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BIOMASS PRODUCTION AND NUTRITIONAL COMPOSITION OF *MORINGA OLEIFERA* UNDER DIFFERENT PLANTING SPACINGS IN A SEMI-ARID CONDITION OF THE NORTHERN SOUTH AFRICA

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ABSTRACT

Moringa oleifera is an important plant with nutrients concentrated in the leaves. The leaves have high nutritional potential, which can contribute significantly towards human and animal nutrition. Therefore, the tree can feed communities when other foods are typically scarce. This study was conducted to evaluate the effect of planting density on biomass and nutritional composition of *Moringa oleifera* planted under the semi-arid conditions of the Limpopo Province. The study was conducted at Eiland (NBef Organic Farm) over two consecutive years, 2014–15 and 2015–16. The initial and post-planting physical and chemical properties of the soil at the site were carried out at depths of 0 to 30 and 30 to 60 cm. The experiment was established as a randomized complete block design and replicated eight times. The treatments included planting densities of 5 000, 2 500, 1 667 and 1 250 plants ha^{-1}. Data collection included total dry matter yield, leaf yield (kg ha^{-1}) and leaf nutritional composition. Results from the soil analysis revealed slight acidity and very low nitrogen content (0.08%) at all sampling depths before moringa establishment. In addition, excessive magnesium, manganese and copper contents in the soil were recorded. Soil properties such as phosphorus, potassium, zinc, copper, organic carbon and nitrogen were reduced after the first harvest. During the second harvest, similar soil nutrient reductions followed the same trend as compared to the first harvest except for phosphorus, which showed an increase as compared to initial soil sampling at the second harvest. During harvests 1 and 2, the increase in planting density resulted in increased biomass production. Planting densities also did not affect moringa leaf nutrient composition. The study showed that a population of 5000 plants ha^{-1} produced the highest biomass yield of more than 1.5 ton ha^{-1}. This study also revealed that moringa contains a high level of leaf nutrients even under marginal production conditions, irrespective of the planting density.

Key words: Biomass production, leaf nutritional composition, moringa, planting population

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INTRODUCTION

Moringa (*Moringa* spp.) is one of the world's most useful plants and promising food sources because of its high nutritional leaf. The tree can survive during dry seasons and, therefore, be able to feed communities when other foods are typically scarce [1]. The tree is used mainly for human food, livestock forage, medicine, dye, and water purification [2, 3]. *Moringa oleifera* can be a suitable crop for climate change mitigation in areas that are already experiencing the effect of climate change, given its high level of adaptability and abundant nutritional, medicinal, industrial, domestic as well as agricultural values [4, 5].

A large volume of literature is available on the nutritional quality of moringa [1]. Moringa leaves are concentrated with different nutrients that can alleviate malnutrition. For example, the leaves mainly in powder form provide significant minerals such as vitamins A and C, calcium, iron, potassium, protein and other nutrients compared to other food crops [1, 6, 7-12]. Moringa can be consumed in many ways. Leaf powder can be mixed with juices, vegetables or soup after being prepared for consumption [13, 14].

Different studies conducted on moringa recognized the tree's nutritional value and the substantial health benefit derived through the consumption of moringa leaf powder, especially in situations where malnutrition is a threat [1, 15]. The majority of moringa consumers prefer the leaves over other products from the tree. Fahey [1] reported that the moringa tree has the potential to help combat malnutrition. Moringa serves as a backbone for food security in disadvantaged communities because all parts (leaves, flowers, young pods and seed) of the plant are edible and have long been consumed by humans [1, 16]. Several studies have already shown that moringa could serve as a solution towards poverty and hunger, which remains unassailable among poor rural communities who cannot afford expensive commercialized food [6, 17, 18].

Production of moringa in South Africa is exclusively for leaf processing and consumption. In Limpopo province of South Africa, moringa is mainly used as a source of income, supplement for good health, food security, immune booster, livestock feeding, water purification and for medicinal purposes [19].

Therefore, this study was conducted to evaluate the effect of planting density on biomass production and nutritional composition of *Moringa oleifera* planted under the semi-arid conditions of the Limpopo Province.

MATERIALS AND METHODS

Study location

The study was conducted during two consecutive years, in 2014–15 and 2015–16, at NBef Organic Farm, Eiland (23°57.691'S and 30°35.205'E) on a farmer's field situated 50 km from Tzaneen town. The area lies in the tropical region of the Limpopo Province. Weather data collected from the nearest weather station during the study period showed a great variation in precipitation (Figure 1), with total annual rainfall of 671.46, 619.74

and 329.14 mm in 2013, 2014 and 2015, respectively. The minimum and maximum temperature ranged between 15.15 and 29.21 °C across all years.

