NFE and nitrates content.

TABLE 5
Correlation among nutritional characteristics of fourteen ecotypes of *Moringa oleifera*

	DM	Ash	CP	EE	CFb	TCarb	TSS	Hemi	Cellu	NFE	Ph	Flav	Tan	Sap	Nitr	Oxl
DM	1.000	0.430**	-0.000^{ns}	0.061^{ns}	-0.104^{ns}	-0.188^{ns}	-0.406**	-0.392*	0.208^{ns}	-0.061^{ns}	0.483**	-0.395**	0.255^{ns}	-0.179^{ns}	-0.395**	0.544**
Ash	0.437**	1.000	-0.034^{ns}	-0.189^{ns}	0.020^{ns}	-0.342*	-0.038^{ns}	-0.219^{ns}	0.281^{ns}	-0.270^{ns}	0.532**	-0.737**	0.527**	-0.250^{ns}	-0.408**	0.492**
CP	-0.017^{ns}	-0.031^{ns}	1.000	-0.339*	-0.102^{ns}	-0.902**	-0.239^{ns}	0.324*	-0.177^{ns}	-0.594**	-0.020^{ns}	-0.057^{ns}	0.216^{ns}	0.065^{ns}	-0.632**	0.101^{ns}
EE	0.062^{ns}	-0.191^{ns}	-0.344*	1.000	-0.089^{ns}	0.178^{ns}	0.063^{ns}	0.166^{ns}	-0.010^{ns}	0.201^{ns}	-0.514**	0.161^{ns}	-0.057^{ns}	0.309*	0.344*	0.412*
CFb	-0.123^{ns}	0.023^{ns}	-0.107^{ns}	-0.092^{ns}	1.000	0.115^{ns}	-0.394**	-0.217^{ns}	0.361*	-0.673**	0.287^{ns}	-0.160^{ns}	0.377*	0.290^{ns}	-0.013^{ns}	-0.133^{ns}
TCarb	-0.183^{ns}	-0.345*	-0.901**	0.181^{ns}	0.119^{ns}	1.000	0.240^{ns}	0.270^{ns}	0.061^{ns}	0.658**	-0.081^{ns}	0.329*	-0.424**	-0.034^{ns}	0.720**	0.407*
TSS	-0.424**	-0.038^{ns}	-0.242^{ns}	0.063^{ns}	-0.397**	0.242^{ns}	1.000	0.243^{ns}	0.117^{ns}	0.477**	-0.105^{ns}	0.296^{ns}	-0.136^{ns}	-0.500**	0.485**	-0.011^{ns}
Hemi	-0.414**	-0.202^{ns}	0.347*	-0.172^{ns}	0.245^{ns}	0.303^{ns}	0.252^{ns}	1.000	-0.753^{ns}	-0.037^{ns}	-0.229^{ns}	-0.054^{ns}	0.216^{ns}	0.164^{ns}	0.339*	0.028^{ns}
Cellu	0.201^{ns}	0.270^{ns}	0.221^{ns}	0.011^{ns}	0.482**	0.108^{ns}	0.140^{ns}	-0.786**	1.000	-0.228^{ns}	0.166^{ns}	-0.152^{ns}	-0.009^{ns}	-0.138^{ns}	-0.237^{ns}	-0.006^{ns}
NFE	-0.042^{ns}	-0.275^{ns}	-0.590**	0.205^{ns}	-0.673**	0.654**	0.483**	-0.039^{ns}	-0.287^{ns}	1.000	-0.278^{ns}	0.366*	-0.602**	-0.245^{ns}	0.546**	-0.202^{ns}
Ph	0.505**	0.536**	-0.021^{ns}	-0.514**	0.290^{ns}	-0.081^{ns}	-0.105^{ns}	-0.238^{ns}	0.194^{ns}	-0.281^{ns}	1.000	-0.496**	0.406**	-0.550**	-0.226^{ns}	0.179^{ns}
Flav	-0.413**	-0.744**	-0.057^{ns}	0.161^{ns}	-0.161^{ns}	0.333*	0.296^{ns}	-0.057^{ns}	-0.183^{ns}	0.370*	-0.496**	1.000	-0.646**	0.123^{ns}	0.192^{ns}	-0.257^{ns}
Tan	0.582**	0.515**	0.104^{ns}	0.421**	-0.142^{ns}	-0.423**	-0.011^{ns}	0.014^{ns}	0.048^{ns}	-0.208^{ns}	0.015^{ns}	-0.654**	1.000	-0.041^{ns}	-0.115^{ns}	0.456**
Sap	-0.183^{ns}	-0.252^{ns}	0.067^{ns}	0.309*	0.295^{ns}	-0.035^{ns}	-0.500**	0.175^{ns}	-0.175^{ns}	-0.251^{ns}	-0.551**	0.123^{ns}	-0.043^{ns}	1.000	-0.062^{ns}	-0.134^{ns}
Nitr	-0.414**	-0.412**	-0.683**	0.344*	-0.014^{ns}	0.727**	0.485**	0.351*	-0.284^{ns}	0.552**	-0.226^{ns}	0.192^{ns}	-0.118^{ns}	0.061^{ns}	1.000	-0.256^{ns}
Oxl	0.582**	0.515**	0.104^{ns}	0.421**	-0.142^{ns}	-0.423**	-0.011ns	0.014^{ns}	0.048^{ns}	-0.208^{ns}	0.185^{ns}	-0.263^{ns}	0.472*	-0.135^{ns}	-0.264^{ns}	1.000

