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Research Article

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NPK Fertilizer Requirements for *Jatropha Zeyheri* Indigenous Tea under Microplot Conditions

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ABSTRACT
Effects of NPK fertilizer could have positive or negative effects in relation to growth of crops under certain environments, with minimum findings on how crops react to fertilizers under microplot conditions. Therefore, the objective of this study was to assess the effects of increasing NPK fertilizer rate on *Jatropha zeyheri* tea growth under microplot conditions. At two-leaf phase, *J. zeyheri* seedlings were transplanted into 25 cm diameter plastic pots. Each pot was filled with heated pasteurized sandy soil and Hygromix at 3:1 (v/v) ratio and placed in a spacing of 0.30 m × 0.30 m inter-and intra-row spacing. Six treatments constituting NPK fertilizer rates (0, 2, 4, 8, 16 and 32 g) were arranged in a randomized complete block design, with five replications. Treatments were initiated a week after transplanting, and 130 days after that, treatments had highly significant effects on leaf width, contributing 66% in TTV, whereas significant effects were reported on vine length, stem diameter, leaf length and dry root mass contributing 61, 67, 68 and 49% in TTV, respectively. NPK fertilizer rates did not affect chlorophyll content, NDVI, dry shoot mass, number of leaves and leaf area index. *Jatropha zeyheri* yield variables when exposed to increasing fertilizer rates displayed positive quadratic relations. Use of fertilizers had setbacks when applied inappropriately leading to inconsistent results. However, determining optimum fertilizer requirement for *J. zeyheri* was a strategical solution for inappropriate application. *Jatropha zeyheri* fertilizer requirements were optimized at 3.30 g fertilizer/plant, which shows that *J. zeyheri* requires a minimum amount of NPK fertilizer to stimulate growth.

Keywords: Botanicals, Fertilizer, *Jatropha Zeyheri*, Primary Nutrients, Tea Yield

Introduction

Tea plant requires enormous quantity of nutrients for its development and growth. However, lack of nutrients could severely have a great effect on the overall tea produce and quality. Nutrients are crucial, their deficiency and poor supply would ultimately result in poor tea crop growth and performance [1]. It was reported that production of tea requires fertilizer input to successfully grow optimally [2,3]. Optimum production of tea requires the use of fertilizers for achieving maximum yield, this is regarded as a beneficial strategy for quicker tea growth [4-6]. The NPK fertilizer has nitrogen, phosphorus and potassium as active ingredients, these essential nutrients allow the crop to grow bigger and faster with improved overall plant health. Farmers utilize fertilizers because these materials contain plant nutrients which are responsible for achieving greater outputs. Plants uptake nutrients more quickly from inorganic fertilizer because they are more digestible and are shortly available for uptake. Chemical fertilizers are man-made soil enhancers utilized to raise the level of nutrients found in soil.

The use of inorganic fertilizer can increase tea yield by 25%. While many studies have evaluated the yield and physical properties of the soil nutrients and water, the impact of fertilizers on tea productivity is not well defined. Several studies have concentrated on fertilization regimes on soil fertility crop yields and microbial communities. However, the results of these reports are still conflicted. It is essential to investigate the effects of fertilization on *Jatropha zeyheri* tea plant. Therefore, the objective of this study was to assess the effects of increasing NPK fertilizer rate on *Jatropha zeyheri* tea growth under microplot conditions.

Materials and Methods

Description of the Study Site

Microplot experiment was established at the Aquaculture Research Unit, University of Limpopo, Limpopo Province, South Africa (23°53'10"S; 29°44'15"E) in October 2021 to April 2022. The site is characterized by sandy soil. The area is commonly hot and has a summer day temperature range between 28 and 38°C, with annual rainfall that is less than 500 mm. Microplot experiment was established by digging single holes where the plastic pots were inserted.

Treatments and Research Design

Experiment comprised six treatments, 0, 2, 4, 8, 16 and 32 g of NPK fertilizer 2:3:2 (22), with 5 replications in a randomized complete block design (RCBD). Treatments were blocked due to

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unequal distribution of sunlight caused by the windbreaks under microplot and field conditions.

