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Influence of Different Levels of Nitrogen on Growth, Yield and Quality of Lemon Grass (*Cymbopogon citratus* L.)

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A B S T R A C T

A field experiment was conducted at College of Agriculture, Raichur during 2021 and 2022 to assess the growth, yield and quality of lemon grass (*Cymbopogan citratus* L.) as influenced by different levels of nitrogen. The experiment was laid out in a factorial randomized completely block design with four replications. The results of the study showed that variety Krishna of lemon grass showed better performance concerning growth and yield attributes when compared to variety Cauvery and variety Prathibha. Nitrogen when applied at the rate of 200 kg ha^{-1} responded better when compared to higher dose and lower dose of nitrogen. Lemon grass of variety Krishna and nitrogen of 200 kg ha^{-1}, increased the plant height (198.69 cm), number of tillers per clump (155.00), number of leaves per tiller (8.33), dry foliage per plant (1.42 kg) dry foliage per hectare (25.75 t ha^{-1}), oil yield per hectare (201.66 kg ha^{-1}), nitrogen uptake(135.80 kg ha^{-1}), phosphorus uptake(34.68 kg ha^{-1}) and potassium uptake (263.20 kg ha^{-1}). Therefore, lemon grass variety Krishna, and nitrogen of 200 kg ha^{-1} was found beneficial for higher growth and yield in lemon grass.

Introduction

Lemon grass belongs to the Gramineae family, which comprises approximately 500 genus and 8,000 herb species. Lemon grass is a tufted perennial grass growing to a height of 1meter with numerous stiff leafy stems arising from short rhizomatous roots (Barbosa *et al.,* 2008). According to the WHO, herbal medicine is considered an important part of the healthcare industry by more than two-thirds of the population in developing countries (Okémy *et al.,* 2015). A strong lemon fragrance, a predominant feature of this grass, is due to the high citral content of its oil. The redolence of the oil enables its use in soaps, detergents, etc. As a good source of citral, it finds an application in the perfumery as well as food industries (Viabhav *et al.,* 2013).

The essential oil of the plant is used in flavour, fragrancing and aromatherapy, medicinal tea, culinary herb (Seaforth and Tikasingh, 2005) and treatment for skin diseases (Balch and Phyllis, 1990). It is known as a source of ethno medicines (Puatanachokchai *et al.,* 2002). *C. citratusis* used in different parts of the world in the treatment of digestive disorders, fevers, menstrual disorder, rheumatism and other joint pains (Simon *et al.,* 1984).

It grows in the sub-tropical and tropical regions of the world due to its wide uses in the cosmetics, food, pharmaceutical, agriculture and flavor industries. Large scale cultivation of Cymbopogon grasses occurs in the sub-tropics and tropics. Endemic to India, *C. flexuosus* is largely grown in several countries, including China, Indonesia, Mexico, Madagascar, Brazil, Haiti and Dominica (Ganjewala and Gupta, 2013). The lemon grass oil is largely composed of citral (65–85 %) (Kamaruddin *et al.,* 2021). Other major compounds of the oil include geraniol, citronellal, citronellol, geranyl acetate, nerol, alpha-pinene, limonene, linalool, caryophyllene and methyl heptanone (Gupta, and Ganjewala, 2015; Sakaria *et al.,* 2012).

It is a tall, clumpy perennial plant. It comes to first harvest 4 to 6 months after planting, then harvest is done every 2 to 3 months Harvesting is done by cutting 20 cm above the ground Level (Bhatnagar, 2020). Supplying appropriate nutrients is vital for the healthy growth of all crops, including medicinal plants that produce essential oils. Utilizing proper fertilization techniques can greatly boost the quantity and quality of the essential oils these plants generate as well as their growth and development (Sharafzadeh *et al.,* 2011; Zheljazkov *et al.,* 2011).

