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Comparative study of Morpho-Physiological and Biochemical assessment of lemongrass (*C. flexuosus*) species under different cultivation practices

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Abstract
Lemongrass (*Cymbopogon flexuosus*) is an aromatic perennial oil bearing grass used in traditional medicine, pharmaceutical and other industries due to having antimicrobial activities increasing in demand. Therefore, to establish the appropriate cultivation practices for its potential production at Chhattisgarh plain as well as to find out the suitable varieties for the region under rain-fed and irrigated conditions in two consecutive year was conducted. Hence, five varieties (Krishna, Pragati, Neema, Kaveri, CG Lemongrass-1) and seven nutrient management treatments *i.e.*, T_1 (Control), T_2 (NPK @ 120:60:60 kg/ha.+ S @ 60 kg/ ha)., T_3 (T_2 + 100 ppm GA_3), T_4 (T_2 + 100 ppm IAA), T_5 (FYM @ 10 tonnes/ha. + S @ 60 kg/ha), T_6 (T_5 + 100 ppm GA_3), T_7 (T_5 + 100 ppm IAA) were used in two cultivation practices *i.e.*, irrigated and rainfed in double split plot design. The morpho-physiological, biochemical were observed to study the response of varieties on three cuttings, first at 120 days after plantation (DAP), second after 240 DAP and third after 360 DAP. Study revealed that variety Krishna performed significantly superior in irrigated as well as in rain-fed conditions to obtain in plant height, number of leaves, leaf area, leaf area index, specific leaf area, absolute growth rate. Variety Krishna and Neema performed superior in both irrigated and rain-fed situations regarding proline content, phenol content. While, the nitrogen and protein content, ash content significantly increased with treatment T_4 (NPK @ 120:60:60 kg/ha. + S @ 60 kg/ ha. +100 ppm IAA).

Keywords: lemongrass, CG lemongrass, rainfed, nutrient management

Introduction
The lemongrass (*Cymbopogon flexuosus*) is a perennial grass belonging to family Poaceae and grouped under genus Cymbopogon. The plant is a native herb from India and is cultivated in other tropical and subtropical countries (Figueirinha *et al*. 2008) [2]. It was introduced in India about a century ago and is now commercially cultivated along the Western Ghats (Maharashtra, Kerala), and in Karnataka and Tamil Nadu, besides the foothills of Arunachal Pradesh and Sikkim, and also throughout tropical Asia. Lemongrass occupies important place amongst aromatic plants at national and international market, due to high level of citral (about 75-80%) in its oil. In the state of Chhattisgarh, it is cultivated in more than 216 hectares, distributed in the districts of Surguja, Bastar, Rajnandgaon and Durg. The water requirement of lemongrass is very low. It is mainly grown in kharif season in most of the part of India and Chhattisgarh. It is a monocotyledonous hypogeal perennial plant with slender sharp edged green leaves that has a pointed apex. Its aqueous extract is commonly used as an aromatic drink while the whole plant is well incorporated into traditional food for its lemon flavors. It also enjoyed wide application in folk medicine. Many biologically active substances have been isolated and elucidated in *Cymbopogon flexuosus*, the most important being citral, which aids digestion as well as relieve spasms, muscle cramps, rheumatism and headache. A tea made from the leave of *Cymbopogon flexuosus* has been used to treat fever, cold, cough and stomach upset. The tea also has diuretic properties and can help in urinating difficulties and water retention. It has also been reported that extracts of both the leaves and stalks of *Cymbopogon flexuosus* are used as an herbal medicine to treat nervous condition and inflammation.
The application of mineral nutrients and plant growth regulators (PGRs) in the cultivation of lemongrass has reached its maximum limit. Plant Growth regulators, also known as plant growth substances, are natural or synthetic organic compounds controlling different kinds of biological and physiological activities, such as the promotion of plant growth, seed germination, shoot elongation, root growth, flower production, suppression of heavy metal stress, etc.

They are required in a very low amounts, ranging from 10-6 to 10-5 M (Daraksha and Feroz 2016; Khan *et al.* 2014) [1, 4].

Materials and Methods

The present study Comparative study of Morpho-Physiological and biochemical assessment of lemongrass (*C. flexuosus*) species under different cultivation practices was carried out at the at Instructional cum Research Farm, IGKV, Raipur (Chhattisgarh). The laboratory work was done in Department of Plant Physiology, Agricultural Biochemistry, Medicinal and Aromatic Plants, College of Agriculture, IGKV, Raipur (Chhattisgarh) during the year 2019-20 and 2020-2021. The treatment details are given follow.