Procedures

Jatropha zeyheri plant seeds were collected in the wild at Zebediela, Lepelle-Nkumpi Municipality (24°33'53" S, 29°23'4" E) in Limpopo Province of South Africa. A seed viability test was performed prior to planting. Seedling trays were used, and after emergence to 5 cm, *J. zeyheri* seedlings were hardened off for a week through intermittent withholding of irrigation water outside the greenhouse. At two-leaf phase, *J. zeyheri* sprouts were planted into 25 cm plastic pots. Each pot was filled with sandy soil and Hygromix at 3:1 (v/v) ratio and placed in a spacing of 0.30 m × 0.30 m inter-and intra-row spacing. After seven days, treatments were applied when seedlings adapted to the newly introduced environment. Chlorine-free tap water was applied per 25 cm pot with 500 ml. Each plant was fertilised with NPK 2:3:2 (22) after 7 days according to their respective treatments and 1 g 2:1:2 (43) Multifeed (Nulandies, Johannesburg). Diseases and pests were scouted and monitored daily, whereas diseases were managed using Malasol and cutworm bait during the seedling stage as per label instructions.

Data Collection

At 130 days after the treatments, vine length was measured from the ground to the tip of the leaf using a 1 m ruler. Stems were severed at the soil surface, and stem diameter was measured at 2 cm from the ground using a Vanier calliper. Chlorophyll content was measured with a chlorophyll meter (Konica, Minolta Spad-502, Osaka, Japan). Leaf yield characteristics such as leaf numbers per plant, leaf width, leaf length, and leaf area index (Plant Canopy Analyzer, LAI-2200C, USA) were determined. Normalised difference vegetative index (NDVI, Green Seekers Crop sensor, Oklahoma, USA) was used to assess the healthiness of the plants. Leaves were harvested and dried at 60°C in an airforced oven for 24 hrs. The dried leaves were ground using an electric grinder to pass through a to a 1 mm sieve (MF 10 basic, IKA WERKE, United States) before analysis. The root system was removed from the field and pots, dipped inside water to get rid of soil particles, and thereafter measured and dried in an oven at 72°C for 48 hrs.

Data Analysis

Data were subjected to analysis of variance (ANOVA) procedures using Statistix 10 software 2021 update. Significant treatment means different at a 5% level of probability. Associated sum of squares resulting from the degree of freedom was separated to establish the contributed percentage among the treatment means and significant means were separated using Fisher's Least Significant Difference. To evade curve-fitting challenges at lower concentration, equidistance between observations were generated by transforming the geometric concentration using $\log_2^2$ transformation. A $\log_2^2$ transformation of the exponential series 2^0, 2^1, 2^2, 2^3, 2^4 and 2^5 g NPK fertilizer rates resulted in 0, 1, 2, 3, 4 and 5 g NPK fertilizer rates, which was used to generate biological indices. Lines of the best fit were used on plant variables with significant treatment means, using the regression curve estimations resulting in a quadratic equation. $Y = b_2x^2 + b_1x + a$ however, Y = Plant response, x = Fertilizer application rate with $-b_1/2b_2$ = x value for optimum application rate.

Results

NPK fertilizer rates depicted highly significant effect ($P \leq 0.01$) on leaf width, contributing 66% in TTV (Table 1), whereas significant effects were illustrated on vine length, stem diameter, leaf length and dry root mass contributing 61, 67, 68 and 49% in TTV, respectively. NPK fertilizer rates were not significant on chlorophyll content, NDVI, dry shoot mass, number of leaves and leaf area index (Table 1).