Considering the fact that soil fertility decline is one of the biggest challenges, an obvious strategy is to increase fertilizer application and promote good agronomic practices to enhance productivity (Borlaug and Dows, 1994). Nitrogen is the most deficient element and its fertilization help in increasing productivity and quality. The crop with the proper amount of nitrogen available to it grows more vigorously and enhances the herb and oil yield. Being a foliage rich crop, it responded well to fertilizer nitrogen application (Singh and Singh, 1998). Fertilizer applications, specially nitrogen, affect the yield of essential oils by the increase of the production of total bio-mass per unit of area (Sangwan *et al.,* 2001).

Materials and Methods

The experiment was conducted in fields of herbal garden, Main Agricultural Research Station, University of Agricultural Sciences, Raichur for two years, which is located in the North Eastern dry zone *i.e.,* Zone - II of the region - I in Karnataka in the year of 2019. The location corresponds to 16^0 25' North latitude and 77^0 33' East longitude. The climate of the experimental location is semi-arid and average annual rainfall is 722 mm. The elevation of Raichur is 406 m above mean sea level. The experiment was laid out in a factorial RCBD design with four replications and twelve treatments. Factor 1 consisted of different varieties of lemon grass I,e., V_1: Krishna V_2: Cauvery and V_3 : Pragathi. Factor 2 consisted of four levels of nitrogen i.e., F_1: N at 100 kg ha -1 + P and K as recommended F_2: N at 150 kg ha -1 + P and K as recommended, F_3: N at 200 kg ha -1 + P and K as recommended, F_4: N at 250 kg ha -1 + P and K as recommended, The land was thoroughly ploughed and brought to a fine tilth. Then the experimental site was divided into small plots and leveled within the plots, each measuring 4.2 m x 4.0 m with a spacing of 0.5 m between two plots. The replications were kept 0.5 m apart to avoid the percolation of nutrients. Healthy lemon grass root slips were planted in the experimental plots at a spacing of 60 cm between the rows and 60 cm between the plants. The recommended dose of phosphorous and potassium were applied to each of the plot as per the recommendation for the crop at the time planting of root slips. Nitrogen was applied in split doses starting from the time of planting, one month after planting and remaining dose after each harvest. Five plants were tagged from each plot. Observations on growth and yield parameters were recorded from these tagged plants at regular intervals.

Results and Discussion

Growth parameters

The recorded and analysed data for growth parameters of lemon grass is presented in table 1. Significantly higher plant height (176.83 cm, 191.87 cm and 184.35 cm during 2021,2022 and pooled data, respectively), number of tillers per clum (133.33, 155.38 and 144.35 during 2021, 2022 and pooled data, respectively), number of leaves per tiller (7.75, 8.33 and 8.04 during 2021,2022 and pooled data, respectively), was recorded in Krishna variety of lemon grass. With respect to different doses of nitrogen, 200 kg N ha^{-1} produced higher plant height (150.00 cm, 165.00 cm and 157.50 cm, during 2021, 2022 and pooled data, respectively), number of tillers per clump (122.22, 144.32 and 133.27 during 2021, 2022 and pooled data, respectively), number of leaves per tiller

(8.00, 7.77 and 7.88 during 2021, 2022 and pooled data, respectively). This was followed by application of 250 kg N ha^{-1}. Lemon grass variety Krishna along with 200 kg N ha^{-1} produced higher plant height (190.66 cm, 202.72 cm and 198.69 cm during 2021, 2022 and pooled data, respectively), number of tillers per clump (144.00, 166.00 and 155.00 during 2021, 2022 and pooled data, respectively), number of leaves per tiller (7.66, 8.00 and 7.83 during 2021, 2022 and pooled data, respectively).

Higher plant height, number of tillers per clump and number of leaves per tiller was higher in variety Krishna, as this might be due to the varietal characteristics. Further, better growth parameters was recorded in this experiment with higher nitrogen levels.