Main plot treatment (Irrigation Management)

W1 - Rainfed (No Irrigation)
W2 - Irrigated (Six Irrigations)

Sub plot treatment (Varieties)

V1 - Krishna
V2 - Pragati
V3 - Neema
V4 - Kaveri
V5 - CG lemongrass-1

Sub-sub plot treatment (Nutrient Management)

T_1 - Control
T_2 - NPK @ 120:60:60 kg/ha/year + 60 kg ha-1 Sulphur
T_3 - T_2 + 100 ppm GA3
T_4 - T_2 + 100 ppm IAA
T_5 - FYM @ 10 tonnes/ ha + 60 kg ha-1 Sulphur
T_6 - T_5 + 100 ppm GA3
T_7 - T_5 + 100 ppm IAA

Results and Discussions

Plant Height: There was significant difference in plant height in all the five experimental varieties of lemongrass under both the conditions of irrigation. Plant height was significantly higher in irrigated conditions over rainfed. Amongst the varieties, Krishna performed best in both the conditions of irrigation in rainfed and irrigated conditions respectively. Amongst the treatments T_4 was found to be superior over other treatments followed by T_3 irrespective of varieties and practices of cultivation. Jayalakshmi *et al.* (2012) [3] reported the nitrogen uptake increased progressively with the crop growth may be due to increase in dry matter accumulation.

Table 1: Pooled average data of Effect of Nutrient management on plant height under rainfed and irrigated condition in different varieties

	Rainfed					Irrigated				
	Krishna	**Pragati**	**Neema**	**Kaveri**	**Cg Lemongrass^{-1}**	**Krishna**	**Pragati**	**Neema**	**Kaveri**	**Cg Lemongrass^{-1}**
T_1	52.22	36.02	48.92	34.43	43.84	53.58	39.95	49.59	38.20	44.88
T_2	54.45	38.88	50.65	37.26	45.98	50.05	40.23	52.21	38.88	47.86
T_3	56.98	41.15	51.81	39.29	47.99	58.33	42.53	53.11	41.01	49.90
T_4	58.25	42.96	54.21	40.53	49.41	60.35	44.98	56.413	42.62	51.66
T_5	53.81	38.07	49.86	36.26	45.02	55.68	40.40	52.10	38.67	47.57
T_6	55.69	39.60	51.69	37.85	46.52	56.87	41.19	53.35	39.55	48.25
T_7	56.31	40.59	52.66	38.66	47.23	58.19	42.45	54.66	40.67	49.16

Leaf Area

Leaf area was significantly different under both the conditions of cultivation and in different cuttings. The average area was significantly higher in irrigated condition as compared to rainfed. The variety Krishna was found to be superior in attaining the leaf area. The treatment T_4 was found to be superior in both conditions of cultivation irrespective of varieties.

Table 2: Pooled average data of Effect of Nutrient management on leaf area under rainfed and irrigated condition in different varieties

	Rainfed					Irrigated				
	Krishna	**Pragati**	**Neema**	**Kaveri**	**Cg Lemongrass^{-1}**	**Krishna**	**Pragati**	**Neema**	**Kaveri**	**Cg Lemongrass^{-1}**
T_1	64.358	60.963	57.872	44.366	41.572	67.484	64.535	62.225	50.165	44.93
T_2	64.331	61.431	57.929	44.474	41.628	67.624	64.849	62.51	50.359	45.199
T_3	64.59	61.635	58.628	44.779	41.971	67.884	65.035	62.822	100.92	45.42
T_4	67.114	61.71	58.798	45.321	42.462	68.4	65.452	63.329	50.823	45.632
T_5	64.212	61.113	58.026	44.673	41.691	67.49	64.755	62.561	50.098	45.226
T_6	64.243	61.052	58.089	44.602	41.87	67.693	64.598	63.254	50.501	45.43
T_7	64.342	61.113	58.195	44.881	42.021	67.635	65.015	63.272	50.786	45.585

Leaf Area Index

The average leaf area index was significantly higher in irrigated conditions as compared to rainfed conditions. The variety Krishna and treatment T_4 was found to be superior regarding the improvement of leaf area index. Singh *et al.* (1997) [6] observed that the plant height and LAI were significantly increased by the rate of nitrogen up to 100 kg/ha.

