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Effect of nitrogen and phosphorus rates on growth, yield and oil content of lemongrass (*Cymbopogon flexuosus* L.)

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ABSTRACT

Lemongrass (*Cymbopogon flexuosus* L.) is one of the most important medicinal plants because it produces an essential oil which has a high economical value. It is a tropical grass which can be successfully produced in Sudan at the commercial level. This study was carried out to investigate the effect of N and P fertilizers on vegetative growth, herbage yield and oil content of lemongrass (*Cymbopogon flexuosus* L.). The experiment was conducted at the Experimental Farm of the Faculty of Agricultural Sciences, University of Gezira, Wad Medani, Sudan. Treatments consisted of three levels of N (0, 43 and 86 kg N ha^{-1}) and two levels of P (0 and 41 kg $P_2O_5ha^{-1}$). The treatments were arranged in a randomized block design with four replicates. Application of N and P had significant effects on vegetative growth, herbage yield and oil content in both cuts. The best results were obtained by the application of 86 kg N ha^{-1} in combination with 41 kg $P_2O_5ha^{-1}$ in both cuts, and the control treatment resulted in the lowest values. Lemongrass oil content was higher in the first cut as compared to the second cut.

INTRODUCTION

Lemongrass (*Cymbopogon flexuosus* L.) is an essential oil producing grass, which is high in citral content. The oil emits a strong lemon scent when leaves are crushed. The oil of lemongrass is widely used for scenting of soaps, as an insect repellent and in the manufacture of perfumes (Ansari and Razadan, 1995).

The essential oil content was found to be higher in young leaves and declined with leaf age (Pal, 1990). Similarly, Elsaeid

(1994) reported that oil yield of lemongrass was higher in young plants as compared to older ones. Oil content also depends on other factors such as climate, cultural practices, soil fertility and harvesting time.

Nitrogen fertilization of lemongrass has been reported to result in more tillers, more number of leaves, large size of leaves, and a higher rate of regrowth after cutting (Singh *et al.*, 2008). Nitrogen has been reported to increase total oil yield in lemongrass. Application of nitrogen at 400kg/ha to lemongrass resulted in the highest herb and oil content, with no significant effect on the quality of the essential oil (Singh *et al.*, 2008). Also, Sharifi and Abbaszadeh (2003) investigated the effect of nitrogen fertilization on the oil content of fennel and found that it increased the essential oil content. Similarly, Ram *et al.* (2005) reported that application of nitrogen at 200 kg ha^{-1} significantly increased the essential oil content of mint.

Phosphorus is one of the most important elements for lemongrass production. Super phosphate is the most widely used phosphorus fertilizer. However, diammonium phosphate is better because it contains both nitrogen and phosphorus in a soluble form (Das *et al.*, 1991). Application of phosphorus at planting was found to result in more vigorous growth and higher herb yield of lemongrass as compared to the control (Mahmoud, 2002).

Research work on nitrogen and phosphorous fertilization of lemongrass in Sudan is lacking. Therefore, the objective of this study was to determine the effect of nitrogen and phosphorus fertilizers on growth, yield and oil content of lemongrass under Gezira conditions.

MATERIALS AND METHODS

The experiment was carried out in the farm of the Faculty of Agricultural Sciences. University of Gezira, Wad Medani, Sudan, during 2009/10. Gezira soil is a heavy clay with 58% clay, organic matter of 0.3%, nitrogen of 0.03% and available phosphorus of 2-4ppm. It is alkaline with a pH of 8.3.

Lemongrass plants were raised from stools obtained from fully mature plants grown in the nursery of the National

Institute for the Promotion of Horticultural Exports, University of Gezira, Wad Medani, Sudan.

The land was ploughed, disc-harrowed and made into 80 cm ridges. Lemongrass sets were planted at a distance of 50cm within rows. Plot size was 4 x 5m.

Nitrogen was applied at the rates of 0, 43 and 86 kg N ha^{-1}, in the form of urea, in two doses. The first dose was applied a month from planting and the second dose was applied one month after the first one. Phosphorus was applied before planting at 0 and 41 kg $P_2O_5 ha^{-1}$.

Treatments were arranged in a randomized block design with four replicates. Harvesting was done twice; the first one was after 4 months from planting and the second was after 3 months from the first harvest.

From each plot, seven plants were selected randomly. Then, plant height, number of leaves, leaf length and number of stools were determined at two weeks interval.

The middle two ridges of lemongrass were harvested after 4 months from planting and then the second cut was carried out after three months from the first one. Herbage was weighed and total yield was calculated in tons/ha.

