CHARITY AMARA OBIOMA NWADINOBI

PLANT SPACING AND ORGANIC FERTILIZATION OF SORREL (*Rumex acetosa* L.)

Dissertation submitted to the Agroecology Graduate Program of the Universidade Federal de Viçosa in partial fulfillment of the requirements for the degree of *Magister Scientiae*

Adviser: Ricardo Henrique Silva Santos
Co-Adviser: Wellington Souto Ribeiro

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Assent:

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Ricardo Henrique Silva Santos
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To God, my husband and my children

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To God Almighty for his protection over my life and for seeing me through this wonderful journey. I would not have been able to accomplish this feat without him. To him I give all the praise and adoration.

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To the friends I made in Viçosa, regardless of nationality, you are appreciated. Thank you for making my stay in Viçosa a memorable one.

The only dreams impossible to reach are the ones you never pursue
(Michael Deckman)

ABSTRACT

NWADINOBI, Charity Amara, M.Sc., Universidade Federal de Viçosa, July, 2023. **Plant spacing and organic fertilization of sorrel (R*umex Acetosa* L.)** . Adviser: Ricardo Henrique Silva Santos, Co-Adviser: Wellington Souto Ribeiro.

The incentive for the cultivation and consumption of non-conventional vegetables enriches the diet of people and contributes to their nutrition and food security. The aim of this study is to evaluate the organic fertilization of sorrel. The experiment was carried out from April to August 2013 in areas of the Experimental Field of Santa Rita belonging to the Agricultural Research Company of Minas Gerais (EPAMIG) in the municipality of Prudente de Morais, Midwest Region of Minas Gerais. The experimental design was in randomized blocks in a split-plot design with four replications. In the plots, five doses of tanned cattle manure corresponded to the application of 0; 25; 50; 75; and 100 t ha^{-1}; in the subplots, two spacings were evaluated: 25 cm X 25 cm and 30 cm X 30 cm. The characteristics evaluated were total yield (YTOT, expressed in t/ha), commercial yield (YC, expressed in t/ha), and non-commercial yield (YNC, g/plant) on a fresh matter basis. The collected data were subjected to an analysis of variance, and means were compared by the SISVAR package (5%). For doses of organic manure, plants show a positive linear correlation for total number of leaves, number of commercial leaves, % of commercial leaves, total number of leaves, and commercial leaves. The maximum point of the curve was not reached. The mean numbers of total number of leaves, number of commercial leaves, % of commercial leaves, total number of leaves, and commercial leaves were higher at the smallest distances between the plants. The export of nutrients observed was K, N, Ca, Mg, P, and S. Different doses of manure and the spacing influence the productivity and the amount of nutrients exposed by the common sorrel.

Keywords: Non-conventional vegetable. Organic cultivation. *Rumex acetosa* L.

RESUMO

NWADINOBI, Charity Amara, M.Sc., Universidade Federal de Viçosa, julho de 2023. **Espaçamento e adubação orgânica de azedinha (R*umex Acetosa* L.)**. Orientador: Ricardo Henrique Silva Santos. Coorientador: Wellington Souto Ribeiro.

O incentivo ao cultivo e consumo de hortaliças não convencionais enriquece a alimentação das pessoas e contribui para sua nutrição e segurança alimentar. Objetivou-se com este trabalho avaliar a adubação orgânica da azedinha. O experimento foi conduzido no período de abril a agosto de 2013 em áreas do Campo Experimental de Santa Rita, pertencente à Empresa de Pesquisa Agropecuária de Minas Gerais - EPAMIG no município de Prudente de Morais, Região Centro-Oeste de Minas Gerais. O delineamento experimental foi em blocos casualizados em esquema de parcelas subdivididas com quatro repetições. Nas parcelas, cinco doses de esterco bovino curtido correspondendo à aplicação de 0; 25; 50; 75 e 100 t ha-1; nas subparcelas foram avaliados dois espaçamentos: (25 cm X 25 cm e 30 cm X 30 cm). As características avaliadas foram produção total (YTOT, expresso em t/ha), comercial (YC, expresso em t/ha) e não comercial (YNC, g/planta) em matéria fresca. Os dados coletados foram submetidos à análise de variância e as médias comparadas pelo pacote SISVAR (5%). Para dose de adubo orgânico as plantas apresentam correlação linear positiva para número total de folhas, número de folhas comerciais, % de folhas comerciais, número total de folhas e folhas comerciais. Os pontos máximos da curva não foram atingidos. As médias de número total de folhas, número de folhas comerciais, % de folhas comerciais, número total de folhas e folhas comerciais foram maiores nas menores distâncias entre as plantas. A exportação de nutrientes observada K, N, Ca Mg P e S Diferentes dosagens de esterco e mudas influenciam a produtividade e a quantidade de nutriente exposta pela azeda.

Palavras-chave: Vegetal não convencional. Cultivo orgânico. *Rumex acetosa* L.

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SUMMARY

1. INTRODUCTION

Despite the immense diversity of plants with food and nutritional potential, Brazil being considered the country with the richest flora in the world (Giulietti *et al.*. 2005), it estimated that 75% of the food base of the entire world population is currently restricted to only 17 plant species (Marinelli,2005). It turns out, therefore, that the man ended up opting for specialization instead of food diversification. Several socio-ecological factors are associated with non-use, underuse and even abandonment of species with food potential and influence the eating habits of the humanity. These plants are valuable resources with high nutritional qualities, often surpassing those of cultivated plants (Ladio, 2005).

Among the list of species called non-conventional vegetables, sorrel (*Rumex acetosa* L.) is about 20 cm tall, forms clumps with dozens of propagules. However, this species rarely flowers in Brazilian climatic conditions (Silveira *et al.*., 2013). These are consumed in salads, soups, juices, salad dressings or to accompany fish, they can also be chopped and added to an omelet or cooked and prepared as spinach (Brasil, 2003). *Rumex acetosa* L. also called common sorrel or garden sorrel is a perennial herbaceous plant in the family Polygonaceae which spreads in at least 70 countries and originated in southern west and Europe. Within the extensive list of species called non-conventional vegetables, sorrel, has pleased the consumers taste for its vinegary acid taste, has good market potential and can contribute to the human diet. In addition, this vegetable is composed of anthraquinones, tartaric acid, beta-carotene, tannins, vitamin C (Pedrosa *et al.*.,2012) and its leaves are used for medicinal purposes such as in the treatment skin irritations and diarrhea and in Europe, modern herbal preparations are available containing extracts of this species legally registered as medicines, indicated for the treatment of acute and chronic infections of the respiratory system (Gescher *et al.*., 2011).Due to its high content of calcium oxalate, its consumption should be limited by those who suffer from kidney problems (Silveira *et al.*., 2013).