Soil sampling, preparation, and planting

Prior to land preparation, the land was demarcated within an area of 60 m length and 40 m breadth. The initial physical and chemical properties of the soil under test were randomly sampled within the demarcated area at a depth of 0 to 30 cm and 30 to 60 cm using a soil auger. The soils were bulked according to depth and a composite sample was taken for analysis. Soil preparation was carried out by conventional tillage using a tractor and by disk ploughing followed by disk harrowing and making shallow holes for planting. Untreated seeds of *Moringa oleifera* were used for planting by placing 2 seeds per hole at a depth of 2 cm.

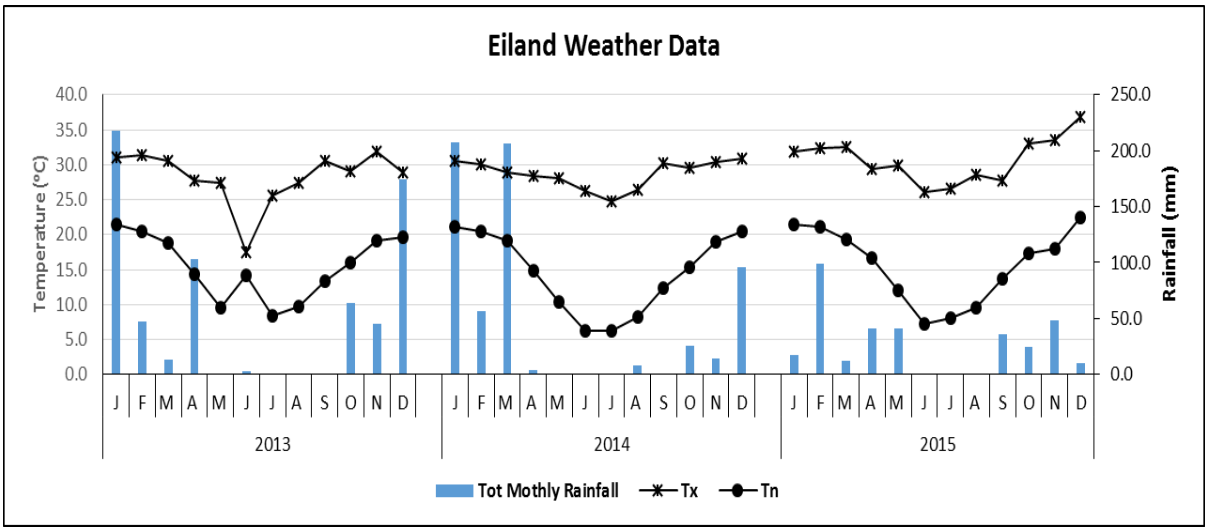

Figure 1: Total monthly rainfall (mm), average maximum (Tx) and minimum (Tn) temperatures collected from the nearest weather station at Eiland during the production seasons

Experimental design and management

The experiment was arranged in a randomized complete block design (RCBD) with eight replicates. Four spacing levels were used as treatments (D1 = 1 m x 2 m, D2 = 2 m x 2 m, D3 = 3 m x 2 m and D4 = 4 m x 2 m), giving total populations of 5 000, 2 500, 1 667 and 1 250 plants ha^{-1}, respectively.

The four treatments were randomly assigned within each of the eight blocks. The experiment was set up in a field that covered an area of 1620 m^2. The size of each plot was 4 m x 12 m and blocks were separated from each other by 2 metre walkways with a tree remaining as a border created around the treatment plots. Eight weeks after planting, plants were thinned and one healthy plant was retained. Prior to data collection, all plants within each experimental unit were uniformly pruned at a height of 50 cm aboveground.

The plants were initially irrigated uniformly for 12 weeks at a rate of 30 mm per week to encourage good plant establishment, after which the experiment was left to run under

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rainfed condition. During planting, compost was applied at 1.5 ton ha^{-1}; thereafter, no additional fertilizer was applied until the experiment was terminated after two years. There were no pest and disease incidences observed during the experiment.