Oil extraction

Oil was extracted by water steam distillation method. Sixty grams of dried lemongrass leaves were weighed using an electronic scale. The samples of lemongrass were placed in one liter round bottom flask. The material was extracted for 3-4 hours until no further increase in oil was observed. The distillate was transferred to a separating funnel where the essential oil was separated from water. The oil weight was determined and the percentage of oil was calculated using the following equation:

$$\text{Oil (\%)} = \frac{\text{Weight of oil (g)}}{\text{Weight of sample (g)}} \times 100$$

Statistical analysis

Data were subjected to analysis of variance. Means separation was done according to Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

The main effects of nitrogen and phosphorus rates on vegetative growth of lemongrass are shown in Tables 1 and 2. Results indicated highly significant differences on vegetative growth in both cuts. Vegetative growth increased as N level increased in both cuts. The lowest vegetative growth was obtained by the application of 0 kg N ha^{-1} (control) and the best vegetative growth was obtained by the application of 86 kg N ha^{-1}. Application of P significantly increased the vegetative growth of lemongrass in both cuts. However, application of P had no significant effects on number of stools in both cuts.

The interaction effects of N and P on the vegetative growth of lemongrass were significant in both cuts (Tables 3 and 4). The best vegetative growth parameters were obtained by the application of 86 kg N ha^{-1} in the first cut (Table 3) and the application of 43KgNha^{-1} in combination with 41Kg $P_2O_5ha^{-1}$ in the second cut (Table 4) and the least vegetative growth was obtained by the control treatments.

The effects of N rate on lemongrass leaf length are shown in Fig 1. Leaf length increased steadily with time and reached its maximum at 7 weeks after planting. Significantly longer leaves were obtained by the application of 86 kg Nha^{-1} as compared with the control.

The effects of P rate on leaf length of lemongrass are shown in Fig 2. Significantly longer leaves were obtained by the application of 41 kg$P_2O_5ha^{-1}$ as compared to the control.

Table 1. The main effects of N and P rates on vegetative growth of lemongrass (first cut).

Treatments	Plant height (cm)	Number of leaves	Leaf length (cm)	Number of stools
N(kg N ha^{-1})				
0	63.04 c	33 c	44.93 b	4.80 b
43	69.86 b	57 b	51.40ab	10.44 a
86	73.71 a	71 a	59.50a	11.93 a
Sig. level	**	***	*	***
P($kgP_2O_5ha^{-1}$)				
0	63.04 b	33 b	44.93 b	4.80 b
41	71.65 a	49 a	58.93a	8.25 a
Sig. level	*	**	**	NS

Means followed by the same letter(s) within columns are not significantly different according to Duncan's Multiple Range Test at 5% level.

*,**,*** and NS indicate significance at 5%, 1%, 0.1% and not significant, respectively.

Table 2. The main effects of N and P on vegetative growth of lemongrass (second cut).

Treatments	Plant height (cm)	Number of leaves	Leaf length (cm)	Number of stools
N(kg N ha^{-1})				
0	70.89 c	82 b	50.43 a	17.68 b
43	75.86 b	138 a	64.89a	28.57 a
86	80.72 a	139 a	68.76a	30.76 a
Sig. level	***	**	NS	**
P($kgP_2O_5ha^{-1}$)				
0	70.89 b	80 b	50.43b	17.68 b
41	77.72 a	116 a	65.98a	24.32 a
Sig. level	*	*	***	NS

Means followed by the same letter(s) within columns are not significantly different according to Duncan's Multiple Range Test at 5% level.

*,**,*** and NS indicate significance at 5%, 1%, 0.1% and not significant, respectively.

Table 3. Interaction effects of N and P on vegetative growth of lemongrass (first cut).

Treatments		Plant height	Number	Leaf	Number
N(kgN ha^{-1})	P(kg P_2O_5 ha^{-1})	(cm)	of leaves	length (cm)	of stools
0	0	63.04 c	33 d	44.93 b	4.80 b
	41	71.65 a	49 c	58.93a	8.25 ab
43	0	69.86 ab	57 b	51.40 ab	10.44 a
	41	72.86 a	55 b	54.75ab	9.75 a
86	0	73.71 a	71 a	59.50a	11.93 a
	41	67.54 b	56 b	57.89a	10.25 a
Sig. level		**	**	* *	***

Means followed by the same letter(s) within columns are not significantly different according to Duncan's Multiple Range Test at 5% level.
*,** and *** indicate significance at 5%, 1% and 0.1%, respectively.