This might be due to better nutrient uptake under increased supply of nitrogen and role of nitrogen in enhancing vegetative growth. The results were in conformity to the findings of Rao *et al.,* (1985). Furthermore, Singh *et al.,* (2008) reported that nitrogen fertilization of lemongrass has resulted in more tillers, number of leaves, the large size of leaves, and a higher rate of re-growth after cutting. This could be due to nitrogen which is responsible for transfer or storage of energy, producing protein, improving the various growth characters and development of plants (Hull and Liu, 2005) and (Bauer *et al.,* 2012).

However in this experiment, it could be seen that the growth parameters increased up to the level of 200 kg ha^{-1} nitrogen and then the growth parameters declined. This could be due to the negative impact of excess nitrogen application. Singh *et al.,* (2016) also observed similar trend in lemon grass.

Yield parameters

Yield parameters such as dry foliage per plant (kg), dry foliage per hectare (t ha^{-1}) and oil yield per hectare (kg ha^{-1}) are presented in table-2.

Significantly higher dry foliage per plant (1.30 kg, 1.44 kg and 1.37 kg during 2021, 2022 and pooled data, respectively), dry foliage per hectare (21.30 t ha^{-1}, 29.70 t ha^{-1} and 25.50 t ha^{-1} during 2021, 2022 and pooled data, respectively) and oil yield per hectare (185.07 kg ha^{-1}, 203.72 kg ha^{-1} and 194.39 kg ha^{-1} during 2021, 2022 and pooled data, respectively), was recorded in Krishna variety of lemon grass. With respect to different doses of nitrogen, 200 kg N ha^{-1} produced higher dry foliage per plant (1.15 kg 1.28 kg and 1.21 kg, during 2021, 2022 and pooled data, respectively), dry foliage per hectare (18.04 t ha^{-1}, 25.85 t ha^{-1} and 21.99 t ha^{-1} during 2021, 2022 and pooled data, respectively), oil yield per hectare (185.55 kg ha^{-1}, 193.02 kg ha^{-1} and 184.98 kg ha^{-1} during 2021, 2022 and pooled data, respectively).

This was followed by application of 250 kg N ha^{-1}. Lemon grass variety Krishna along with 200 kg N ha^{-1} produced higher dry foliage per plant (1.33 kg, 1.51 kg and 1.42 kg during 2021, 2022 and pooled data, respectively), dry foliage per hectare (21.50 t ha^{-1}, 29.99 t ha^{-1} and 25.75 t ha^{-1} during 2021, 2022 and pooled data, respectively) and oil yield per hectare (186.75 kg ha^{-1}, 212.21 kg ha^{-1} and 201.66 kg ha^{-1} during 2021, 2022 and pooled data, respectively). The current experiment documented higher yield parameters with variety Krishna. Lemon grass var. Krishna exhibited higher growth parameters, as a result of which it exhibited higher yield parameters. This may be due to the influence of nitrogen in promoting the vegetative growth, which resulted in increased herbage production, consequently, essential oil yield increased to a greater extent. In fact N and P fertilizer do have a synergistic effect and hence N might have stimulated the uptake of P and vice versa (Sharma and Tandon, 1992). In the current study, it could be noticed that there was a significant increase in oil yield up to the application of 200 kg ha^{-1} N. These results were in contradictory to the results found by Mannu *et al.,* (2005) and Melkamu *et al.,* (2019), who stated that the essential oil content was not affected by the application of different levels of nitrogenous fertilizers.

