Effects of pH, Nitrogen and Phosphorus on the Establishment and Growth of *Moringa oleifera* Lam

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Abstract  Adoption and production of *Moringa oleifera* Lam. as an agroforestry and vegetable crop in Zimbabwean smallholder farming sector is considerably low. pH, phosphorus and nitrogen have been identified as major limiting factors for *Moringa* initial establishment and growth. A study was carried out to investigate the effects of pH, N and P on initial establishment and growth of *M. oleifera*. The objectives of this study were to determine optimum application rates of agricultural lime, N and P, and interaction of lime and fertilizers on *Moringa* growth. Sandy soil from Marange was used in the greenhouse experiment at Africa University. Three lime levels (0, 4000 and 8000 kg ha⁻¹) and four N levels (0, 200, 400 and 800 kg ha⁻¹ ammonium nitrate) were combined factorially with four levels of P (0, 100, 200 and 400 kg ha⁻¹ P₂O₅), in a randomized complete block design. *Moringa* plant height, shoot dry matter and root dry matter significantly increased with an increase in the amount of lime, N and P applied. Significant interaction between lime and fertilizers was observed, with best results being obtained where 276 kg N ha⁻¹ and 400 kg/ha P₂O₅ were applied at a pH of 6.2 (4000 kg ha⁻¹ lime).

Keywords  *Moringa oleifera* Lam, pH, Nitrogen, Phosphorus, Growth, Establishment

1. Introduction

There is need to improve nutrition in sub-Saharan Africa, including Zimbabwe, through the use of cheap alternative food. The nutritional value of *Moringa oleifera* has aroused the interests of countries and organization working among poor communities in Africa. The pods, leaves and seed of *Moringa* have high levels of nutrition, containing large amounts of protein (5-10%), calcium, iron and Vitamin A and B and high quality of oil that does not easily turn rancid [1]. In Zimbabwe, *M. oleifera* Lam. has become an important source of livelihood for a number of people as villagers in parts of Matebeleland are growing the tree in large quantities for sale to other villagers and other provinces [2].

Promotion of Moringain Zimbabwe is mainly in low input agricultural systems (small holder farming sector), where human nutrition is compromised. These are areas characterized by nutrient depleted sandy soils of granitic origin. These soils were shown to be deficient in phosphorus and nitrogen, with soil pH often below pH 5 CaCl₂ scale [3, 4]. These soil characteristics have adverse effects on crop productivity. During establishment, *M. oleifera* Lam. seedlings have shown symptoms of stunted growth and yellowing of leaves, resulting in death or reduced growth. This has been attributed to low initial soil nutrition and water logging in some cases [5]. There is need to apply fertilization during establishment of *M. oleifera* Lam. in soils with low inherent fertility. Despite claims that the plant grows well in poor soil without additions of fertilizer, work by Francis and Liogier [5] has also shown that addition of fertilizer to *M.oleifera* Lam. during establishment resulted in increased foliage and seed yields.

Most publications on *M.oleifera* Lam. report information from simple observations and few are based on targeted research hence there is need for concrete experimentation on the crop. In Zimbabwe, there are no standard recommended agronomic practices for Moringa production; practices used for growing of the crop are therefore based on conjecture. Knowledge on optimum pH requirements, seedbed requirements to nitrogen (N) and phosphorus (P) would significantly assist in scaling up production of *M. oleifera* Lam. as a vegetable since this is not well documented. Previously, research on *M. oleifera* Lam. has mainly focused on Moringanutritional values and its uses while research on establishment has not received much attention despite the growing realization that Moringa establishment can be affected by nutrient status of soil or media.
Phosphorous is one of the mineral nutrients essential for plant growth and development. It plays diverse regulatory, structural, and energy transfer roles and consequently is required in significant quantities, constituting up to 0.2% of the dry weight of the plant cell [6].

Considering the nutritive value of *M. oleifera* Lam. as well as the importance of soil nutrition in the cultivation of the crop, the present study was carried out with the objective of determining the effect of pH, N and P on the initial establishment and growth of *M. oleifera* Lam.

### 2. Materials and Methods

The experiment was conducted in a greenhouse at Africa University during the 2009/2010 cropping season using sandy soils from Marange communal lands. Marange soils are classified mainly as fersiallitic, 5G soils in the Zimbabwean soil classification system [7]. The chemical and physical properties of the soil used are shown on Table 1. The university is located at an altitude of 1063 m above sea level and on 32°36’ E and 18°53’ S. The area falls in Natural Region 1 of Zimbabwe’s Agro-ecological Zones which receives > 1000 mm rainfall per year and low mean temperature of < 15°C.