Note: Phenotypic correlation is on right-upper side of table; genotypic correlation is on left-lower side of table.
Note: DM - dry matter, OM - organic matter, CP - crude protein, EE - Either extract, CFb - crude fibre, TCarb - total carbohydrate, TSS - total soluble sugars, Hemi - hemicellulose, Cellu - cellulose, NFE - nitrogen free extracts, Ph - phenols, Flav - flavonoids, Tan - tannins, Sap - saponin, Nitr - Nitrate, Oxl - oxalate.

REFERENCES

Abeza, R. H., I. T. Black, and E. J. Fisher, 1968 : Oxalate determination. Analytical problems encountered with certain plant species. *JAOAC* **51** : 853-61.

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

Anonymous 2012 : *Nutritive values of commonly available feeds and fodders in India*. Animal nutrition group, National Dairy Development Board, Anand, Gujarat. pp. 1-126.

AOAC 2005 : *Official Methods of Analysis 18th ed*. Association of Official Analytical Chemists. Maryland, USA.

APHA 2005 : Standard methods for the examination of water and waste water. 21st edition. American Public Health Association, Washington, DC, USA.

ARC 1984 : The nutrient requirements of ruminant livestock, Agril. Res. Council, Commonwealth Agril. Bureaux, England.

Arif, M., M. Singh, S. Onte, D. Dey and Kumar, 2020 : Comparative evaluation of fodder qualities in different parts of locally available moringa (*Moringa oleifera*) strains. *Ind. J. Ani. Sci.,* **90** : 80-84.

Asiedu-Gyekye J., S. Frimpong-Manso, C. Awortwe, D. A. Antwi and Nyarko, A. K. 2014 : Micro-and Macroelemental composition and safety evaluation of the nutraceutical *Moringa oleifera* leaves. *J. Toxicol.,* **1** : 1-13.

Cataldo, D. A., L. E. Schrader and V. L. Youngs, 1975 : Rapid calorimetric determination of nitrate in plant tissiue by nitration of salicylic acid. *Commu. Soil Sci. Pl. Ana.,* **6** : 1-30.

Chang, C. C., M. H. Yang, H. M. Wen and J. C. Chern, 2002 : Estimation of total flavonoid content in propolis by two complementary colorimetric methods. *J. Food Drug Ana.,* **10** : 178-182.

Dalla, R. 1993 : Food value of the lesser utilized tropical plant. *Food Chem.,* **46** : 239-46.

Dangi, S. Y., C. I. Jolly and S. Narayanam, 2002 : Antihypertensive activity of the total alkaloids from the leaves of *Moringa oleifera*. *Pharmaceut Bioi.,* **40** : 144-48.

Dei, H. K., S. P. Rose and M. Mackenzie, 2007 : Shea nut (*Vitellaria paradoxa*) meal as a feed ingredient for poultry. *World's Poult. Sci. J.,* **63** : 611-24.

Detmann, E. and S. C. V. Filho, 2010 : On the estimation of non-fibrous carbohydrates in feeds and diets. *Arq. Bras Med. Vet. Zootec,* **62** : 980-84.

Dhakad, A. K., M. Ikram, S. Sharma, S. Khan, V. V. Pandey, and A. Singh, 2019 : Biological, nutritional and therapeutic significance of *Moringa oleifera* Lam. *Phytother Res.,* **33** : 2870-903.

Dillard, C. J. and J. B. German, 2000 : Phytochemicals: nutraceuticals and human health: A review. *J. Sci. Food Agric.,* **80** : 1744-56.

Dubois, M., K. A. Gilles, J. L. Hamilton, P. A. Rebers, and F. Smith, 1956 : Calorimetric method for determination of sugars and related substances. *Anal. Chem.* **28** : 350-56.