Table 1: Partitioning mean sum of squares for vine length (VL), stem diameter (STD), chlorophyll content (CHL), normalized difference vegetation index (NDVI), number of leaves (NOL), leaf width (LW), leaf length (LL), leaf area index (LAI), dry shoot mass (DSM) and dry root mass (DRM) of *Jatropha zeyheri* to increasing NPK fertilizer rates under microplot conditions (n = 30)

Source	DF	VL (cm)		STD (mm)		CHL		NDVI		NOF		LW (cm)	
		MSS	TTV (%)	MSS	TTV (%)	MSS	TTV (%)	MSS	TTV (%)	MSS	TTV (%)	MSS	TTV (%)
Replication	4	26,40	19	0.48	12	83.49	34	0.0030	22	12.58	36	1.02	18
Treatment	5	87.62	61**	2.84	67**	72.85	30ns	0.0069	49ns	14.08	40ns	3.71	66***
Error	20	30.62	20	0.96	21	88.41	36	0.0041	29	8.56	24	0.93	16
Total	29	144.64	100	4.29	100	244.75	100	0.015	100	35.22	100	5.66	100

Source	DF	LL (cm)		LAI (mm^2)		DSM (g)		DRM (g)	
		MSS	TTV (%)	MSS	TTV (%)	MSS	TTV (%)	MSS	TTV (%)
Replication	4	1.00	5	0.0329	64	14.73	32	55.31	36
Treatment	5	14.56	68**	0.0099	19ns	21.59	47ns	75.20	49**
Error	20	5.67	27	0.0089	17	10.10	21	23.17	15
Total	29	21.23	100	0.052	100	46.42	100	153.68	100

***: Treatment effects were highly significant at $P \leq 0.01$; **: Significant at $P \leq 0.05$, ns: Not significant at $P \geq 0.05$

Relative to control, NPK fertilizer rates increased vine length, stem diameter, leaf width and leaf length by 7-26, 15-44, 3-76 and 1-57%, respectively (Table 2). However, inhibition was observed at high NPK fertilizer rates, dry root was decreased by 11-48%. Similarly, at 32 g of NPK fertilizer vine length, and stem diameter reduced by 45 and 4%, respectively (Table 2). Vine length, stem diameter, leaf width, leaf length and dry root mass demonstrated positive quadratic relations when exposed to increasing NPK fertilizer rates thus indicating density-dependent growth pattern. The models were explained by 96, 92, 86, 79 and 87% associations for vine length, stem diameter, leaf width, leaf length and dry root mass, respectively (Figure 1). Using the relation $x = -b_1/2b_2$, rates for optimum vine length, stem diameter, leaf width, leaf length and dry root mass were 2.02, 2.51, 4.92, 4.22 and 2.83, respectively (Table 3). Optimum NPK fertilizer application rate under microplot conditions was optimised at 3.30 g (Table 3).