Table 3: Pooled average data of Effect of Nutrient management on leaf area index under rainfed and irrigated condition in different varieties

	Rainfed					Irrigated				
	Krishna	**Pragati**	**Neema**	**Kaveri**	**Cg Lemongrass^{-1}**	**Krishna**	**Pragati**	**Neema**	**Kaveri**	**Cg Lemongrass^{-1}**
T_1	0.108	0.108	0.108	0.078	0.068	0.15	0.143	0.143	0.113	0.103
T_2	0.111	0.111	0.101	0.081	0.068	0.15	0.143	0.143	0.113	0.103
T_3	0.108	0.108	0.108	0.084	0.074	0.153	0.147	0.147	0.127	0.11
T_4	0.118	0.114	0.114	0.094	0.078	0.153	0.147	0.153	0.133	0.113
T_5	0.104	0.104	0.104	0.084	0.074	0.147	0.15	0.143	0.117	0.11
T_6	0.108	0.111	0.108	0.091	0.078	0.15	0.143	0.15	0.12	0.11
T_7	0.118	0.114	0.114	0.094	0.078	0.15	0.153	0.15	0.127	0.113

Specific Leaf Weight

The overall Specific leaf weight was significantly higher in rainfed conditions as compared to irrigated condition. Amongst the varieties, CG Lemongrass-1 and treatment T_4 was found to be significantly superior in both the conditions of cultivation.

Table 4: Pooled average data of Effect of Nutrient management on Specific leaf weight under rainfed and irrigated condition in different varieties

	Rainfed					Irrigated				
	Krishna	**Pragati**	**Neema**	**Kaveri**	**Cg Lemongrass^{-1}**	**Krishna**	**Pragati**	**Neema**	**Kaveri**	**Cg Lemongrass^{-1}**
T_1	0.178	0.186	0.176	0.193	0.2	0.102	0.11	0.102	0.125	0.14
T_2	0.169	0.17	0.176	0.196	0.202	0.102	0.11	0.113	0.125	0.14
T_3	0.173	0.266	0.176	0.201	0.21	0.124	0.118	0.12	0.14	0.155
T_4	0.19	0.208	0.316	0.219	0.206	0.124	0.12	0.137	0.142	0.16
T_5	0.163	0.181	0.32	0.2	0.202	0.104	0.11	0.118	0.125	0.14
T_6	0.173	0.186	0.193	0.199	0.21	0.113	0.118	0.118	0.135	0.153
T_7	0.171	0.196	0.193	0.203	0.212	0.124	0.118	0.124	0.135	0.16

Specific Leaf Area

The overall performance of Specific leaf area was significantly higher in irrigated conditions as compared to rainfed. Regarding the response of varieties, variety Neema was found to be superior followed by Krishna. Amongst the treatments, T_4 was found significantly superior in enhancing specific leaf area.

Table 5: Pooled average data of Effect of Nutrient management on Specific Leaf Area under rainfed and irrigated condition in different varieties

	RAINFED					IRRIGATED				
	Krishna	**Pragati**	**Neema**	**Kaveri**	**Cg Lemongrass^{-1}**	**Krishna**	**Pragati**	**Neema**	**Kaveri**	**Cg Lemongrass^{-1}**
T_1	6.744	6.411	6.822	5.978	5.711	7.733	7.245	7.622	6.533	6.211
T_2	6.778	6.234	6.822	6	5.734	7.733	7.267	7.622	6.556	6.311
T_3	6.6	6.389	6.822	6.1	5.834	7.778	7.422	7.667	6.722	6.433
T_4	6.878	6.511	7.044	6.3	5.944	7.933	7.511	7.933	6.933	6.733
T_5	6.678	6.256	6.878	6.1	5.922	7.733	7.289	7.733	6.745	6.533
T_6	6.667	6.344	6.822	6.144	5.889	7.867	7.311	7.889	6.833	6.622
T_7	6.644	6.344	6.822	6.256	5.944	7.867	7.367	7.889	6.833	6.733

Absolute growth rate

The overall absolute growth rate was significantly higher in irrigated conditions than rainfed. Amongst the varieties, Krishna and treatment T_4 (NPK@ 120:60:60 kg/ha. + Sulphur 60 kg/ha. +100 ppm IAA) was found relatively better among treatments and varieties.

Table 6: Pooled average data of Effect of Nutrient management on Absolute Growth Rate under rainfed and irrigated condition in different varieties

	Rainfed					Irrigated				
	Krishna	**Pragati**	**Neema**	**Kaveri**	**Cg Lemongrass^{-1}**	**Krishna**	**Pragati**	**Neema**	**Kaveri**	**Cg Lemongrass^{-1}**
T_1	0.587	0.41	0.523	0.393	0.51	0.653	0.48	0.623	0.463	0.593
T_2	0.597	0.423	0.537	0.413	0.523	0.67	0.52	0.633	0.497	0.603
T_3	0.61	0.44	0.543	0.417	0.537	0.683	0.543	0.647	0.517	0.65
T_4	0.637	0.46	0.553	0.437	0.573	0.69	0.577	0.66	0.59	0.663
T_5	0.597	0.427	0.533	0.403	0.517	0.663	0.493	0.63	0.51	0.673
T_6	0.6	0.427	0.54	0.403	0.523	0.673	0.537	0.643	0.52	0.68
T_7	0.61	0.45	0.547	0.413	0.527	0.68	0.557	0.653	0.53	0.683
	4.238	3.037	3.776	2.879	3.71	4.712	3.707	4.489	3.627	4.545