Nutrient uptake

Significantly higher N uptake (116.47 kg ha^{-1},126.57 kg ha^{-1} and 121.52 kg ha^{-1} during 2021,2022 and pooled data, respectively), P uptake (26.56 kg ha^{-1}, 34.62 kg ha^{-1} and 30.59 kg ha^{-1} during 2021, 2022 and pooled data, respectively) and K uptake (243.71 kg ha^{-1}, 258.82 kg ha^{-1} and 251.27 kg ha^{-1} during 2021, 2022 and pooled data, respectively), was recorded in Krishna variety of lemon grass. With respect to different doses of nitrogen, 200 kg N ha^{-1} resulted in higher N uptake (106.32 kg ha^{-1} 116.57 kg ha^{-1} and 111.37 kg ha^{-1}, during 2021, 2022 and pooled data, respectively), P uptake (24.72 kg ha^{-1}, 32.85 kg ha^{-1} and 28.79 kg ha^{-1} during 2021, 2022 and pooled data, respectively) and K uptake (212.26 kg ha^{-1}, 227.35 kg ha^{-1} and 219.81 kg ha^{-1} during 2021,2022 and pooled data, respectively). This was followed by application of 250 kg N ha^{-1}.

Table.1 Plant height, number of tillers per clump, number of leaves per tiller, as influenced by different varieties of lemon grass with different nitrogen levels

	Plant height (cm)			Number of tiller per clump			Number of leaves per tiller		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
V1 (Krishna)	176.83	191.87	184.35	133.33	155.38	144.35	7.75	8.33	8.04
V2 (Cauvery)	136.41	141.51	138.96	119.25	142.32	130.78	7.41	7.85	7.60
V3 (Pragathi)	97.91	112.96	105.43	85.91	107.95	96.93	7.66	7.08	7.37
SE.m.±	0.55	0.58	0.38	0.92	0.98	0.63	0.13	0.16	0.10
C.D. at 5 %	1.64	1.68	1.09	2.76	2.72	NS	NS	0.49	0.30
F1 (N at 100 kg ha^{-1} + P and K as recommended)	126.50	141.55	134.05	103.11	125.22	114.16	7.11	7.66	7.38
F2(N at 150 kg ha^{-1} + P and K as recommended)	136.22	151.22	143.72	107.44	129.56	118.50	7.66	7.88	7.77
F3(N at 200 kg ha^{-1} + P and K as recommended)	150.00	165.00	157.50	122.22	144.32	133.27	8.00	7.77	7.88
F4(N at 250 kg ha^{-1} + P and K as recommended)	148.77	163.75	156.27	118.55	140.56	129.55	7.66	7.33	7.50
SE.m.±	0.64	0.69	0.44	1.06	1.08	0.73	0.15	0.19	0.12
C.D. at 5 %	1.89	1.92	1.26	3.14	3.18	2.10	0.44	NS	0.35
V1F1	160.33	177.37	168.85	120.66	142.72	131.69	7.00	7.33	7.16
V1F2	176.66	191.68	184.17	130.33	152.34	141.35	7.33	7.33	7.33
V1F3	190.66	202.72	198.69	144.00	166.00	155.00	7.66	8.00	7.83
V1F4	179.62	194.63	187.14	138.33	160.52	149.33	7.66	7.66	7.66
V2F1	90.00	106.00	98.00	108.33	130.42	119.33	7.00	8.00	7.50
V2F2	97.33	112.33	104.83	109.66	131.65	120.65	8.33	8.33	8.33
V2F3	100.00	116.00	107.50	132.33	154.22	143.35	8.33	8.00	8.16
V2F4	104.33	119.55	111.83	126.66	148.75	137.66	7.33	9.00	8.16
V3F1	109.3	124.33	116.83	80.33	102.22	91.27	7.33	7.66	7.50
V3F2	114.66	129.72	122.16	82.33	104.30	93.31	8.00	7.00	7.50
V3F3	139.33	154.35	146.83	90.33	112.52	101.41	7.33	6.66	7.00
V3F4	142.33	157.45	149.83	90.66	112.24	101.65	8.00	7.00	7.50
SE.m.±	1.11	1.18	0.76	1.84	1.92	1.27	0.25	0.33	0.21
C.D. at 5 %	3.28	3.52	2.19	5.45	5.65	3.63	NS	NS	NS