The plant spreads in meadows and forages, terrains where animals are fed, abandoned places and North America along ways. Sorrel is well adapted to acidic soils with high availability of aluminum, however, its mechanisms of resistance to phytotoxic Al are not well understood (Tolra *et al.*., 2005) As there are no specific fertilizer recommendation for this species and considering its rusticity, it is suggest the application of half the doses indicated by the soil Fertility commission of the state of Minas Gerais (Ribeiro *et al.*., 1999) for lettuce corresponding to 25 tons of barn yard manure per hectare at planting, supplemented by mineral fertilizers.(Madeira *et al.*., 2013)

Enhancing productivity and plant nutrition, are directly associated with nutritional values of foods, is affected by substrate composition, availability of nutrients and amount of fertilizer added (Ramos *et al.*, 2011). Furthermore, knowing the plant nutrient content allows quantifying the nutrients exported by the harvest, which must be replenished to ensure maintenance of soil fertility.

OBJECTIVES

- Evaluate doses of organic fertilizer for *Rumex acetosa* production.
- Evaluate spacing for *Rumex acetosa* cultivation.
- Evaluate the number of cuts for *Rumex acetosa* production.
- Evaluate the accumulation of nutrients in *Rumex acetosa.*

2. MATERIAL AND METHODS

2.1 study area

The studies were carried out from April to August 2013 in areas of the Experimental Field of Santa Rita, belonging to the Empresa de Pesquisa Agropecuária de Minas Gerais (EPAMIG), the Minas Gerais Agricultural Research Agency, in the municipality of Prudente de Morais, Midwest Region of Minas Gerais. The experimental field is located at 19o 27 15" south latitude and 44o 09 11" west longitude. The average altitude is 730 meters above sea level, with an average annual temperature of 22.1 C and an average annual precipitation of 1,340 mm.

Cultivation was carried out in the field, with the analysis of soil and manure used as organic fertilizer shown in Table 1.

Table 1: Analysis of soil and Manure used as organic fertilizer

	pH	OM	P	K	Na	Ca	Mg	Al^{+3}	H+Al	SB	t	T	V	M	B	Cu	Fe	Mn	Zn
		dag/kg	.....mg/dm^3....		....cmolc/dm^3....................................								........%..........		....................mg/dm^3.............................				
Soil	5.8	2.7	93.7	98	0.1	6.2	0.8	0.0	3.2	7.4	7.4	10.6	70	0	0.6	1.0	32.6	28.0	3.9

	pH	N	P	K	Ca	Mg	S	CO	C/N	Zn	Fe	Mn	Cu	B	Moisture %	
		..........................%...						%		..........................ppm.......................					Air	75°C
Manure	6.35	1.66	0.66	0.80	1.23	0.37	0.65	15.75	9.48	142	32325	382	36	6.35	41.6	46.82

Soil solution pH, determined in calcium chloride solution; OM: organic matter, determined by colorimetry; P: phosphorus, Mehlich; K^+: potassium, Mehlich; Ca^{2+}: exchangeable calcium, determined in KCl; Mg^{2+}: exchangeable magnesium, determined in KCl; S:Sulfur as sulfates, extracted with calcium phosphate and determined by colorimetry; Al^{3+}: exchangeable aluminum, extracted with 1 $mol{\cdot}L^{-1}$ potassium chloride; H + Al: total soilacidity, determined in SMP buffer, pH 7.5; SB: sum of bases ($K^+ + Ca^{2+} + Mg^{2+}$); CEC: cationic exchange capacity ($K^+ + Ca^{2+} + Mg^{2+}$ + H + Al); V: soil base saturation (SB/CEC); m: aluminum saturation [$Al^{3+}/(SB + Al^{3+})$]; Cu, Fe, Mn and Zn: copper, iron, manganese and zinc, extracted with Mehlich solution.

2.2 Experimental design

The experimental design was in randomized blocks in a split-plots design with four replications. In the plots, five doses of tanned cattle manure corresponding to the application of 0; 25; 50; 75 and 100 t ha^{-1}; in the subplots, two spacings were evaluated: 25 cm X 25 cm and 30 cm X 30 cm. The plots consist of beds measuring 1.20 m X 4.00 m, 0.20 m high, with 48 plants per plot and 24 plants per subplot and eight useful plants planted in the central area of each subplot. For fertilization, 2/3 of each dose of manure were applied to the beds five days before planting in the beds and 1/3 applied in coverage, 20 days after transplanting the seedlings. The seedlings were produced in plastic bags from matrices from the Bank of unconventional vegetables at Experimental Field of Santa Rita whose sample is deposited in the EPAMIG Herbarium PAMG, Belo Horizonte – MG, under registration PAMG 57029. Planting were carried out on 05/21/2013, 30 days after seedling preparation. Three successive harvests were performed. After the first and second harvests, the plants were regrowth and harvested when they reached the point considered suitable for commercialization and the necessary evaluations were carried out. The first cut for harvesting were performed 57 days after transplanting the seedlings (DAT). Second and third cuttings were performed at 45 and 90days after the first harvest. No fertilizer was applied during the second and third growth period. Plants were harvested at 3 cm above ground.

For the evaluation of production and nutritional composition, four plants of the useful plot were harvested making the total harvest of the plants. The leaves of each plant were counted and the total fresh mass obtained. The commercial leaves (leaf blade greater than or equal to 10 cm) were separated, counted and the commercial fresh masses were obtained. To determine the dry mass, samples of commercial leaves were dried in an oven with forced air circulation at 65°C for 72 hours., were prepared and their nitrogen, phosphorus, potassium, magnesium, calcium and sulphur content was determined. The accumulations of nutrients were calculated by multiplying the nutrient content by dry matter accumulation, expressed in a per plant basis (Nacc, Pacc, Kacc, Caacc, Mgacc, Sacc, g/plant). After each cut, the leaves were taken to the laboratory where the following variables (Silva *et al.*., 2013) were evaluated:

Total yeild (YTOT, expressed in t/ha), commercial yield (YC, expressed in t/ha), and non-commercial yield leaves (YNC, g/plant) in fresh matter basis, total number of leaves (NTOTL, in number/plant), number of commercial leaves (NCL, number/plant), considered those greater than 10 cm in length, including the petiole, number of non-commercial leaves (NNCL, number/plant), and Percentage of commercial leaves (%CL).

Subsequently, the total production in three cuts and the total accumulation of nutrients in three harvests were calculated.

2.3. Statistical analysis

Data was analyzed for normality by Kolmogorov-Smirnov (K-S) and homogeneity of variance by Bartlet test. The effects of manure doses were analyzed by regression analysis and the effects of spacing by the F test, both considering p=0.05, by the SISVAR package (Ferreira, 2014).

3.0 RESULTS

3.1 Effect of cut production in sorrel plants as a function of manure doses at the time of first cut.

The results of the statistical analyzes showed that there was a significant difference between spacing in the first and second cuts for NTOTL, NNCL, YTOT, YC, YNC, and in the third cut for YTOC, YC and YNC, with higher values for the 25 cm spacing (Table 2).

The statistical analysis results showed that there was significant difference ($p<0.05$) in the percentage of dose. Spacing of 25cm resulted in the highest number of total of leaves, total yield and commercial yield in the first growing cycle. The same occurred in the second and third growing circles and in all total number of leaves were found to be significantly different figure 1 showed an increasing linear response in the first cut of total number of leaves and with number of commercial leaves with 25cm spacing. The maximum point of the curve was not reached suggests that the plant may respond to higher dose of manure. Despite sorrel is considered a rustic plant and resistant to acidity and the soil used has presenting low acidity, high base saturation and high caution exchange capacity (figure 2), number of commercial yield and total yield figure 3 and as well as commercial yield (Figure 4) were higher in the lowest spacing (25 x25cm). This spacing supports a population of 160,000 plants per hectare.