Soil properties analysis
In order to compare soil nutrient cycling and utilization by moringa tree, the soils were sampled during each harvest for each treatment and compared with initial soil sample results. The soils at the two depths (0-30 and 30-60 cm) were collected within a sampling area (12 m^2), 30 cm away from the base of the plant. Soils were analyzed for P, K, Ca, Mg, Zn, Mn, Cu (mg/L), pH (KCl), organic carbon, total N (%), using standard analytical methods [20].

Leaf biomass production
During the experiment, year one traversed the period from December 2013 to March 2015, while year two ran from April 2015 to February 2016. In those two years, data on biomass production were collected from a net plot of 12 m^2 at harvest according to treatments. The new soft branches toward the tip of the tree and the leaf petioles attached to the hard branches were harvested and determined as total dry matter yield (kg ha^{-1}). The leaf yield (kg ha^{-1}) was determined by separating the leaves from the petiole. The total aboveground fresh biomass was shade-dried at room temperature for 72 hours to ease separation of leaves and stem. Shoots were further oven-dried for 48 hours at 65 ^{o}C until the samples had reached constant dry weight.

Leaf nutritional composition analysis
After observing discrepancies in soil nutrients, sampled leaves from year two were analyzed for nutritional composition to evaluate whether moringa stored nutrients in the leaves or used them for growth. Leaf samples harvested according to treatments were dried at room temperature (24 ^{o}C) for 72 hours and then ground to pass through a 2 mm sieve and 10 g of the fine fraction was used to determine the chemical composition of moringa leaves. Crude protein was determined using the Kjeldahl method [21]. Minerals P, K, Ca, Mg, Mn and Zn were determined using atomic absorption spectroscopy [22].

Gravimetric soil moisture determination
Soils were sampled every month using an auger for a period of 12 months at depths of 0 to 15, 15 to 30 and 30 to 45 cm to determine gravimetric soil moisture percentage. The soils were immediately placed in zip-lock plastic bags after sampling to keep the soil moisture intact before measurement and then using a battery-operated top loading weighing balance (RADWAG, W/C6/12/C1/R Model) to determine fresh weight. The soils were then placed inside six brown bags and dried in an oven (Scientific oven Economy, 240 litres, Model 223) for 24 hours at a temperature of 105 ^{o}C until constant weight. Gravimetric soil moisture percentage was determined when the soil samples had reached a constant weight, using a method described by Black [23] as Fresh soil x Dry soil/Dry soil x 100.

Data analysis
Data were subjected to analysis of variance using Statistix 10.0 to determine the effect of planting density on measured variables. Where significant F-values from treatment

effects were found, means were separated by least significant difference (LSD) at a probability level of 0.05.

RESULTS AND DISCUSSION

Effect of planting density on soil gravimetric moisture, physical and chemical properties

Rainfall and temperature affected the soil moisture level during year 2 compared to year 1. Gravimetric soil moisture showed a drastic drop across all planting densities from April 2015. Drought continued throughout the growing season of harvest 2, which led to a decrease in gravimetric soil moisture (Figure 2).