Table.2 Dry foliage per plant, dry foliage per hectare and oil yield per hectare, as influenced by different varieties of lemon grass with different nitrogen levels

	Dry foliage per plant (kg)			Dry foliage per hectare (t ha^{-1})			Oil yield per hectare (kg ha^{-1})		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
V1 (Krishna)	1.30	1.44	1.37	21.30	29.70	25.50	185.07	203.72	194.39
V2 (Cauvery)	1.13	1.22	1.17	16.97	25.29	21.13	140.99	158.05	149.52
V3 (Pragathi)	0.97	1.08	1.03	14.29	22.66	18.48	181.24	197.22	189.23
SE.m.±	0.02	0.02	0.33	0.78	0.72	0.75	2.29	0.55	1.22
C.D. at 5 %	0.56	0.56	0.63	2.30	2.42	2.36	6.76	1.64	3.47
F1 (N at 100 kg ha^{-1} + P and K as recommended)	1.10	1.29	1.20	17.00	25.34	21.18	167.66	187.85	177.75
F2(N at 150 kg ha^{-1} + P and K as recommended)	1.13	1.28	1.19	17.41	25.77	21.60	162.74	181.15	171.94
F3(N at 200 kg ha^{-1} + P and K as recommended)	1.15	1.26	1.21	18.14	25.85	21.99	185.55	193.02	184.98
F4(N at 250 kg ha^{-1} + P and K as recommended)	1.08	1.18	1.13	17.54	24.72	21.13	169.03	183.28	176.15
SE.m.±	0.23	0.23	0.13	0.90	0.1	0.5	2.64	0.64	1.41
C.D. at 5 %	NS	NS	0.43	NS	NS	NS	7.81	1.89	4.01
V1F1	1.24	1.46	1.35	20.73	29.10	24.91	185.55	200.21	192.88
V1F2	1.26	1.46	1.36	21.44	29.77	25.60	185.79	204.80	195.29
V1F3	1.33	1.51	1.42	21.50	29.99	25.75	186.75	212.21	201.66
V1F4	1.21	1.37	1.30	21.57	29.82	25.66	180.87	196.84	188.85
V2F1	0.94	1.05	1.00	13.26	21.61	17.43	137.05	149.25	143.15
V2F2	0.86	1.10	1.02	13.87	22.18	18.02	126.41	152.57	139.49
V2F3	1.07	1.23	1.16	13.61	21.98	17.80	151.61	173.06	162.33
V2F4	0.99	1.09	1.04	16.40	24.77	20.58	148.88	157.32	153.10
V3F1	1.14	1.30	1.22	17.00	25.35	21.16	179.44	196.08	187.76
V3F2	1.12	1.27	1.19	16.94	25.31	21.13	174.74	195.89	185.32
V3F3	1.08	1.24	1.16	17.54	25.91	21.73	182.10	195.44	198.77
V3F4	1.20	1.28	1.24	16.39	24.64	20.52	177.34	195.68	186.51
SE.m.±	0.40	0.40	0.26	1.56	1.62	1.59	4.58	1.11	2.44
C.D. at 5 %	NS	NS	NS	NS	NS	NS	13.52	3.28	6.95

Table.3 Nutrient uptake, as influenced by different varieties of lemon grass with different nitrogen levels