Table 2: Growing cycle of first, second and third cut of sorrel plant

	NTOTL	NCL	NNCL	CL	YTOT	YC	YNC
				First Growing Cycle			
Sp 25 cm	120.9 a	46.6 a	74.3 a	53.5	55.6 a	32.9 a	22.6 a
Sp 30 cm	101.9 b	42.26 a	59.7 b	52.8	31.4 b	19.1 b	12.3 b
				Second Growing Cycle			
Sp 25 cm	85.4 a	13.76 a	30.36 a	48.8 a	13.15 a	6.88 a	6.26 a
Sp 30 cm	65.2 b	9.95 b	25.4 b	41.93 b	7.22 b	3.51 b	3.7 b
				Third Growing Cycle			
Sp 25 cm	46.98	17.82	29.15	59.04	18.10 a	10.85 a	7.24 a
Sp 30 cm	49.44	18.21	31.23	57.48	13.44 b	7.99 b	5.45 b

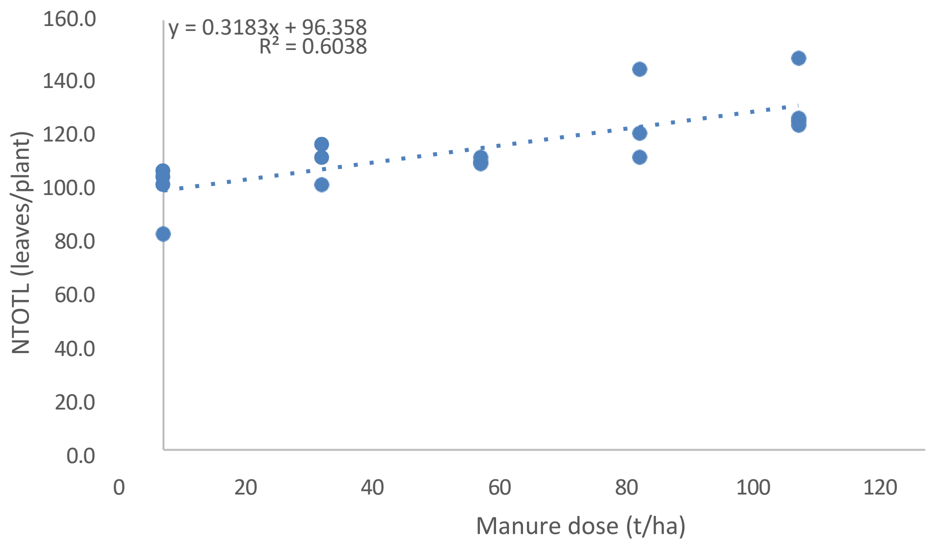

Figure 1: Total number of leaves in sorrel plants (NTOTL) as a function of manure doses at the time of first cut

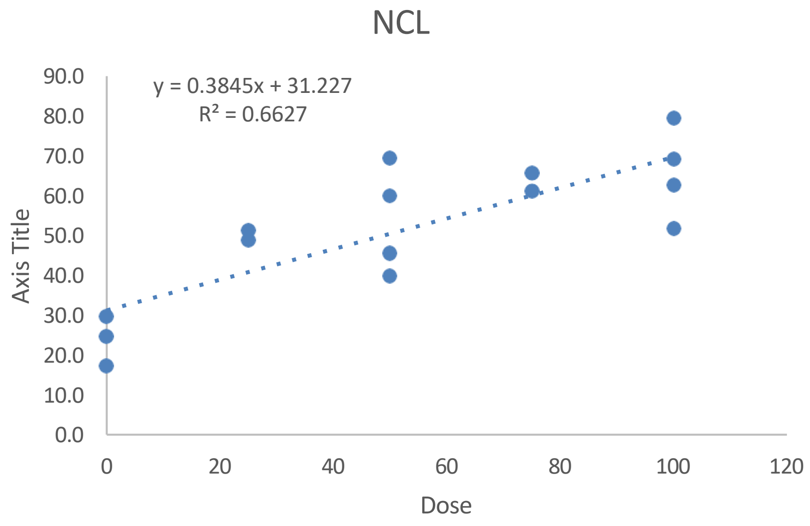

Figure 2: Total number of commercial leaves in sorrel plants (NCL) as a function of manure doses at the time of first cut

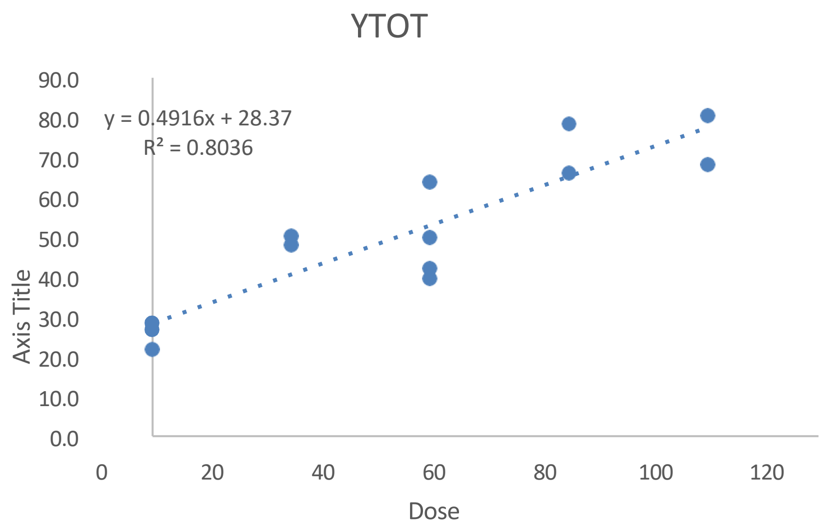

Figure 3: Total yield leaves in sorrel plants (YTOT) as a function of manure doses at the time of first cut

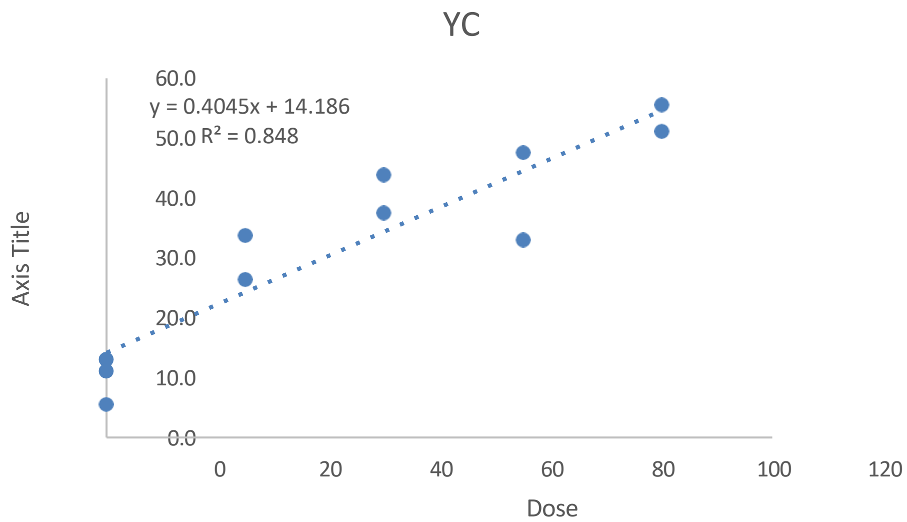

Figure 4: Commercial leaves in sorrel plants (YC) as a function of manure doses at the time of first cut