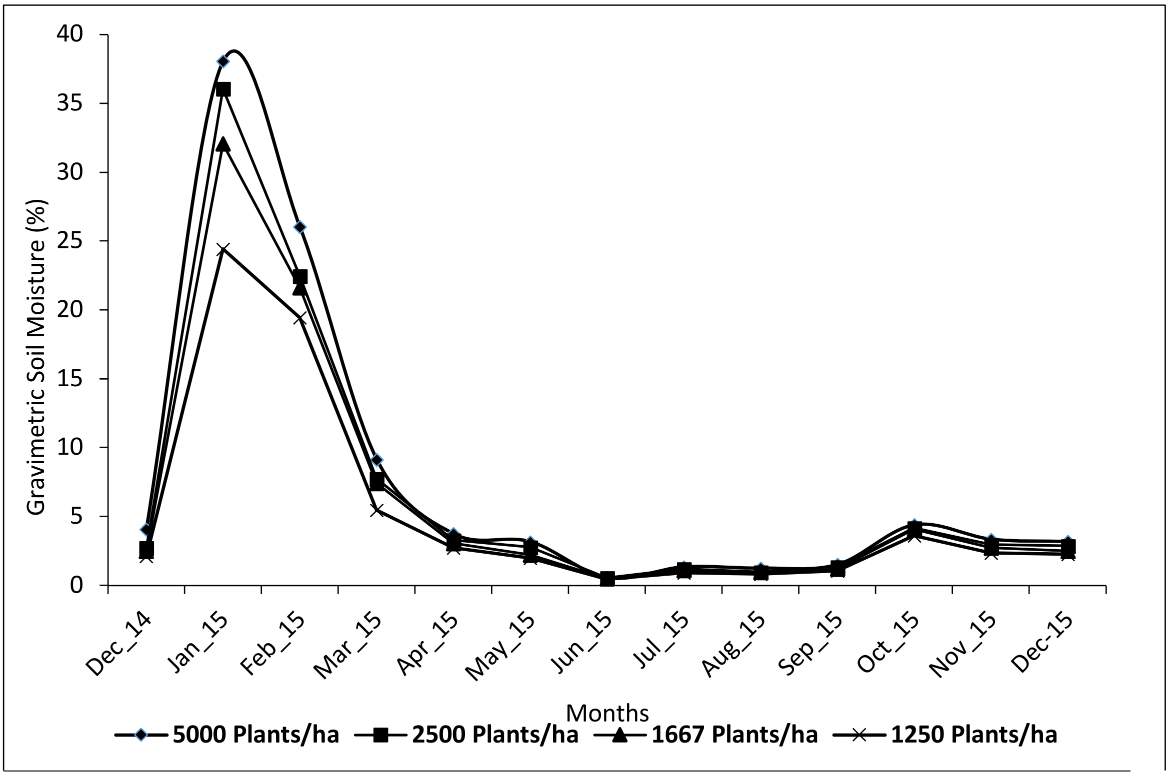

Figure 2: Monthly gravimetric soil moisture content recorded for different planting densities

The soil pH was slightly acidic before moringa establishment. Very low nitrogen content was observed at all sampling depths with a value of 0.08%. The soil nutrient profiles revealed excessive concentrations of Mg, Mn and Cu at all sampling depths with values of more than 550 mg/l, 10 mg/l and 5.5 mg/l, respectively (Table 1).

The soil analysis further showed adequate concentrations of phosphorus, potassium, calcium, zinc and organic carbon for all the depths except for phosphorous at the 30 to 60 cm depths, which was slightly lower. These soils thus contained satisfactory amounts of nutrient elements for crop growth except for nitrogen (Table 1).

The soil nutrient ion concentrations after the first and second harvests are indicated in Tables 2 and 3. Significant differences in potassium and calcium concentrations in terms of nutrient utilization by moringa plants were evident under varying densities. All other measured nutrient ion concentrations were not significantly affected by planting density except for manganese at 30-60 cm depth during the first harvest.

The results showed an increase in calcium, magnesium, pH and manganese during harvest 1. During harvest 2, there were increases in phosphorus, calcium, pH, and manganese. The increases were mainly observed from plants established at a higher density at both depths of 0 to 30 and 30 to 60 cm. Some of the properties such as potassium were mainly affected at the surface soils as compared to deeper soil profile. The densities further showed great variability with the population of 5000 plants/ha showing higher nutrient recycling.

Soil nutrients such as phosphorus, potassium, zinc, copper, organic carbon and nitrogen were reduced after the first harvest. However, during the second harvest, the same soil nutrients followed the same reduction trend as observed in the first harvest except for phosphorus which showed increased levels as compared to initial soil sampling at the second harvest (Tables 2 and 3). In many cases, moringa utilized more soil nutrients to enhance growth. However, some nutrients such as P, Ca, and Mn were recycled by showing an increase in the soil nutrient content (Tables 2 and 3).

The study showed that maintaining adequate soil nutrients is an important management consideration in moringa growth and development due to the observed reduction in some of the soil nutrients during the study. Moringa was established under rainfed conditions and with the addition of 1.5 ton/ha of compost to the field, which might not have been adequate for full growth and development of the plant. A study by Lamb *et al*. [24] showed that loss of nutrients from the soil system could be greatly affected by soil type and climate of the area.

Soil nutrients can be lost in many forms, such as through leaching, crop removal or soil erosion and runoff. From this study, it was observed that nutrient loss was through biomass removal since moringa is a fast growing crop. Looking at the number of nutrients available in the leaves as indicated in Figures 3 to 5, it is evident that moringa requires enough soil nutrients in order to accumulate enough nutrients that are available in the leaves, except K and P, which were recycled even without the further addition of nutrients to the soil.