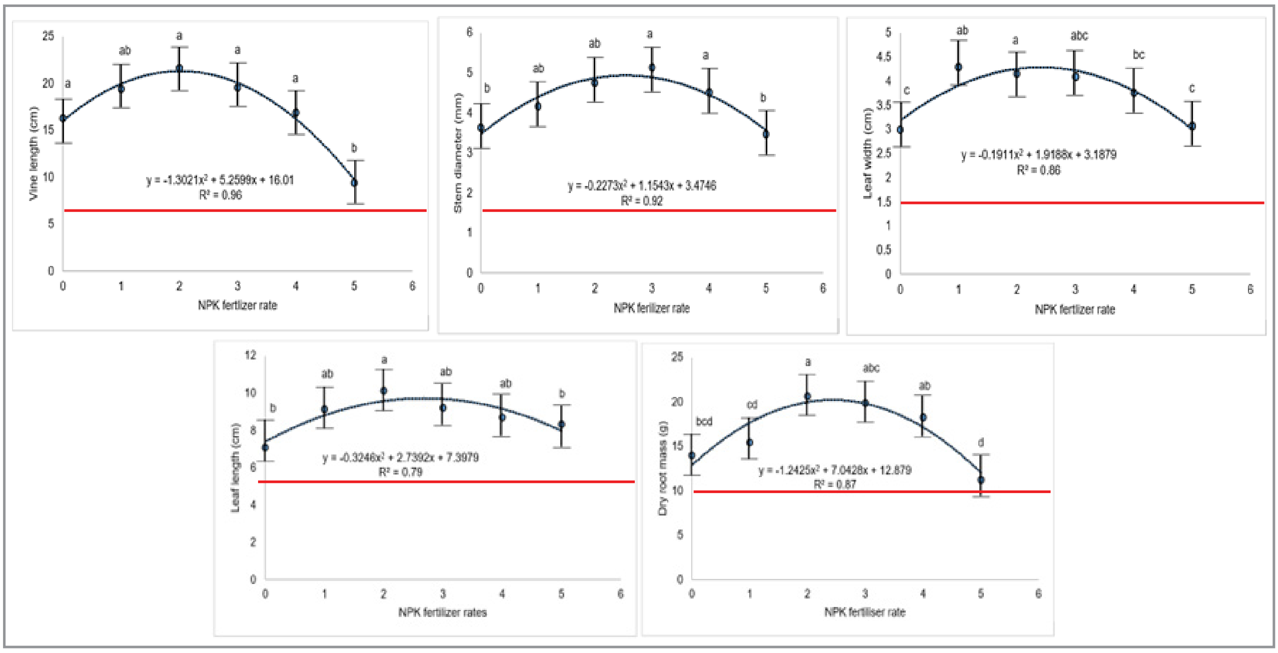

Figure 1: Response of vine length, stem diameter, chlorophyll content, leaf length and dry root mass of *Jatropha zeyheri* plant to increasing rates of NPK fertilizer under microplot conditions (n = 30).

Table 2: Responses of vine length (VL), stem diameter (STD), leaf width (LW), leaf length (LL) and dry root mass (DRM) of *Jatropha zeyheri* to increasing NPK fertilizer rates under microplot conditions (n = 30).

NPK fertilizer rates (g)	VL (cm)		STD (mm)		LW (cm)		LL (cm)		DRM (g)	
	Variable^{y}	R.I. (%)^{z}	Variable	R.I. (%)	Variable	R.I. (%)	Variable	R.I. (%)	Variable	R.I. (%)
0	17.26^{a}	–	3.63^{b}	–	3.00^{c}	–	7.08^{b}	–	14.02^{bcd}	–
2	18.46^{ab}	7	4.16^{ab}	15	4.68^{ab}	56	9.14^{ab}	29	12.42^{cd}	-11
4	21.66^{a}	26	4.76^{ab}	31	5.16^{a}	72	11.14^{a}	57	20.68^{a}	-48
8	19.60^{a}	14	5.13^{a}	41	4.10^{abc}	37	9.22^{ab}	30	17.92^{abc}	28
16	16.92^{a}	-2	5.21^{a}	44	3.76^{bc}	25	8.70^{ab}	23	19.26^{ab}	37
32	9.44^{b}	-45	3.47^{b}	-4	3.08^{c}	3	7.14^{b}	1	11.28^{d}	-20

^{y}Column means followed by the same letter were not significantly different ($P \leq 0.05$) according to Fisher's Least Significant Difference test.

^{z}Relative impact (%) = [(treatment/control - 1) x 100].

Table 3: Quadratic relationship, coefficient of determination and computed optimum of NPK fertilizer rate (g) for vine length, stem diameter, leaf width, leaf length and dry root mass of *Jatropha zeyheri* under microplot conditions (n = 30)

Plant Variable	Quadratic Equation	R^2	X	P ≤
Vine length (cm)	$Y = -1.302x^2 + 5.259x + 16.01$	0.96	2.02	0.05
Stem diameter (mm)	$Y = -0.227x^2 + 1.154x + 3.47$	0.92	2.51	0.05
Leaf width (cm)	$Y = -0.191x^2 + 1.919x + 3.19$	0.86	4.92	0.01
Leaf length (cm)	$Y = -0.325x^2 + 2.739x + 7.40$	0.79	4.22	0.05
Dry root mass (g)	$Y = -1.243x^2 + 7.043x + 12.88$	0.87	2.83	0.05
	Optimum NPK fertilizer application rate		3.30	

Calculated optimum NPK fertilizer application rate $(x) = -b_1/2b_2$, where for $b_1 = 5.259$ and $b_2 = -1.302$.