3.2 Effect of cut production in sorrel plants as a function of manure doses at the time of second cut.

The result obtained shows that there were significant differences in the second cut production with the smallest spacing of 25cm in total number of leaves, number of commercial leaves, total commercial leaves and total yield, (figure 5,6,7,8,9 10)

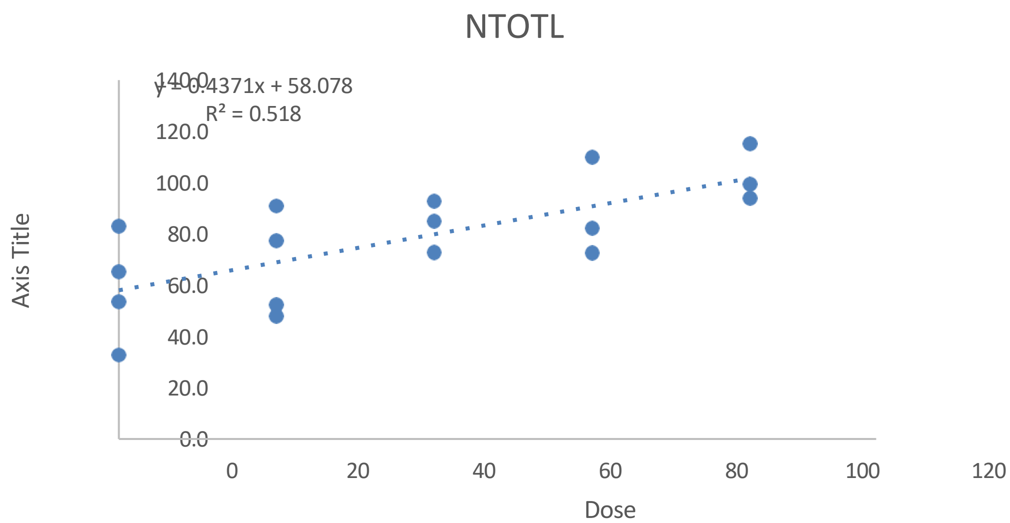

Figure 5: Total number of leaves in sorrel plants (NTOTL) as a function of manure doses at the time of second cut

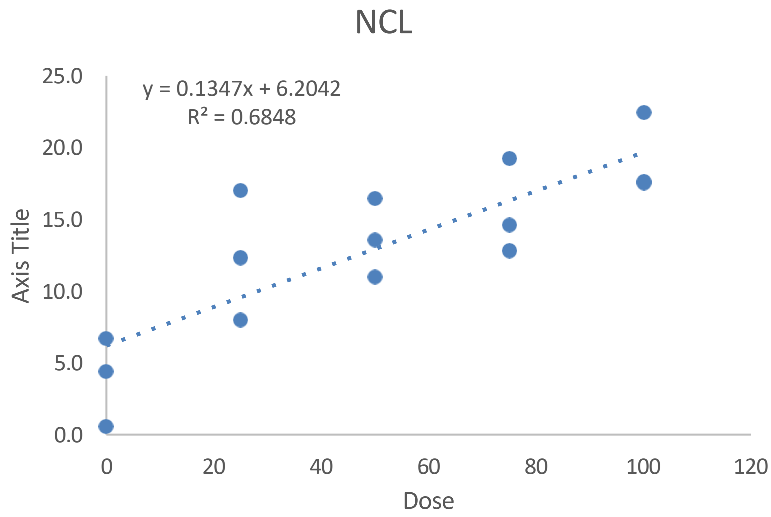

Figure 6: Total number of commercial leaves in sorrel plants (NCL) as a function of manure doses at the time of second cut

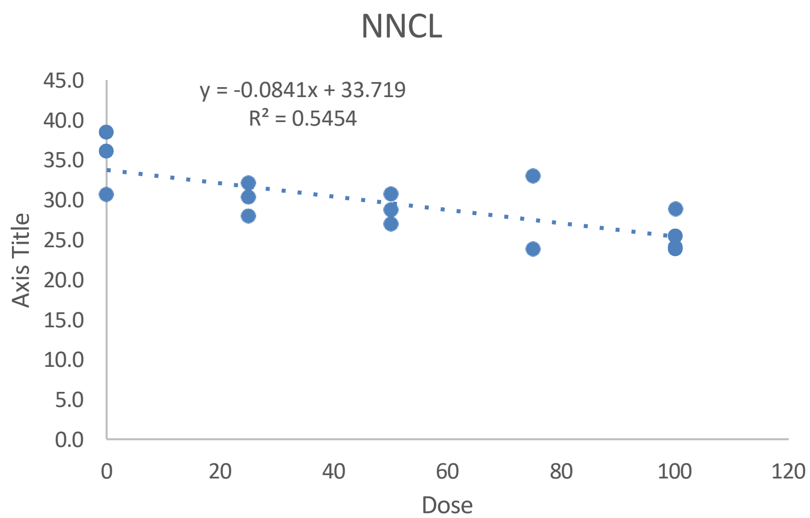

Figure 7: Number of non-commercial leaves in sorrel plants (NNCL) as a function of manure doses at the time of second cut.

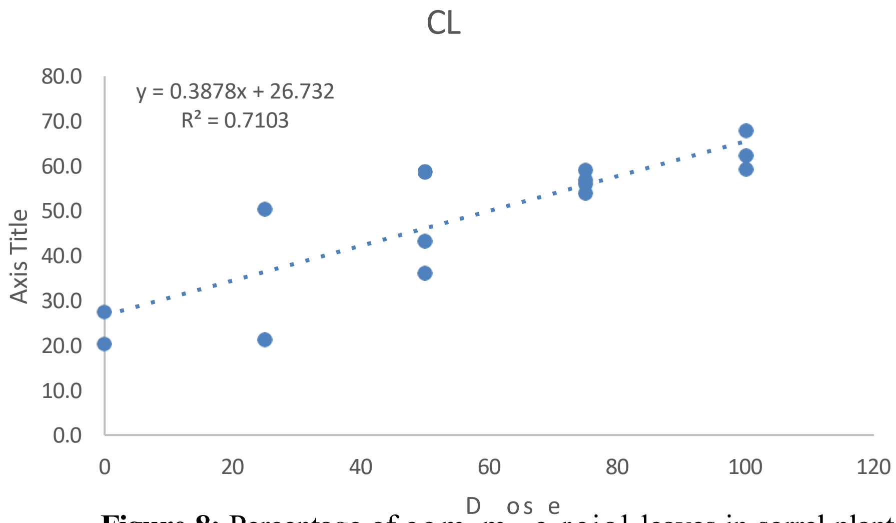

Figure 8: Percentage of commercial leaves in sorrel plants (CL) as a function of manure doses at the time of second cut.