In 2014, the production site received higher rainfall, which might have contributed to rapid decomposition of fallen leaves on the ground thereby enhancing nutrient cycling in the soil. Hence, there was an increase in calcium, magnesium, manganese, and pH during the first harvest at the depth of 0-30 cm. During the second harvest, phosphorus and manganese were relatively higher compared to the results from the initial soil test (Tables 1, 2 and 3). Several studies have reported that moringa can survive harsh conditions including less fertile soils [3, 25, 26]. This study demonstrated that indeed moringa can survive harsh conditions such as that prevailing in Limpopo province. However, the crop can perform better if adequate soil fertility and soil moisture could be maintained during

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growth. It was observed that production of moringa under drought in low rainfall conditions could negatively affect the soil fertility status.

Warm temperatures accompanied by low precipitation impact soil organic carbon [27]. Warm temperatures decrease the soil organic carbon by increasing the microbial activities and decomposition rate whilst high mean annual rainfall increases accumulation by stimulating the production of organic matter and associated organic carbon [27]. This was evident in this study, whereby low rainfall with high temperatures might have affected the microbial activities, hence reducing or negatively affecting the soil chemical properties, mainly nitrogen and soil organic carbon.

The study site received a total annual rainfall of 619.74 mm and 329.14 mm during the years 2014 and 2015, respectively, as indicated in Figure 1. The influence of moisture on the soil chemical properties was evident in both years. A study by Lee *et al*. [28] showed that soil organic carbon plays a major role in crop production because it improves physical and chemical properties of the soil through the increase in cation exchange capacity. The study further showed that continuous application of compost increased soil organic carbon, which contributed towards improved soil physical conditions such as bulk density, porosity, and aggregate stability, while no fertilizer application can negatively affect soil organic carbon and result in deteriorating physical properties [28, 29].

Effect of planting density on biomass production

During harvests 1 and 2, the increase in planting density resulted in increased biomass production (Table 4). Total dry biomass accumulation was higher during the second harvest, while the leaf biomass was drastically reduced to less than 255 kg ha^{-1} (Table 4). The increase in planting density led to a higher total biomass yield of more than 1.6 tons ha^{-1} as compared to the other planting densities. During harvest 1, the yield was slightly lower at 1.2 tons ha^{-1}.

Higher planting density of 5000 plants ha^{-1} produced the highest total dry biomass yield of 1658.4 kg ha^{-1} during the second harvest. The effect of planting density on biomass production, which is in agreement with this study, has been reported by several authors. In a study that was conducted with a population of up to 16 000 000 plants ha^{-1}, the total highest dry matter production of 44.03 tons ha^{-1} was reported [13]. Basra *et al*. [18] reported total dry matter yield of 1.10 and 1.12 tons ha^{-1} at a spacing of 15 x 30 cm during two subsequent seasons, whereas at the spacing of 15 x 60 cm, the total dry biomass was 0.9 and 1.01 tons ha^{-1} during the 1st and 2nd harvests, respectively. However, in another study, Sánchez *et al*. [30] and Abdullahi *et al*. [31], reported increase dry matter yield influenced by planting density. A similar finding was observed in this study.

Rainfall and temperature, as well as soil nutrients, played a significant role on biomass production of the moringa plant. It was observed that leaf yield was low in harvest 2 compared to harvest 1. This might have been due to low rainfall accompanied by high temperatures during the second harvest, which affected leaf production of moringa. A study by Zheng *et al.* [12] reported similar findings by indicating that, dry or low rainfall conditions resulted in stunted growth and led to lower biomass production of less than 1

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ton ha^{-1}, whereas during the time when the rainfall was higher, the total biomass was also reported to be higher at about 3.1 tons ha^{-1}.

Dry leaf yield was higher during harvest 1 at all densities compared to harvest 2. This might be due to the drought that was experienced during 2015. Zheng *et al*. [12] and Sánchez *et al*. [30] showed that biomass production of moringa is greatly influenced by the amount of rainfall, particularly during the dry seasons. Sánchez *et al*. [30] reported that harvesting in months followed by dry or low rainfall conditions resulted in stunted regrowth and lower total dry mass yield. However, when plants are allowed to grow during the rainy season and are harvested in the wet season or the start of the dry season they gave higher total dry mass yield. In the current study, the rainfall received after the first harvest influenced the vegetative growth and the reproductive stage of moringa, leading to an increase in total dry biomass yield as compared to leaf yield. Price [32] reported that one of the strategies that moringa uses to avoid drought is to lose some of its leaves and this was evident from this study.

Although leaf yield was low while the total biomass yield was higher in the second harvest, this might be positively influenced by ratooning that enhanced branching after the first harvest. Similar findings were reported where tilling density and forage yields were generally influenced by shorter cutting heights maintained at harvest [12].