Table 4. Interaction effects of N and P on vegetative growth of lemongrass (second cut).

Treatments		Plant height	Number	Leaf	Number
N(kgN ha^{-1})	P(kg P_2O_5 ha^{-1})	(cm)	of leaves	length (cm)	of stools
0	0	70.89 b	82 d	50.43 a	17.68 b
	41	80.72 a	116 c	65.98a	24.33 ab
43	0	75.86 ab	138 a	64.89a	28.57 a
	41	78.24 a	142 a	67.75a	27.86 a
86	0	77.72 a	139 a	68.76a	30.76 a
	41	77.04 a	128 b	69.09a	26.18 a
Sig. level		**	***	*	***

Means followed by the same letter(s) within columns are not significantly different according to Duncan's Multiple Range Test at 5% level.
** and *** indicate significance at 1% and 0.1%, respectively.

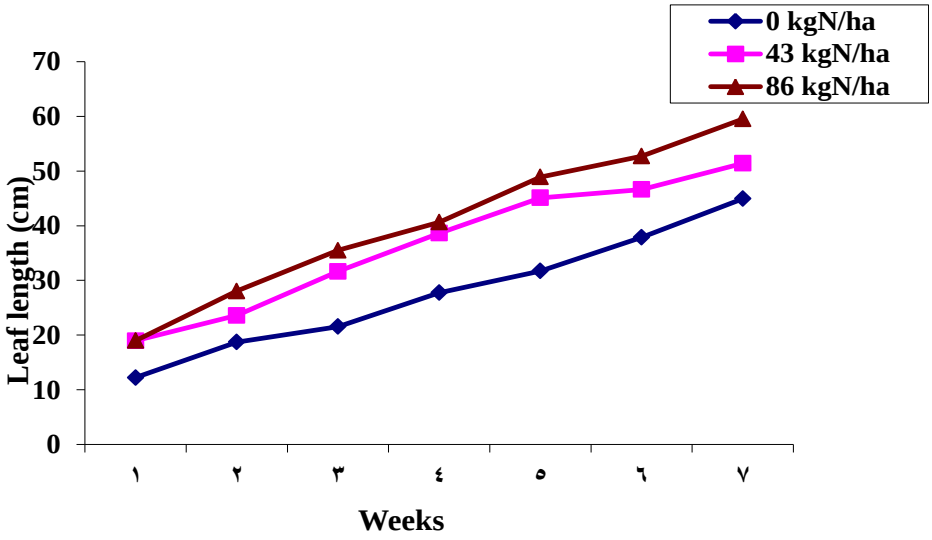

Figure 1. Effects of N rate on leaf length of lemongrass with time (average of two cuts).

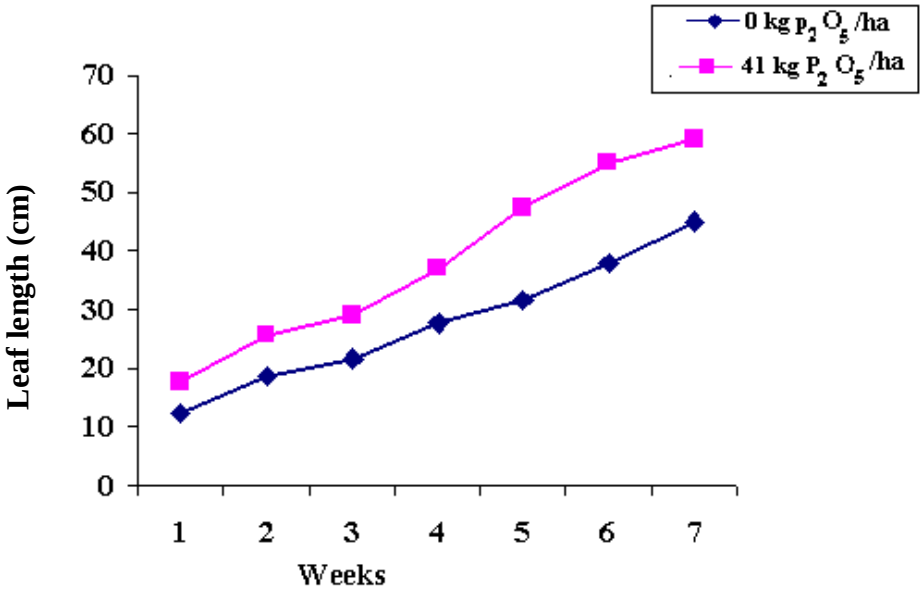

Figure 2. Effects of P rate on leaf length of lemongrass with time (average of two cuts).