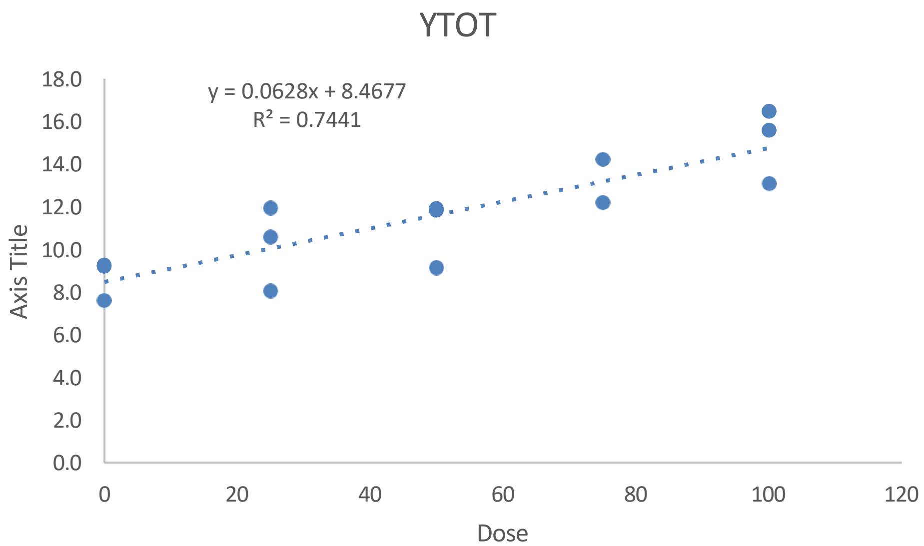

Figure 9: Total yield in sorrel plants (YTOT) as a function of manure doses at the time of second cut.

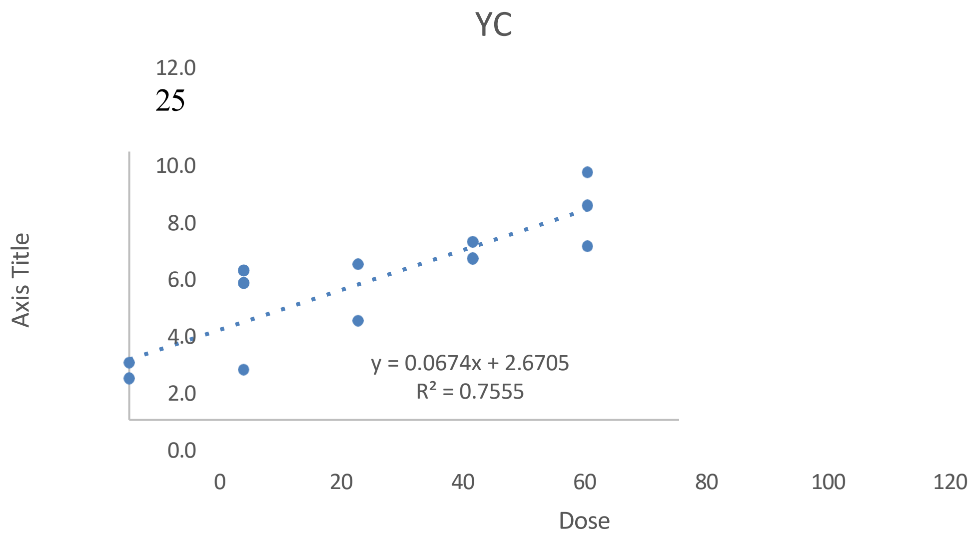

Figure 10: Commercial yield leaves in sorrel plants (YC) as a function of manure doses at the time of second cut.

3.3 Effect of cut production in sorrel plants as a function of manure doses at the time of third cut.

The result obtained showed that only the % of commercial leaves had significant differences with spacing of 30 x30cm to compare with other cut on sorrel plant in the third cut.

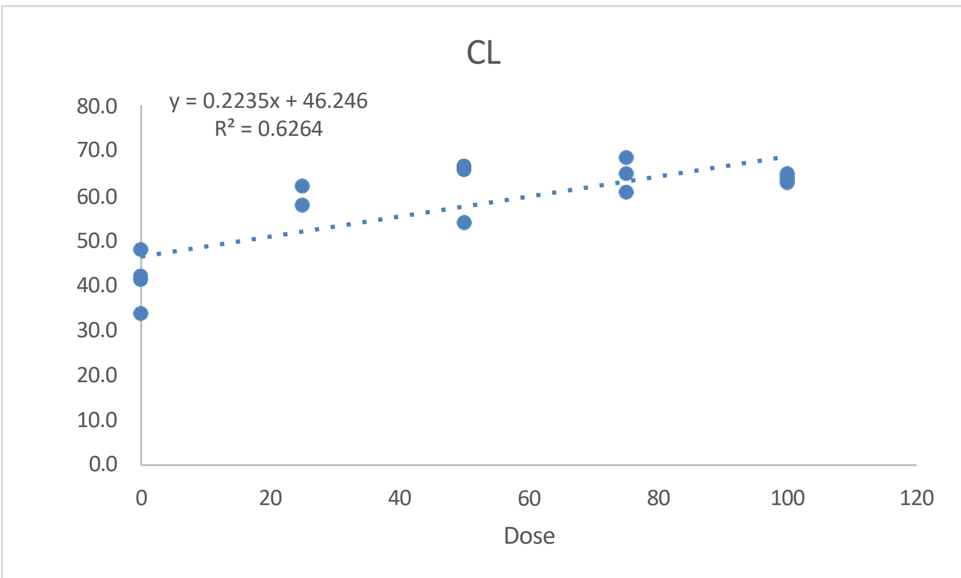

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Figure 11: Commercial leaves in sorrel plants (CL) as a function of manure doses at

the time of third cut.

3.4 **Effect of Nutrient Accumulation in sorrel plants as a function of manure doses at the time of first cut**.

There were significant interaction ($p<0.05$) between the dose and spacing for N, P, K, S, Ca and Mg accumulation (Figure 11,12,13,14,15,16) represent the regression analysis within the spacing that had a significant effect (25x25cm). There was an increase in amount of N exported between doses of 25 to 75t ha-1. The result shows that N and P accumulation increased with an increase in cattle manure dose. With an R-square value (coefficient of determination being studied is explained by the variance of the cattle manure dose. For K it was also verified in the largest spacing (30 x 30cm) a decreasing linear tendency with the dose increase.