Nutritional composition of moringa leaves under different planting populations

No significant differences were found between planting densities and nutritional composition as well as for protein content of the crop (Figures 3, 4 and 5). Only zinc concentration was found to be significant ($P<0.05$), with high planting density having a high zinc level of 29.4 mg/kg from a 100 g leaf powder. The protein content was found to be satisfactory at a value above 33 percent (Figure 5).

Findings from this study are in agreement with findings by Sánchez *et al*. [30] and Mendieta-Araica *et al*. [8], who reported that the crude protein contents did not differ among planting densities. Zheng *et al*. [12], on the other hand, reported that the crude protein of moringa consistently increased as the planting density increased during the rainy season. However, the effect was not significant during the dry season. The significant crude protein was 26.8, 24.7 and 23.5 % at a density of 20 x 20, 40 x 40 and 80 x 80 cm, respectively, during the rainy season.

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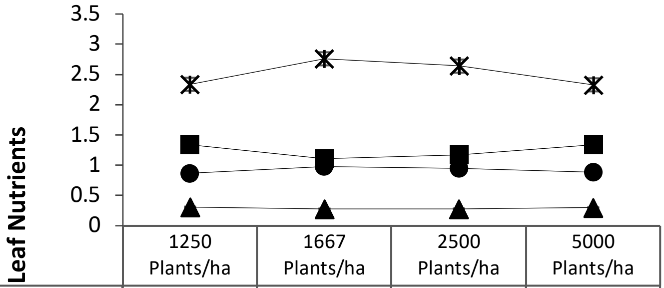
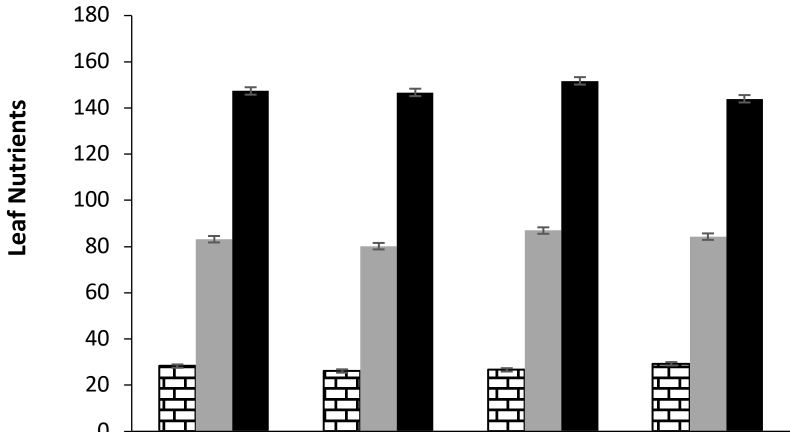


	1250 Plants/ha	1667 Plants/ha	2500 Plants/ha	5000 Plants/ha
Calcium (%)	2.34	2.76	2.64	2.33
Magnesium (%)	0.87	0.98	0.95	0.89
Potassium (%)	1.34	1.11	1.17	1.34
Phosphorus (%)	0.31	0.28	0.28	0.3

Figure 3: Selected mineral composition per 100 g of *Moringa oleifera* leaf powder at different planting densities



	1250 Plants/ha	1667 Plants/ha	2500 Plants/ha	5000 Plants/ha
Zinc (mg/kg)	28.37	26.25	26.75	29.38
Manganese (mg/kg)	83.25	80.25	87	84.37
Iron (mg/kg)	147.38	146.75	151.75	144

Figure 4: Zinc, manganese, and iron composition per 100 g of *Moringa oleifera* leaf powder at different planting densities

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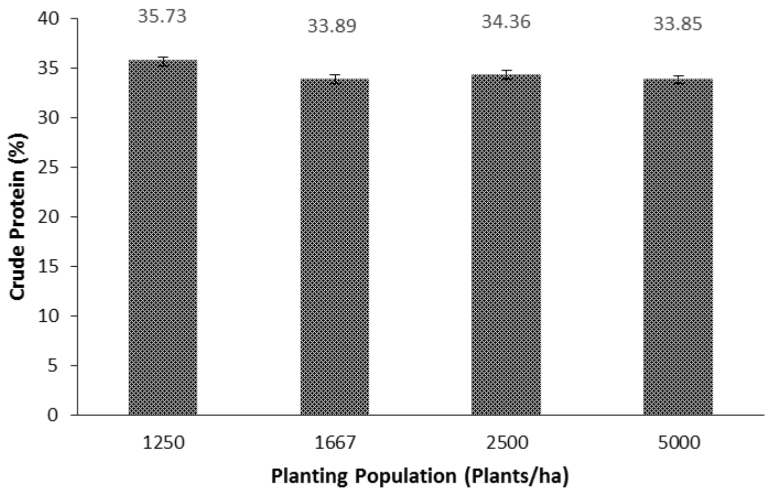