The effects of N and P rates on the number of leaves of lemongrass are shown in Figs 3 and 4, respectively. Number of leaves increased with time till the seventh week after planting. The largest number of leaves was obtained at the highest rate of N (Fig 3) and the higher rate of P (Fig 4) as compared to the control.

The effects of N and P rates on number of stools are shown in Figs 5 and 6. Number of stools progressively increased with time till the seventh week after planting. The largest number of stools was obtained at the highest rate of N (Fig 5) and at the higher rate of P (Fig 6). These results agreed with the results reported by Gupta *et al.* (1978) who found that plant height of palmarosa grass increased as a result of the balanced application of 80 kg ha^{-1} of a mixed fertilizer containing N, P and K. The effect of phosphorus on vegetative growth was reported in several investigations. Munshi *et al.* (1990) reported an increase in plant height and number of branches of *Carum carvi* when phosphorus was applied at the rate of 40 kg ha^{-1}. Das *et al.* (1991) found an increase in plant height, number of branches, fresh weight and dry weight of black cumin with increasing phosphorus rate from 20 to 40 kg ha^{-1}. El-Khateeb *et al.* (1994) reported that phosphorus fertilization (20-40 kg/ha) increased plant height of turnip. Also, Mahmoud (2002) reported an increase in plant height of several medicinal plants as a result of the application of N, P and K.

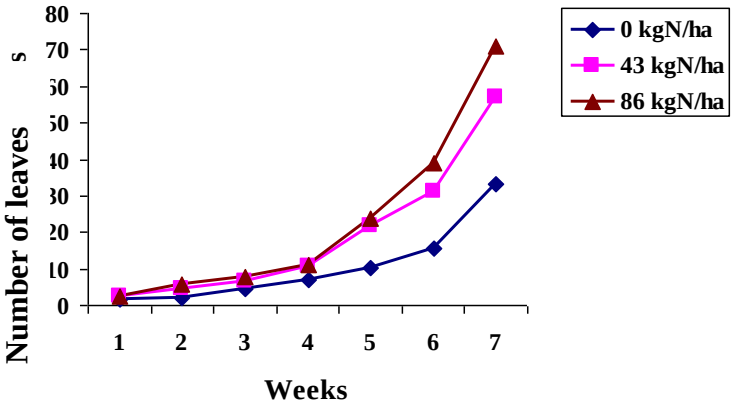

Figure 3. Effects of N rate on number of leaves of lemongrass with time (average of two cuts).

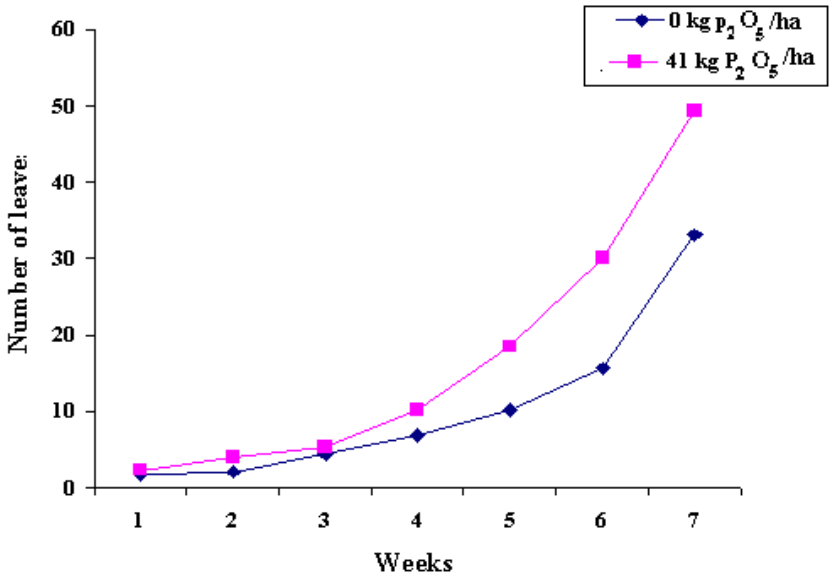

Figure 4. Effects of P rate on number of leaves of lemongrass with time (average of two cuts).