	Nitrogen uptake (kg ha^{-1})			Phosphorous uptake(kg ha^{-1})			Potash uptake(kg ha^{-1})		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
V1 (Krishna)	116.47	126.57	121.52	26.56	34.62	30.59	243.71	258.82	251.27
V2 (Cauvery)	95.05	105.12	100.08	21.66	29.32	25.70	198.69	213.72	206.20
V3 (Pragathi)	71.30	81.55	76.43	18.25	26.34	22.29	172.98	187.99	180.48
SE.m.±	2.82	2.85	2.84	1.13	1.15	1.14	2.38	2.42	2.40
C.D. at 5 %	8.34	8.45	8.40	3.34	3.55	3.44	7.50	7.52	7.51
F1 (N at 100 kg ha^{-1} + P and K as recommended)	83.68	93.72	88.70	19.73	27.82	23.78	183.85	198.98	191.42
F2(N at 150 kg ha^{-1} + P and K as recommended)	88.62	98.72	93.67	21.35	29.42	25.39	196.00	211.00	203.50
F3(N at 200 kg ha^{-1} + P and K as recommended)	106.32	116.42	111.37	24.72	32.85	28.79	212.26	227.35	219.81
F4(N at 250 kg ha^{-1} + P and K as recommended)	98.47	108.57	103.52	22.82	30.92	26.87	228.41	243.45	235.93
SE.m.±	3.26	3.34	3.3	1.30	1.5	1.4	2.75	2.82	2.785
C.D. at 5 %	9.63	9.72	9.675	NS	NS	NS	8.14	8.25	8.195
V1F1	104.99	114.10	109.55	23.85	31.92	27.89	210.13	225.18	217.66
V1F2	109.54	119.62	114.58	25.87	33.95	29.91	224.58	239.68	232.13
V1F3	130.78	140.82	135.80	30.61	38.75	34.68	284.48	299.52	292.00
V1F4	120.55	130.62	125.58	25.92	33.10	29.51	255.67	270.22	263.20
V2F1	57.48	67.52	62.50	15.65	23.75	19.70	155.65	170.73	163.19
V2F2	66.04	76.08	71.06	17.70	25.82	21.76	165.57	180.62	173.10
V2F3	78.33	88.34	83.34	19.62	27.72	23.67	180.21	195.20	187.70
V2F4	83.34	93.45	88.40	20.01	28.05	24.03	190.52	205.62	198.07
V3F1	88.58	98.6	93.59	19.68	27.72	23.70	185.76	200.82	193.29
V3F2	90.28	100.36	95.32	20.48	28.52	24.50	197.85	212.92	205.39
V3F3	96.54	106.58	101.56	22.93	30.95	26.94	200.91	215.98	208.45
V3F4	104.83	114.86	109.85	23.54	31.65	27.60	210.24	225.32	217.78
SE.m.±	5.65	5.72	5.685	2.26	2.32	2.29	2.75	4.77	3.76
C.D. at 5 %	NS	NS	NS	NS	NS	NS	8.14	14.1	11.12

Lemon grass variety Krishna along with 200 kg N ha^{-1} resulted in higher N uptake (130.78 kg ha^{-1}, 140.82 kg ha^{-1} and 135.80 kg ha^{-1} during 2021, 2022 and pooled data, respectively), P uptake (30.61 kg ha^{-1}, 38.75 kg ha^{-1} and 34.68 kg ha^{-1} during 2021, 2022 and pooled data, respectively) K uptake (284.48 kg ha^{-1}, 299.52 kg ha^{-1} and 292.00 kg ha^{-1} during 2021, 2022 and pooled data, respectively).

Higher uptake of nutrients by lemon grass var. Krishna could be attributed to its vigorous growth habits. As far as different levels of nitrogen is concerned, it could be seen that the nutrient uptake increased with the increase in nitrogen levels and the uptake decreased beyond the level of 200 kg ha^{-1} nitrogen application. This trend could be due to the side effects of excess nitrogen application.

The present study clearly indicates that the application of nitrogenous fertilizers have the potential for improving the fresh herbage yield and essential oil yield, number of tillers and number of leaves of lemongrass (*Cymbopogon citrates* L.). Our finding demonstrated that application of 200 kg ha^{-1} of nitrogen produced the maximum herbage and oil yields in lemongrass.

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Author Contributions

Udayakumar: Investigation, formal analysis, writing—original draft. G. Ramesh Sanganna: Validation, methodology, writing—reviewing. M. Sajjanar:—Formal analysis, writing—review and editing. R. Jyothi: Investigation, writing—reviewing.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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