The experiment was a 3×4×4 factorial treatment structure laid in a randomized complete block design with 3 replications, giving a total of 144 experimental units. Three agricultural lime (CaCO₃) levels were used namely inherent agricultural lime levels were used. Single super phosphate (SSP) was used as the P source in the experiment while ammonium nitrate was used as the N source. Potassium (K) was applied three weeks before planting. Single super phosphate (SSP) was used as the P source in the experiment while ammonium nitrate was used as the N source. Potassium (K) was applied at the standard rate of 100kg K₂O ha⁻¹ (0.23g/10kg soil).

Moringa seeds were sourced from local farmers’ agroforestry fields in Mutare District. Black polythene bags were used in the experiment. Each plastic pot was filled with 10 kg of soil. The soil in the pots was adjusted to 3 pH levels by applying 0, 4000 and 8000 kg lime ha⁻¹, translating to 0, 1.23 and 2.46 g lime per 10 kg soil. The fertilizer and lime was thoroughly mixed with the soil. Water was added to field capacity and pots left for 3 weeks with regular watering, however, making sure there was no nutrient leaching. At the end of 3 weeks, Moringa seeds were sown in the pots. N application was split into 3 equal applications done at sowing, at 4 weeks after emergence (WAE) and 8WAE whilst, P was applied all at once on the day of sowing. Watering was done every day in the first two weeks, thereafter watering was done less frequently (when required), and equal amounts of water were applied across all treatments.

Data collection was done at the end of the experiment i.e. 12 WAE. Seedling height (up to the tip of the growing point), shoot dry matter mass and root dry matter mass were recorded. Seedling height was measured using a ruler up to the tip of the growing point. For the dry matter measurements, the plastic pots were removed and the plants were placed on running tap water to remove all the soil before weighing. Paper bags were labelled corresponding to the treatment on the pots and the age of seedling. The paper bags were weighed using a sensitive digital scale prior to placing of plant material. The bag with the plant was placed in an oven at 70°C for three days to dry the sample. After three days (72 hours), the mass of the seedlings plus paper bag was weighed. The mass of the empty bag was subtracted to find dry mass of the plants.

Data on seedling height, shoot dry mass and root dry matter were subjected to analysis of variance (ANOVA) using GenStat version 8.1 statistical package. Least significant difference (LSD) was used in mean separation at 5% significance level.

### 3. Results

There was significant interaction (p<0.001) between N and pH on plant height of *M. oleifera*. As the amount of N applied increased there was a general increase in height of Moringa seedlings. In treatments where no lime was applied, height increased by 34.4, 95.3 and 153% after application of 69, 138 and 276kg N ha⁻¹ compared to 0kg N ha⁻¹ (Figure 1). Application of lime resulted in an increase in height; height increased by 58 and 25.1% compared to control after application of 4000 and 8000kg lime ha⁻¹ respectively. N and lime interacted to increase height of *M. oleifera* seedlings. When 4000kg lime ha⁻¹ was applied in combination to 0, 69, 138 and 276kg N ha⁻¹, height increases of 57.9, 81.2, 116.2 and 153.9% respectively were recorded compared to where no lime and N were added (control) (Figure 1). Highest percentage height increase of 153% (compared to control)
was recorded in treatment where 4000kg lime ha\(^{-1}\) (pH 6.2) was applied together with 276kgN ha\(^{-1}\) (Figure 1).

**Figure 1.** Interaction effect of pH and N levels on plant height of *M. oleifera*.

Interactions of N × P (p<0.05) and pH × N (p<0.01) significantly influenced shoot dry matter accumulation. As amount of N applied increased, there was an increase in shoot dry matter (Figure 2). In treatments where 69, 138 and 276 kg N ha\(^{-1}\) was applied, shoot dry matter increased by 55.7, 132 and 230%. Application of lime increased shoot dry matter accumulation of *M. oleifera*. When 0, 4000 and 8000kg lime ha\(^{-1}\) was applied without N, 17.83, 20.4 and 17.61g of shoot dry mass were recorded respectively. When lime levels, 0, 4000 and 8000kg N ha\(^{-1}\) were applied in combination with 138kg N ha\(^{-1}\), shoot dry matter increased by 134.4 and 96.7% respectively compared to when lime was applied alone (Figure 2). The treatment that had 276kg N ha\(^{-1}\) and 4000kg lime ha\(^{-1}\) had the highest shoot dry matter increase of 241% when compared to the control treatment. Figure 3 shows the effect of P levels at different N levels on shoot dry matter. As the amount of N and P applied increased, shoot dry matter also increased. When 69 and 138kg N ha\(^{-1}\) was combined with 0 and 100kg P\(_2\)O\(_5\) ha\(^{-1}\), shoot dry masses recorded were not significantly different from each other (Figure 3).