Figure 5: Protein content (%) of *Moringa oleifera* at different planting densities

Basra *et al*. [18] reported contradictory results on leaf phosphorus and calcium concentration during year one, where the nutrients were significantly influenced by plant density. The non-significant effect on chemical composition of foliage was expected, especially when the differences in planting density were not high enough to create competition for plant nutrient ions [8]. Under circumstances where leaf nutrients are affected, factors such as agro-climatic conditions, soil type, fertilization, and tree age, could contribute to some of the differences [30].

Moyo *et al*. [33] conducted the study at Sedikong sa Lerato in Tooseng Village, Ga-Mphahlele in the Limpopo Province of South Africa and concluded that powdered dried moringa leaves are a useful form of concentrated nutrients through the powder for consumption since the powder can be transported to other areas where environmental conditions do not favour cultivation of the tree.

CONCLUSION

This study indicates that moringa can be produced successfully in the Limpopo Province of South Africa. A population of 5000 plants ha^{-1} produced the highest biomass yield production. This study further proved that ratooning is important in moringa since it stimulated new shoot development leading to a bigger canopy and increased yield under both favourable and unfavourable environmental conditions. Due to its high nutritional content, moringa can serve as a source of nutrients important to human and animal health in combating malnutrition and food insecurity (through leaf powder or addition into juice beverages and as a source of income) in developing countries. With low inputs, moringa can easily be cultivated in marginal rainfall areas and by small-holder farmers who are interested in leaf production. This study revealed that moringa contains a sufficient level of leaf nutrients even under marginal production areas irrespective of the planting density. Further studies on *Moringa oleifera* are recommended for multiple locations and improved management practices for enhanced biomass production.

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Table 1: Initial soil physical and chemical properties prior to planting

Soil Depth (cm)	Soil properties									
	P (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	pH (KCl)	Zn (mg/L)	Mn (mg/L)	Cu (mg/L)	Org C (%)	N (%)
0-30	23	184.5	1821	580	5.7	5.9	11.5	5.9	1.3	0.08
30-60	10.5	107.5	2177	675.5	5.5	2.5	13	5.8	1.3	0.08

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Table 2: Soil physical and chemical properties after harvest 1 during 2015 season

Soil Depth (cm)	Plant density (Plantha^{-1})	P (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	pH (KCl)	Zn (mg/L)	Mn (mg/L)	Cu (mg/L)	Org C (%)	N (%)
0-30	**5000**	17.5[a]	96.2[b]	2741.3[a]	610.7[a]	6.3[a]	2.0[a]	26.5[a]	5.4[a]	0.9[a]	0.06[a]
	2500	12.2[a]	90.0[b]	2436.7[ab]	593.5[a]	5.8[a]	1.6[a]	22.5[a]	4.6[a]	0.7[a]	0.05[a]
	1667	21.7[a]	134.2[a]	1903.1[b]	534.0[a]	6.3[a]	2.5[a]	24.7[a]	6.0[a]	0.6[a]	0.05[a]
	1250	15.3[a]	104.5[b]	1887.5[b]	581.0[a]	6.2[a]	2.4[a]	23.5[a]	5.2[a]	0.8[a]	0.04[a]
	P value	0.34	0.01	0.00	0.09	0.88	0.30	0.22	0.34	0.08	0.51
	CV%	62.5	25.5	23.8	16.9	22.4	44.9	31.6	28.4	44.6	43.8
	Significance (0.05)	ns	**	**	ns	ns	ns	ns	ns	ns	ns
30-60	**5000**	18.7[a]	101.5[a]	3102.5[a]	520.5[a]	6.7[a]	2.3[a]	19.0[b]	4.8[a]	0.6[a]	0.03[a]
	2500	18.3[a]	110.5[ab]	1683.8[b]	505.3[a]	6.1[a]	1.4[a]	33.2[a]	4.6[a]	0.6[a]	0.04[a]
	1667	18.5[a]	98.50[b]	2066.5[b]	512.8[a]	5.8[a]	2.3[a]	18.2[b]	4.6[a]	0.6[a]	0.04[a]
	1250	18.5[a]	135.1[a]	1829.3[b]	486.0[a]	6.1[a]	1.4[a]	23.2[b]	4.1[a]	0.6[a]	0.04[a]
	P value	0.26	0.05	0.00	0.06	0.53	0.26	0.00	0.79	0.94	0.88
	CV%	104.2	25.3	26.8	26.5	20.8	64.6	32.0	33.3	28.8	61.8
	Significance (0.05)	ns	*	**	ns	ns	ns	**	ns	ns	ns