Discussion

Vine length, stem diameter, leaf width, leaf length and dry root mass with increasing NPK fertilizer rates, each displayed positive quadratic relations, which is characterized by density-dependent growth (DDG) patterns. Surprisingly, the reaction of J*atropha zeyheri* plant variables to increasing NPK fertilizer rates supports the results of Liu and Lovett, who postulated that stimulation occurs at lower concentration whereas inhibition appears at high concentration. Similar interpretations were made when *J. zeyheri* was exposed to increasing NPK fertilizer rates under greenhouse conditions [7]. Surprisingly, comparable results were obtained when different doses of NPK fertilizer were used on *Cichorium intybus* [8]. Consubstantially, increasing neem leaf extracts had density dependent growth patterns on lettuce [9]. Generally, biological entities react to extraneous and internal factors in a DDG patterns which are characterized by three growth phases; stimulation, neutral and inhibition in support of the theory suggested by Liu et al. [10]

In the present study, at lower rates of NPK fertilizer high level of growth was achieved. Similarly, growth of Actinidia chinensis, plant height and stem leaf fresh weight showed better adaptability and responsiveness to the lower fertilizer dose [11]. Correspondingly, Du et al. reported that after 20 days of planting tomato, fresh and dry weight of tomato leaves increased with a decreasing fertilizer rates [12]. Similarly, lower concentrations of crude extracts of neem (*Azadirachta indica*) leaf had stimulatory effects on growth of maize and tomato [13,14] plants.

In contrast, at higher rates, NPK fertilizer was highly toxic to *J. zeyheri* plant variables when applied specifically at 32g, resulting in inhibition of plant development as observed by stunted growth. Similarly, when 2% of crude extracts of yellow nutsedge (*Cyperus esculentus L*) was utilized, it did not affect germination of lettuce, whereas at 5% (highest concentration) extracts inhibited germination. Also, similar observation were reported when tomato plant was exposed to increasing phytonematicide concentration, whereby inhibitory effects were observed at high concentration [15]. The current study revealed that high NPK fertilizer rates were toxic to *J. zeyheri* plant cells. Effects of increased NPK fertilizer might have led to death of *J. zeyheri* plant cells, which later caused malfunctioning of J. zeyheri thus affecting the overall performance of the tea plant. Contradictorily, yield variables of *Camellia sinensis* were enhanced when maximum dose of organic fertilizer was applied [16]. Surprisingly, Du et al. [12] observed that after applying different fertilizer rates on tomato plant, significance was observed 20 days, remarkably after 60 days there were no significance difference on tomato growth. This showed that fertilizer had an effect during the early stages of plant growth.

The detected positive quadratic models showed the NPK fertilizer rate at which the tea plant growth would be stimulated rather than stunted. Similarly, Bango et al. [7] observed positive quadratic models which provided optimum NPK fertilizer rate at which *J. zeyheri* growth would be at optimum under greenhouse conditions Inappropriate application of NPK fertilizer evidently shown undesired effects on the test plant. However, the optimum fertilizer application rate was crucial for determining proper NPK fertilizer requirement of *J. zeyheri* tea. The optimum NPK fertilizer application rate under microplot conditions was optimised at 3.30 g, which can be translated to 33 kg NPK fertilizer mixture/ha [17].

Conclusion

NPK fertilizer mixture at high rates was highly toxic to J. zeyheri plant growth. The inhibition of yield variables observed in this study when exposed to high NPK fertilizer rates, should be avoided by utilizing the appropriate developed optimum application rate. *Jatropha zeyheri* plant growth requires 33 kg NPK fertilizer mixture for providing essential nutrients, increased yield and improved tea quality under microplot conditions.

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