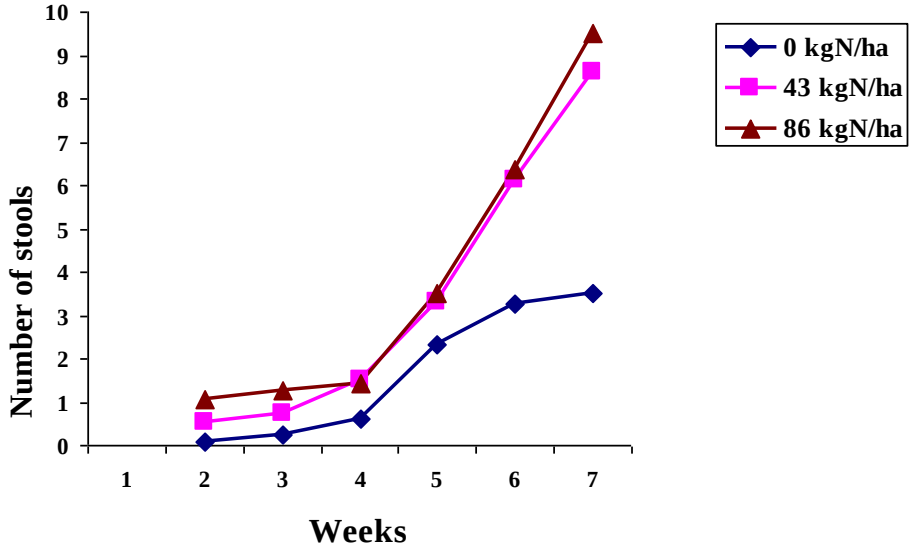

Figure 5. Effects of N rate on number of stools of lemongrass with time (average of two cuts).

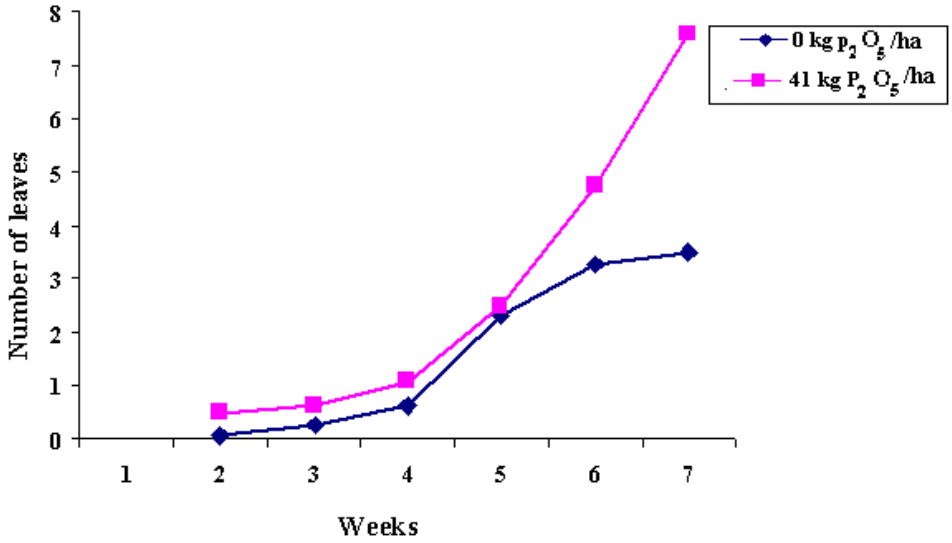

Figure 6. Effects of P rate on number of stools of lemongrass with time (average of two cuts).

Yield

The main effects of N and P on the fresh yield of lemongrass are shown in Table 5. Fresh yield significantly increased as N rate increased and the highest yield was obtained at the rate of 86 kg Nha^{-1} in both cuts. These results are in agreement with those reported by Mahmoud (2002). Application of P significantly increased the fresh yield of lemongrass in both cuts. The highest yield was obtained by the application of 41 kg $P_2O_5ha^{-1}$.

The interaction effects of N and P rates on the fresh yield of lemongrass are significant in both cuts (Table 6). The highest lemongrass fresh yield was obtained at the N rate of 86 kg ha^{-1} combined with 41 kg P_2O_5 ha^{-1} and the lowest yield was obtained by the control treatment.

Table 5. Main effects of N and P on fresh yield and oil content of lemongrass.