Elkhalifa, A. E. O., S. A. Ahmed, and S. Adam, 2007 : Nutritional evaluation of *Moringa oleifera* leaves and extracts. *Ahfad J.* **24** : 113-122.

Fenwick, D. E. and D. Oakenfull 1983 : Saponin content of food plants and some prepared foods. *J. Sci. Food Agric.* **34** : 198-191.

Foidl, N., H. P. S. Makkar, K. Becker, 2001 : The potential of *Moringa oleifera* for agricultural uses. What Development Potential for Moringa Products? Dar Es Salaam. pp. 1-20.

Foline, O. F., A. F. Emenike, and B. I. Eunice, 2011 : Comparative analysis of the nutritional composition of three different drying methods of *Moringa oleifera* leaves. *Int. J. Appl. Agril. Res.* **6** : 131-38.

Forster, N., C. Ulrichs, M. Schreiner, N. Arndt, R. Schmidt, and Mewis 2015 : Ecotype variability in growth and secondary metabolite profile in *Moringa oleifera*: impact of sulfur and water availability. *J. Agric. Food. Chem.* **63** : 2852-61.

Fuglie, L. J. 2005 : The Moringa tree: A local solution to malnutrition. USA: Church World Service in Senegal.

Garrido, M. L. 1964 : Determination of sulphur in plant material. *Analyst* **89** : 61-66.

Goering, H. D. and P. J. Vansoest, 1975 : Forage fiber analysis US Dept of Agriculture. Agricultural Research Service Washington, USA.

Gowrishankar, R., M. Kumar, V. Menon, S. M. Divi, M. Saravanan, P. Magudapathy, B. K. Panigrahi, K. G. M. Nair, and K. Venkataramaniah, 2010 : Trace element studies on *Tinospora cordifolia* (Menispermaceae), *Ocimum sanctum* (Lamiaceae), *Moringa oleifera* (Moringaceae), and *Phyllanthus niruri* (Euphorbiaceae) using PIXE. *Biol. Trace Elem. Res.* **133** : 357-63.

Kasolo, J. N., G. S. Bimenya, L. Ojok, J. Ochieng, and J. W. Ogwal-okeng, 2010 : Phytochemicals and uses of *Moringa oleifera* leaves in Ugandan rural communities. *J. Med. Plants Res.* **4** : 753-57.

Kumar, B., N. Tirkey, and S. Kumar 2017 : Anti-nutrient in fodders: A Review. *Chem. Sci. Rev. Lett.* **6** : 2513-19.

Lalas, S. and J. Tsaknis, 2002 : Characterization of *Moringa oleifera* seed oil variety "Periyakulam I". *J. Food Comp. Ana.* **15** : 65-77.

Mahima, A. R., R. Mandil, A. K. Verma, and V. Kumar, 2014 : Nutritional potentials of *Moringa oleifera* leaves in Uttar Pradesh, India. *Res. J. Med. Pl* **8** : 283-89.

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

Martin, E. A. and A. A. Coolidge, 1978 : *Nutrition in action*, 4th (ed). Holt, R and Wilson Co, New York, USA.

Melesse A, W. Tiruneh, and T. Negesse, 2011 : Effects of feeding *Moringa stenopetala* leaf meal on nutrient intake and growth performance of Rhode Island Red chicks under tropical climate. *Trop Subtrop Agroecosys* **14** : 485-92.

Mohammed, S. and F. A. Manan, 2015 : Analysis of total phenolics, tannins and flavonoids from *Moringa oleifera* seed extract. *J. Chem. Pharmaceut Res.* **7** : 132-35.

Moyo, B., P. J. Masika, A. Hugo, and V. Muchenje, 2011 : Nutritional characterization of moringa (*Moringaoleifera*) leaves. *Afr J Biotechnol* **10** : 12925-33.

Mulyaningsih, T. R. and S. Yusuf, 2018 : Determination of minerals content in leaves of *Moringa oleifera* By Neutron Activation Analysis. *Ganendra J. Nuclear Sci. Technol.* **21** : 11-16.

Mutayoba, S. K., E. Dierenfeld, V. A. Mercedes, Y. Frances and C. D. Knight, 2011 : Determination of chemical composition and anti-nutritive components for Tanzanian locally available poultry feed ingredients. *Int. J. Poultry Sci.* **10** : 350-57.

Noonan, S. and G. Savage, 1999 : Oxalate content of food and its effect on humans. *Asia Pacific J. Clin. Nutri.* **8** : 64-74.

Nouman, W., M. T. Siddiqui, S. M. A. Basra, H. Farooq, M. Zubair, and T. Gull, 2013 : Biomass production and nutritional quality of *Moringa oleifera* as a field crop. *Turk J Agri For* **37** : 410-19.