Significance levels: *P<0.05, ** P<0.01, *** P<0.05, ns: not significant. Means with different letters are statistically significant

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Table 3: Soil physical and chemical properties after harvest 2 during 2016 season

Soil Depth (cm)	Plant density (Plantha^{-1})	P (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	pH (KCl)	Zn (mg/L)	Mn (mg/L)	Cu (mg/L)	Org C (%)	N (%)
0-30	**5000**	24.2^{b}	125.0^{b}	2078.0^{a}	503.5^{a}	6.7^{a}	2.0^{a}	21.7^{a}	4.8^{a}	0.8^{a}	0.04^{a}
	2500	24.0^{b}	100.2^{b}	1452.0^{a}	482.0^{a}	6.6^{a}	2.5^{a}	19.5^{a}	5.0^{a}	0.6^{a}	0.04^{a}
	1667	40.5^{b}	160.7^{a}	1903.8^{a}	480.2^{a}	6.9^{a}	2.8^{a}	20.0^{a}	4.6^{a}	0.8^{a}	0.04^{a}
	1250	61.5^{a}	165.1^{a}	1652.0^{a}	374.0^{a}	7.0^{a}	3.3^{a}	19.0^{a}	4.3^{a}	0.6^{a}	0.04^{a}
	P value	0.00	0.00	0.21	0.16	0.86	0.53	0.83	0.64	0.45	0.86
	CV%	50.6	17.9	34.6	26.2	15.4	62.0	31.3	23.5	45.2	51.4
	Significance (0.05)	**	**	ns	ns	ns	ns	ns	ns	ns	ns
30-60	**5000**	19.7^{b}	132.7^{a}	2072.5^{a}	456.0^{a}	6.5^{a}	1.9^{a}	22.3^{a}	4.7^{a}	0.7^{a}	0.03^{a}
	2500	13.7^{b}	83.2^{b}	1636.0^{a}	427.7^{a}	6.1^{a}	1.8^{a}	30.0^{a}	4.7^{a}	0.7^{a}	0.04^{a}
	1667	36.7^{a}	142.5^{a}	1959.5^{a}	419.0^{a}	6.6^{a}	2.3^{a}	24.5^{a}	4.7^{a}	0.9^{a}	0.04^{a}
	1250	41.5^{a}	163.7^{a}	1620.0^{a}	409.5^{a}	6.7^{a}	2.5^{a}	27.2^{a}	4.1^{a}	0.7^{a}	0.04^{a}
	P value	0.00	0.00	0.43	0.44	0.64	0.06	0.12	0.42	0.58	0.92
	CV%	32.7	27.2	36.4	28.8	16.9	51.3	24.7	19.6	51.0	51.9
	Significance (0.05)	**	**	ns	ns	ns	ns	ns	ns	ns	ns

Significance levels: *P<0.05, ** P<0.01, *** P<0.05, ns: not significant. Means with different letters are statistically significant

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Table 4: Biomass production of moringa under different densities at Nbef organics during 1st and 2nd harvests

Year of Harvest	Density (Plants ha^{-1})	Dry leaf yield (kg ha^{-1})	Total Dry Biomass yield (kg ha^{-1})
1st Harvest (2015)	**5000**	447.91^{a}	1250.6^{a}
	2500	338.80^{b}	1006.6^{ab}
	1667	263.13b^{c}	805.2^{bc}
	1250	205.33^{c}	647.3^{c}
	P value	0.000	0.001
	CV%	23.79	28.18
	Significance (0.05)	**	**
2nd Harvest (2016)	**5000**	252.31^{a}	1658.4^{a}
	2500	223.81^{a}	1218.9^{b}
	1667	209.16^{ab}	1065.3^{bc}
	1250	160.06^{b}	889.8^{c}
	P value	0.012	0.000
	CV%	24.00	23.72
	Significance (0.05)	**	**

Significance levels: *P<0.05, ** P<0.01, *** P<0.05, ns: not significant. Means with different letters are statistically significant

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