Fertilizer	Yield (ton ha^{-1})		Oil content (% fresh wt.)	
	First cut	Second cut	First cut	Second cut
N (kg ha^{-1})				
0	7.2 c	9.6 c	0.40 b	0.32 b
43	9.8 b	12.4 b	0.50 ab	0.39 ab
86	12.7 a	14.3 a	0.58 a	0.47 a
Sig. level	*	*	*	*
P (P_2O_5 ha^{-1})				
0	7.2 b	9.6 b	0.40 b	0.32 b
41	11.7 a	13.2 a	0.52 a	0.40 a
Sig. level	*	*	*	*

Means followed by the same letter(s) within columns are not significantly different according to Duncan's Multiple Range Test at 5% level.
* indicate significance at 5% level.

Table 6. Interaction effects of N and P rates on fresh yield and oil content of lemongrass.

Fertilizer		Yield (ton ha^{-1})		Oil content (% fresh wt.)	
N (kg N ha^{-1})	P (kg P_2O_5 ha^{-1})	First cut	second cut	First cut	second cut
0	0	7.2 d	9.6 d	0.40 c	0.32 d
	41	11.7 b	13.2 b	0.52 bc	0.40 c
43	0	9.8 c	12.4 c	0.50 bc	0.39 c
	41	10.9 c	13.9 b	0.47 bc	0.46 b
86	0	12.7 b	14.3 ab	0.58 ab	0.47 b
	41	14.5 a	15.7 a	0.67 a	0.56 a
Sig. level		*	*	**	*

Means followed by the same letter(s) within columns are not significantly different according to Duncan's Multiple Range Test at 5% level.
* and ** indicate significance at 5% and 1%, respectively.

Oil content

Application of nitrogen and P had significant effects on oil content in both cuts (Table 5). Application of N at 86 kg Nha^{-1} resulted in the highest oil content as compared to the other treatments in both cuts. Similar results were reported by Fatima *et al.* (2000). These findings are also in agreement with those of Omer *et al.* (2008), who reported that nitrogen fertilizer was effective in increasing essential oil content of sweet basil, and

found a positive correlation between nitrogen fertilizer rate and essential oil content in all cuts. Nitrogen application might enhance the essential oil biosynthetic process through its direct or indirect role in plant metabolism resulting in more plant metabolites. Addition of 41 kg $P_2O_5ha^{-1}$clearly enhanced the oil content more than the control in both cuts. Phosphorus was also found to increase oil content in palmarosa grass (Gupta *et al.*, 1978).

The interaction effects of N and P rates on the oil content of lemongrass were significant in both cuts (Table 6). The highest oil content was obtained by the application of 86 kg Nha^{-1} in combination with 41 kg $P_2O_5ha^{-1}$in both cuts and the lowest oil content was obtained by the control treatment. The oil yield was higher in the first harvest, and decreased during the second harvest. This result agrees with that reported by Herath *et al.* (1979) who found that under high temperature, the oil content was higher in young leaves and declines with the advancement in age. They also found that the photosynthetic rate and oil content in citronella grass decreased with the increase in leaf age.

In conclusion, lemongrass can be successfully grown under Gezira conditions. The highest yield and oil content can be achieved by the application of 86 kg Nha^{-1} and 41kg $P_2O_5ha^{-1}$.

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تأثير معدلات النتروجين والفسفور على نمو و انتاجية ومحتوى الزيت لحشيشة الليمون (*Cymbopogon flexuosus* L.)

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الخلاصة

حشيشة الليمون هي إحدى النباتات الطبية المهمة المنتجة للزيت الأساسي ذا القيمة الاقتصادية العالية وهي حشيشه مدارية يمكن أن تنتج بنجاح في السودان على المستوى التجاري. أجريت التجربة بهدف معرفة تأثير السماد النتروجيني والفسفوري على النمو الخضري وإنتاج العشب ونسبة الزيت في حشيشة الليمون. أجريت التجربة بالمزرعة التجريبية بكلية العلوم الزراعية- جامعة الجزيرة بود مدني. اشتملت المعاملات على 3 مستويات من النتروجين (0 و 43 و86 كجم نايتروجين للهكتار) ومستويين من الفسفور (0 و41 كجم فسفور للهكتار) نفذت التجربة باستخدام تصميم القطاعات العشوائية الكاملة بأربع مكررات. إضافة سماد النتروجين والفسفور كان لهما أثراً معنوياً على النمو الخضري وإنتاج العشب ومحتوى الزيت في كلا القطعتين. أفضل النتائج كانت عند إضافة 86 كجم نتروجين للهكتار مع 41 كجم P_2O_5 للهكتار في كلا القطعتين. أعطت معاملة الشاهد أقل التقديرات. محتوى الزيت لحشيشة الليمون كان أعلى في القطعة الأولى بالمقارنة مع القطعة الثانية.