Oduro, I., W. O. Ellis, and D. Owusu, 2008 : Nutritional potential of two leafy vegetables: *Moringa oleifera* and *Ipomoea batatas* leaves. *Scient Res. Essay* **3** : 57-60.

Ogbe, A. O. and J. P. Affiku, 2011 : Proximate study, mineral and anti-nutrient composition of *Moringa oleifera* leaves harvested from lafia, Nigeria: potential benefits in poultry nutrition and health. *J. Microbiol Biotechnol Food Sci.* **1** : 296-308.

Olugbemi, T. S., S. K. Mutayoba, and F. P. Lekule, 2010 : Effect of *Moringa (Moringa oleifera)* Inclusion in Cassava based diets to broiler chickens. *Int. J. Poultry Sci.* **9** : 363-67.

Padayachee, B. and H. Baijnath, 2012 : An overview of the medicinal importance of Moringaceae. *J. Med. Plants Res.* **6** : 5831-39.

Panse, V. G. and P. V. Sukhatme, 1989 : *Statistical Methods for Agricultural Workers*. ICAR, New Delhi, India.

Pearson, D., 1976 : The Chemical Analysis of foods. *Churchill Livingstone New York* **7** : 54.

Radek, M. and G. P. Savage, 2008 : Oxalates in some Indian green leafy vegetables. *I. J. Food Sci. Nutri.* **59** : 246-60.

Ramachandran, C., K. V. Peter, and P. K. Gopalakrishnan, 1980 : Drumstick (*Moringa oleifera*): A multipurpose Indian vegetable. *Econ. Bot.* **34** : 276-83.

Richter, N., S. Perumal and B. Klaus, 2003 : Evaluation of nutritional quality of moringa (*Moringa oleifera* Lam.) leaves as an alternative protein source for Nile tilapia (*Oreochromis niloticus L.*). *Aquacul* **217** : 599-611.

Sadasivam, S. and A. Manickam, 1992 : Phenolics. In: Biochemical methods for agricultural sciences. pp. 187-88. Wiley Eastern Ltd, New Dehli, India.

Sanchez, N. R., S. Ledin, and I. Ledin, 2006 : Biomass production and chemical composition of *Moringa oleifera* under different management regimes in Nicaragua. *Agrofor. Syst.* **66** : 231-42.

Siddhuraju, P. and K. Becker, 2003 : Antioxidant properties of various solvent extracts of total phenolic constituents from three different agro-climatic origins of drumstick tree (*Moringa oleifera* Lam.). *J. Agric. Food Chem.* **15** : 2144-55.

Singh, K., 2021 : Evaluation of Moringa oleifera lam. seed sources for nutritional value and mineral content. M. Sc. Thesis submitted to Department of Forestry and Natural Resources, Punjab Agricultural University, Ludhiana, India.

Singh, S., A. K., Dhakad, G. P. S. Dhillon and K. K. Dhatt, 2021 : Extended BBCH scale of *Moringa oleifera* and its implications for growing in Urban Food Forests. *Trees, Forests & People* 5(100107): 1-10.

Sohani, S., 2018 : A multipurpose tree - *Moringa oleifera*: review on nutritive importance and its medicinal evidence. *Int. J. Eng. Sci. Mgmt.* **8** : 1-4.

Stadtlander, T. and K. Becker, 2017 : Proximate composition, amino and fatty acid profiles and element compositions of four different moringa species. *J. Agril. Sci.* **9** : 43-57.

Stevens, C. G., F. D. Ugese, G. T. Otitoju and K. P. Baiyeri, 2015 : Proximate and anti-nutritional composition of leaves and seeds of *Moringa oleifera* in Nigeria: A comparative study. *Agro-Sci.* **14** : 9-17.

Swain, T. and W. E. Hillis, 1959 : The phenolic constituents of prunus domestica. I-The quantitative analysis of phenolic constituents. *J. Sci. Food. Agri.* **10** : 63-68.

Van Soest, P. J. J. B. Robertson, and B. A. Lewis, 1991 : Methods for dietary fibre neutral detergent fibre and non-strach polysaccharides in relation to animal nutrition. *J. Dairy Sci.* **74** : 3583-97.

Verma, K. S. and R. Nigam, 2014 : Nutritional assessment of different parts of *Moringa oleif*era Lam. collected from Central India. *J. Nat. Prod. Pl. Resou.,* **4** : 81-86.

Yameogo, C. W., M. D. Bengaly, A. Savadogo, P. A. Nikiema, and S. A. Traore, 2011 : Determination of chemical composition and nutritional values *Moringa oleifera* leaves. *Pak. J. Nutr.,* **10** : 264-68.