Table 3: Nutrient accumulation of first, second and third cut of sorrel plants

	N ACC	P ACC	K ACC	SA CC	CA ACC	MG ACC
			First Cut Accumulation			
Sp 25 cm	100 a	0.017[a]	0.173a	0.007a	0.027a	0.022 a
Sp 30 cm	0.057 b	0.009b	0.098 b	0.004b	0.015 b	0.012 b
			Second Cut Accumulation			
Sp 25 cm	0.286 a	0.005 a	0.043 a	0.002 a	0.007 a	0.006a
Sp 30 cm	0.016b	0.003 b	0.025b	0.001 b	0.004 b	0.003 b
			Third Cut Accumulation			
Sp 25 cm	0.041a	0.006a	0.055a	0.0026a	0.009 a	0.010 a
Sp 30 cm	0.031b	0.004b	0.040b	0.0020b	0.006b	0.007b

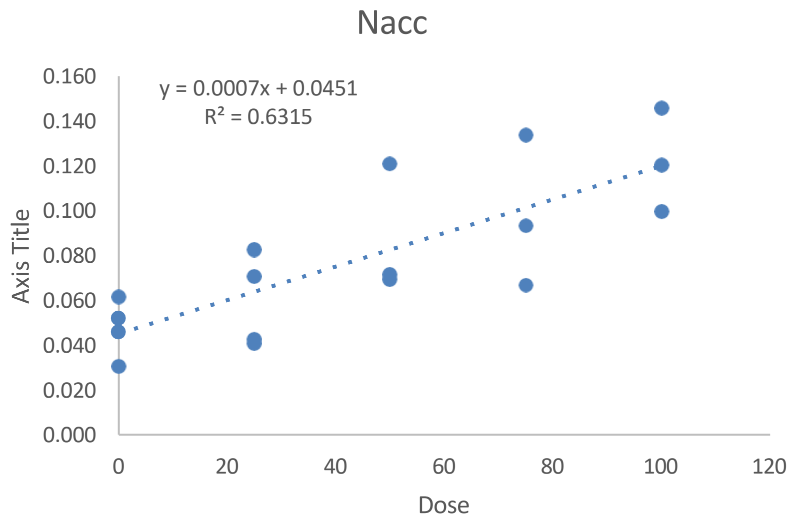

Figure 12: Nitrogen accumulation in sorrel plants (N) as a function of manure doses at the time of first cut in nutrient accumulation

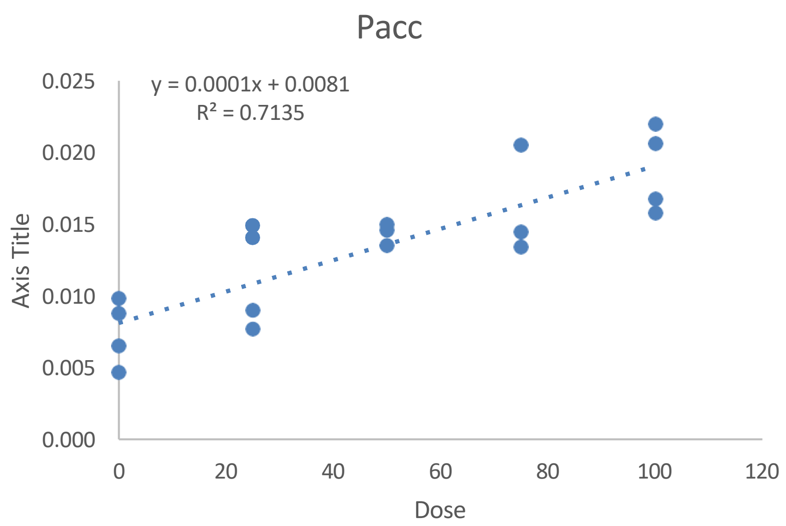

Figure 13: Phosphorus accumulation in sorrel plants (P) as a function of manure doses at the time of first cut in nutrient accumulation

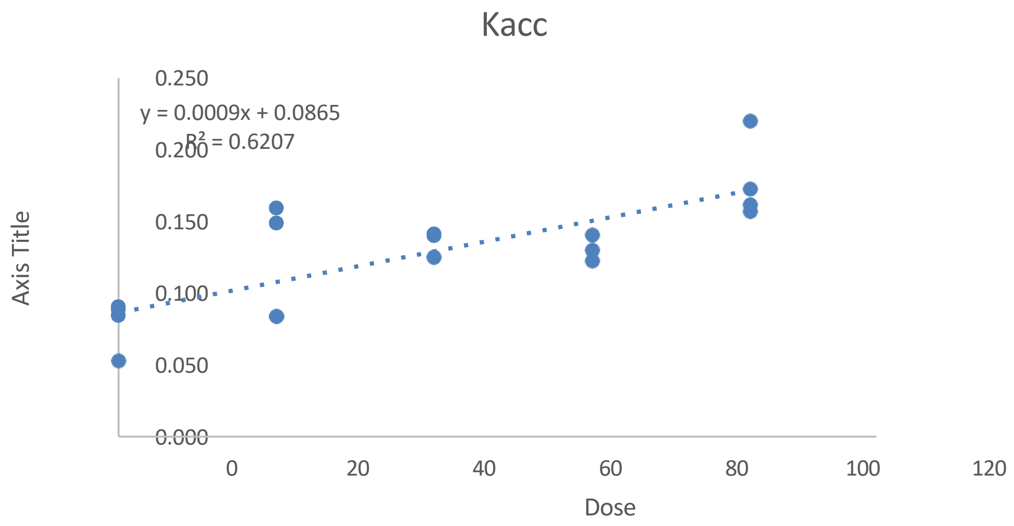

Figure 14: Potassium accumulation in sorrel plants (K) as a function of manure doses at the time of first cut in nutrient accumulation

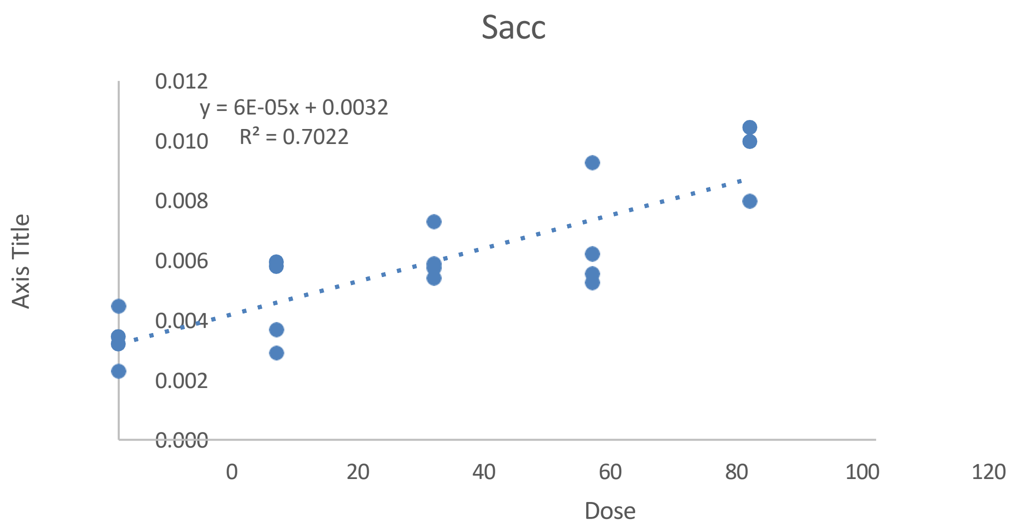

Figure 15: Sulphur accumulation in sorrel plants (S) as a function of manure doses at the time of first cut in nutrient accumulation