**Figure 2.** Interaction effect of pH and N levels on shoot dry matter of *M. oleifera*

Analysis of variance showed that the interaction of pH ×P (p<0.01) significantly affected root dry matter. Application of P increased root dry matter accumulation; root dry mass increased by 22.7, 33.2 and 48.2% where 100, 200 and 400kg P\(_2\)O\(_5\) ha\(^{-1}\) were applied respectively (Figure 4). Application of lime also increased root dry matter; highest root dry matter accumulation was obtained in the treatments when 4000kg lime ha\(^{-1}\) (pH 6.2) was applied at 400kg ha\(^{-1}\) P\(_2\)O\(_5\). Separation of means using the least significant difference (LSD) shows that application of 8000kg lime ha\(^{-1}\) at 100kg P\(_2\)O\(_5\) ha\(^{-1}\) did not significantly improve root dry matter when compared to application of 4000 lime ha\(^{-1}\) at the same P level (Figure 4). Application of 4000 and 8000kg lime ha\(^{-1}\) at 100kg P\(_2\)O\(_5\) ha\(^{-1}\) increased root dry mass by 36.2 and 33.1% respectively whilst application of the same lime levels at 200kg ha\(^{-1}\) P\(_2\)O\(_5\) increased root dry mass by 57% and 39% respectively (Figure 4).

**Figure 3.** Interaction effect of P and N levels on shoot dry matter of *M. oleifera*.

**Figure 4.** Interaction effect of pH and Plevenson root dry matter of *M. oleifera*.

4. Discussion

Soil used in this study typically represents sandy soils found in Zimbabwean smallholder farming sector in terms of physical and chemical properties. The low pH and organic
matter content recorded are similar to those recorded by Chikowo [8]. The soil also had low N and P concentrations; this can be attributed to the fact that acid soils generally have low P in solution [9]. Chikowo [8] also reported that total soil N content is generally low in soils with low organic matter hence this is consistent with that in the soil used in this study (Marange sandy soil) which had 23 ppm exchangeable N.

Nitrogen is the most limiting plant nutrient and an essential element for plant growth in most soils in Zimbabwe [3] and elsewhere in Africa [10]. Low growth rates were recorded in treatments where N was not applied. This can be attributed to the fact that insufficient N may culminate in stunted growth of plants, firing of older leaves and premature senescence, thereby reducing yield [11]. In this study, a significant increase in plant height, shoot dry matter and root dry matter with application of N was observed. Where 69, 138 and 276 kg N ha\(^{-1}\) were applied, percentage increases of height by 28, 64 and 95.6% were observed. This high response to N application could have been caused by the low exchangeable N (23 ppm) in the soil used.

The marked increase in Moringa growth with increasing N fertilizer rate indicates that N fertilizer was readily absorbed by the Moringa seedlings. Increased height with N application can be linked to the role of N in promoting apical dominance. The greenhouse experiment in this study showed an increase in dry matter with increases in applied N. This is similar to findings by Grenato and Rapper [12], who recorded increases in protein content, fresh weight, area and thickness of leaves with increase in N. Nitrogen plays a pivotal role on plant growth and development. Increase in the dry matter depends on the amount of photo-assimilates fixed through photosynthesis [13]. Nitrogenous fertilizer increases leaf area, which increases the amount of solar radiation intercepted and consequently increasing dry matter production through increased photosynthesis [14]. Nitrogen can induce a wide range of developmental effects that are attributed to its influence on hormonal factors [15]. Moreover, Shibairo [15] discussed the possible involvement of growth substances as mediators of N-induced effects of growth and development. Increase in endogenous levels of nitrogen supply were recorded. According to Shibairo [15], N stimulates respiration, either directly or by promoting auxin synthesis.

Application of P resulted in a positive response to yields of Moringa plants. Low inherent concentrations of P (11 ppm) recorded in the soils used could be the reason for the yield response to P application. Root dry matter increased by 17%, 33.9% and 56% respectively when compared to control after application of 100, 200 and 400 kg/ha \(P_2O_5\), respectively. Root dry matter recorded the highest percentage increase compared to shoot weight in treatments where P was applied. Findings by Havlin et al. [16] revealed that, when soluble phosphate compounds are applied, plant roots proliferate extremely in the treated soil area leading to high root growth rates compared to shoot growth. The increase in growth of Moringa recorded in this study could be as a result of increased available P after P application, as was reported by Munangwa and Tagwira [17] in an experiment to determine effects of single super phosphate on groundnut yield. The results confirm reports by Buresh et al. [18] that small additions of soluble fertilizers to P deficient soils with low to moderate sorption capacity increase crop productivity.