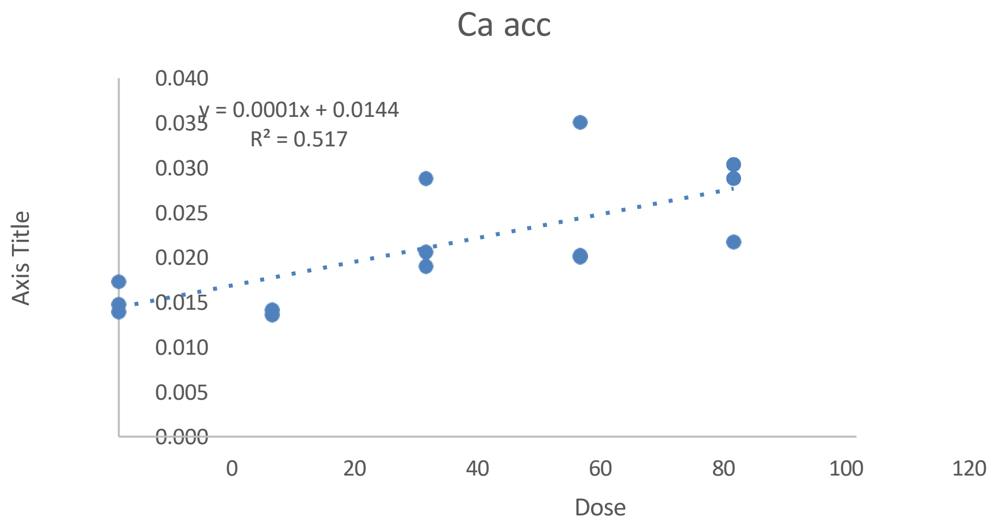

Figure 16: Calcium accumulation in sorrel plants (Ca) as a function of manure doses at the time of first cut in nutrient accumulation

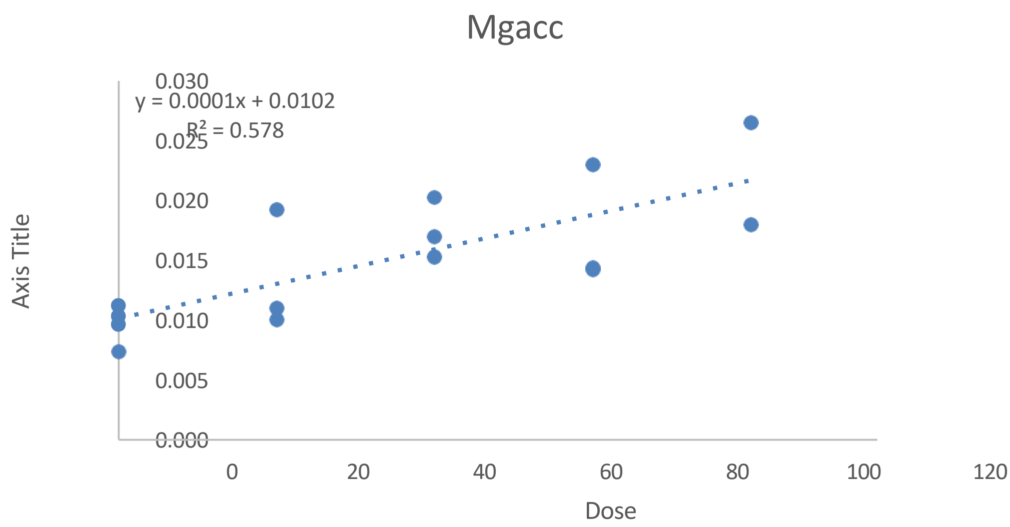

Figure 17: Magnesium accumulation in sorrel plants (Mg) as a function of manure doses at the time of first cut in nutrient accumulation

3.5 Effect of Nutrient Accumulation in sorrel plants as a function of manure doses at the time of second cut.

The result showed that the spacing of 25cm was significant among all the nutrient accumulation on the second cut, the increases obtained in relation to the accumulation of N,K, S,C and Mg in the second cut above ground times, respectively, when comparing the spacing that were receive (figure 16,17,18,) . The regression analysis shows that P accumulation, S accumulation was significant difference among other nutrients combination in the dose received. P accumulation had the highest result obtained in the dose and spacing followed by K accumulation.

3.6 Effect of Nutrient Accumulation in sorrel plants as a function of manure doses at the time of third cut.

The result obtained in the third nutrient accumulation showed that the above ground parts no significant interaction between all the nutrients.

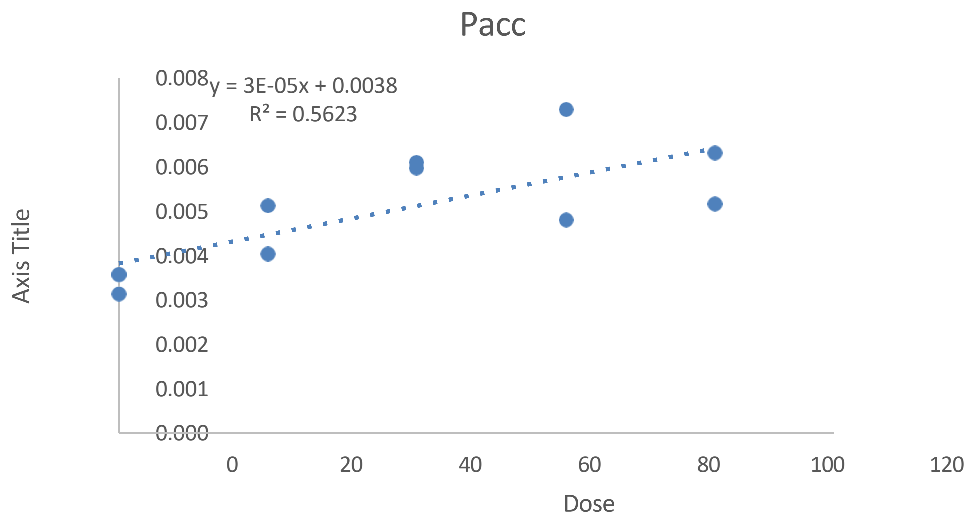

Figure 18: Phosphorus accumulation in sorrel plants (P) as a function of manure doses at the time of first cut in nutrient accumulation

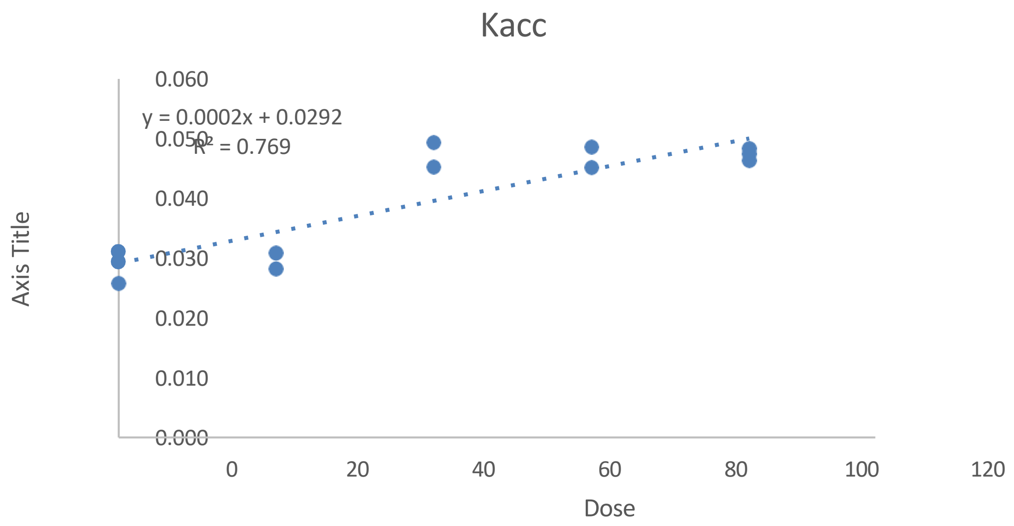

Figure 19: Potassium accumulation in sorrel plants (K) as a function of manure doses at the time of first cut in nutrient accumulation

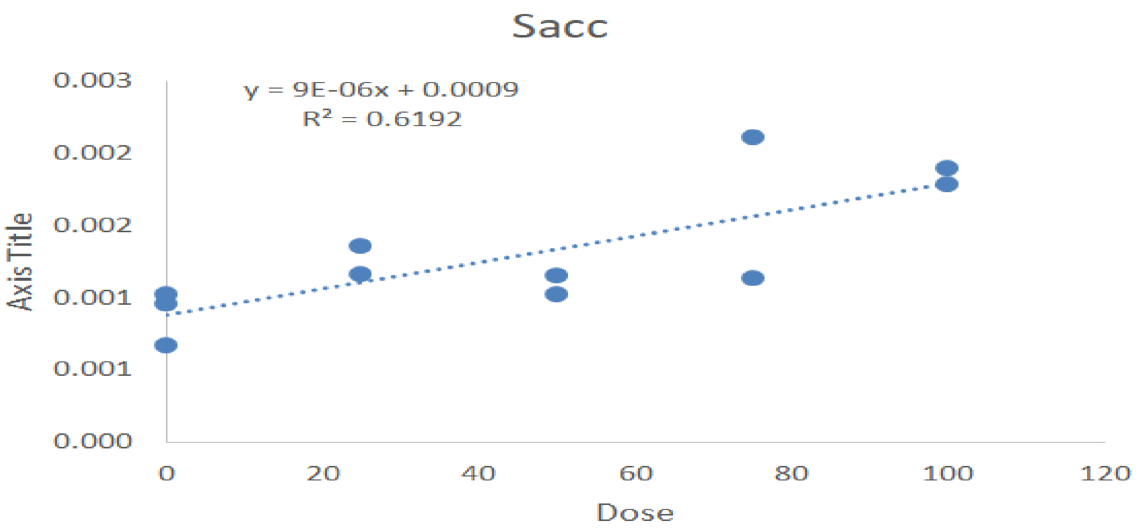

Figure 20: Sulphur accumulation in sorrel plants (S) as a function of manure doses at the time of first cut in nutrient accumulation

DISCUSSION

From the results of soil and manure analysis, it can be inferred that the manure applied influenced the pH of the soil. According to Dechen & Nachiigall,(2006), at higher pH values when elevated ,the concentration of micronutrients Fe, Cu, Mn, and Zn in the soil solution decreases making them less available to plants. According to Kiehl (1985), organic matter when decomposed under aerobic conditions, it presents alkaline reactions contributing to raise the pH, at least temporarily. The amount of organic matter, according to Dechen &Nachtigall, (2006) exerts great influence on the availability of micronutrients.

These authors mention that despite an increase in organic matter content will usually result in an increase in micronutrients, in some situations, the opposite occurs, which probably indicates high fixation of micronutrients in soils with high organic matter content. Corroborating with these authors, Abreu *et al.* (2001) mention that Cu and Mn can be complexed by organic matter, interfering with the availability of these elements for plants. Therefore, there seems to be several factors that can affect the availability of micronutrients to plants. Also noteworthy are soil texture, oxidation-reduction conditions, climatic conditions, moisture content and soil temperature s decrease the rate of mineralization of organic matter by reducing the availability of nutrients contained therein (Dechen&Nachtigall,2006).

The total results obtained in this study showed that there were significant difference ($p<0.05$) in relation to spacing and also effect to dose, However , Pedrosa *et al.* (2012), obtained greater plants heights from sorrel with a dose of 50t ha-1 of bovine manure in the spacing of 25cm between plants and with dose of 50 and 75 t ha-1 at a spacing of 30cm between plants. The regression analysis of nutrient accumulation showed the increase in amount of Nitrogen exported between does of 25 to 75 t ha-1, for potassium it was also verified in the largest spacing (30 x30cm) a decreasing linear tendency with the dose increase contributing to the supply of K to the plants. Thomas *et al.* (1975) found extracted amounts of K in the aerial part of spinach, at 90 days, equivalent to 120.6kg ha-1, higher than those of N (39.7 kg ha-1). According to Cantarella (2007). Nitrogen is a constituent of several compounds and participates in the main biochemical reactions in plants that make it one of the elements absorbed in greater amounts by most crops. Potassium, although not part of any organic compound, participates in important reactions in the plants, as an enzymatic activator is vital for photosynthesis, regulate the process of opening and closing stomata, confers plant resistance to attack by pests and diseases among others (Dechen & Nachtigall 2007). Potassium was the nutrient found in greater quantity also in lettuce cultivars (Grangeiro *et al.,* 2006).

For the nutrients accumulation S was exported in smaller quantities, followed by P. Although, extracted in smaller amounts, these macronutrients play important roles functions in several process that occure in plants such as storage and energy transfer promoted by phosphorus or in the production of amino acids, proteins and chlorophyll in which sulfur participates (Dechen &Nachtigall 2007) Fertilization doses did not interfere with the exported amount of macronutrient Ca and Mg, whose highest average values were obtained in the smallest spacing in second cut .Calcium is a constituent of the cell wall and is essential for the growth of meristems, particularly at root apexes, and Magnesium has a structural role as a component chlorophyll molecule (Dechen & Nachtigall,2007).Micronutrients are essential elements for plant growth, but required in smaller amounts than macronutrients (Abreu *et al.* 2007) spacing significantly influenced all the cut production both in the first, second and the third cut which is in the smallest spacing 25 x 25cm ($p<0.05$) and also between dose and spacing for all the nutrients.

According to Stevenson,1994), roots can exude a large amount of organic substances, usually resulting in increased availability of micronutrients, However, according to this author, differences in the susceptibility of plants to micronutrients deficiency have often been attributed to their abilities in synthesize and excrete organic acids and other chelating agents that complex metal ions.

4.0 CONCLUSION

Sorrel plants can be regarded as a source of vegetables. Its encouragement of the production and consumption of non-traditional vegetables enhances diets, improves nutrition, and increases food security for people. The plants responded to manure doses by producing more sorrel, and for doses at the lowest spacing, there was an increase in the total number of leaves, the number of commercial leaves, the total number of commercial leaves, and the overall yield productivity. The export of nutrients from sorrel occurred in the following order: N>S>K>P>Ca and Mg. Therefore, the productivity and quantity of nutrients exported by the common sorrel plants were affected by different manure doses and spacing.

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