Soil pH has a considerable influence to nutrient availability and plant growth. In this study, poor root growth and low dry matter accumulation were recorded in treatments where no lime was applied. Generally, there were significant plant height, shoot and root dry matter increases in \textit{M. oleifera} plants. Low pH (4.2), Ca and Mg concentrations recorded in the sandy soils could be the reason for the positive response to lime application by Moringa seedlings. Growth and dry matter increases can also be related to the enhanced release of fixed nutrients, increasing availability of nutrients to plants. Al and Mn accumulate to toxic levels in root cortex with increasing acidity, inhibiting root growth and reducing yields, particularly at pH 4.2 and below [19]. Grant et al. [20] observed that at pH 4.2, the Al levels in Zimbabwean soils increase exponentially. Thus, liming raises soil pH, enhancing availability and uptake of inherent nutrients by reducing extractable Al, thereby increasing crop growth and yields [21].

Experimentation by Unkovich, et al. [22] revealed improvement in plant growth in trees after application of lime. Application of 4000 kg lime ha\(^{-1}\) was optimum in this experiment. A percentage increase of 38.7% compared to control was recorded in treatments where 4000 kg lime ha\(^{-1}\) was added, however further increasing amount of lime to 8000 kg reduced the benefit in terms of height to 14.2%. This could be as a result of unavailability of nutrients like P, zinc, copper and boron at higher pH (>7.0) because of fixation. Too much lime can reduce availability of P and other trace elements like zinc and copper [23]. In this study, pH levels in the alkaline range are undesirable for plant growth and also inhibit nutrient availability. Studies by Tagwira et al. [24] showed that availability of P and other trace elements increases with liming at certain pH levels but decrease at high pH levels in some Zimbabwean soils. The results show that low pH and very high pH affect Moringa growth and pH 6.2 was close to the optimum than the other two levels.

Findings from this study revealed greater benefit in application of lime in combination with fertilizers compared to when lime and fertilizers were applied solely. Root dry matter increased by 48.3% where 400 kg ha\(^{-1}\) \(P_2O_5\) was applied alone, whilst 80.9% increase was recorded when 400 kg ha\(^{-1}\) was combined with 4000 kg ha\(^{-1}\) lime. On the other hand, application of 4000 kg lime ha\(^{-1}\) and 276 kg N ha\(^{-1}\) produced 153% increase in height compared to control, whilst a 95% increase was recorded where only 276 kg N ha\(^{-1}\) was applied alone. This could be as a result of the multiple effect of release of fixed nutrients by lime, supply of Ca by lime and also supply of N and P from the fertilizers. Britto and Kronzucker [25] reported that response of plant growth and nutrient absorption to nutrients vary with pH. At pH 4.2
and below, Al and Mn concentrations increase exponentially, fixing available P. More so, most organisms responsible for the conversion of ammonium to nitrates require large amounts of Ca, nitrification is enhanced by liming. Application of 4000 kg lime was optimum and this increased inherent pH (4.2) to approximately 6.2. pH 6.0-6.5 is the optimum pH range for biological activity of nitrification [19]. This is in support of reports by Duble [26] that P is most readily available between pH 6.0 and 7.0. Kisinyo et al. [27] observed interaction of P and lime in increasing P availability and Sesbania sesban growth in Kenyan acidic soils while Duguma et al. [28] showed that application of P at high Al concentration was not beneficial, revealing importance of applying lime and fertilizers in combination.

5. Conclusions

Basing on the research findings, low pH and low available N and P are the major constraints to M. oleifera production. Application of lime, N and P has been found to be effective in increasing growth rate and establishment of M. oleifera. Liming is important for good plant growth in soils where pH is low. Increasing pH above 6.2 is not desirable for M. oleifera production. Applications of N influences more on above ground parameters like height and shoot dry matter whilst P has greater influence on root growth. Lower growth rates were recorded where N and P was applied without lime as compared to where fertilizers were applied together with lime, proving that pH can affect availability of some nutrients. The rate of fertilizer has an effect on Moringa dry matter yield and growth. The higher the amount of N and P fertilizer applied, the higher the growth rate of M. oleifera. In acidic sandy soils, liming increases Moringa growth but raising the soil pH above 6.2 results in retarded growth.

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REFERENCES


Replenishing soil fertility in Africa. Buresh RJ, Sanchez PA and Calhoun F. (eds). SSSA, Special publication Number 51.SSSA.