Proline Content

The overall proline content was higher in rainfed condition as compared to Irrigated condition. In both irrigated and rainfed condition variety CG Lemongrass-1 performed best. also reported the maximum proline content was accumulated in plants under severe water stress condition.

Table 7: Pooled average data of Effect of Nutrient management on Proline Content under rainfed and irrigated condition in different varieties

	Rainfed					Irrigated				
	Krishna	**Pragati**	**Neema**	**Kaveri**	**Cg Lemongrass^{-1}**	**Krishna**	**Pragati**	**Neema**	**Kaveri**	**Cg Lemongrass^{-1}**
T_1	0.48	0.443	0.45	0.43	0.48	0.286	0.256	0.256	0.256	0.266
T_2	0.493	0.466	0.45	0.453	0.47	0.306	0.266	0.276	0.286	0.256
T_3	0.506	0.466	0.463	0.446	0.506	0.266	0.246	0.256	0.266	0.286
T_4	0.51	0.463	0.446	0.453	0.516	0.296	0.276	0.286	0.246	0.276
T_5	0.483	0.473	0.473	0.443	0.48	0.256	0.266	0.306	0.276	0.266
T_6	0.506	0.476	0.473	0.473	0.516	0.306	0.256	0.266	0.286	0.296
T_7	0.476	0.48	0.46	0.453	0.493	0.296	0.246	0.246	0.266	0.286

Phenolic Content

The phenol content was significantly different in both irrigated and rainfed condition in leaves. The overall phenol content was higher in irrigated conditions as compared to rainfed condition. In both irrigated and rainfed condition variety CG Lemongrass-1 performed relatively better.

Table 8: Pooled average data of Effect of Nutrient management on Phenolic Content under rainfed and irrigated condition in different varieties

	Rainfed					Irrigated				
	Krishna	**Pragati**	**Neema**	**Kaveri**	**Cg Lemongrass^{-1}**	**Krishna**	**Pragati**	**Neema**	**Kaveri**	**Cg Lemongrass^{-1}**
T_1	0.243	0.213	0.243	0.223	0.263	0.252	0.223	0.253	0.233	0.273
T_2	0.283	0.233	0.273	0.243	0.293	0.293	0.243	0.283	0.253	0.303
T_3	0.303	0.253	0.303	0.233	0.303	0.313	0.263	0.313	0.243	0.313
T_4	0.273	0.223	0.283	0.263	0.283	0.283	0.233	0.293	0.273	0.293
T_5	0.263	0.263	0.253	0.253	0.293	0.273	0.273	0.263	0.263	0.303
T_6	0.293	0.283	0.293	0.273	0.313	0.303	0.293	0.303	0.283	0.323
T_7	0.313	0.273	0.263	0.283	0.273	0.323	0.283	0.273	0.293	0.283

Nitrogen content

Overall nitrogen content of leaves was significantly higher in irrigated conditions as compared to rainfed conditions. Amongst the varieties CG Lemongrass-1 performed best and treatments T_4 was found to be superior.

Table 9: Pooled average data of Effect of Nutrient management on Nitrogen Content under rainfed and irrigated condition in different varieties

	Rainfed					Irrigated				
	Krishna	**Pragati**	**Neema**	**Kaveri**	**Cg Lemongrass^{-1}**	**Krishna**	**Pragati**	**Neema**	**Kaveri**	**Cg Lemongrass^{-1}**
T_1	0.454	0.489	0.29	0.183	0.753	0.651	0.583	0.386	0.252	0.831
T_2	0.53	0.545	0.327	0.198	0.775	0.673	0.605	0.413	0.287	0.851
T_3	0.619	0.589	0.354	0.221	0.815	0.699	0.637	0.435	0.314	0.89
T_4	0.655	0.628	0.378	0.266	0.869	0.741	0.682	0.483	0.361	0.932
T_5	0.513	0.524	0.303	0.19	0.759	0.658	0.613	0.394	0.271	0.845
T_6	0.572	0.567	0.313	0.218	0.792	0.674	0.632	0.418	0.298	0.872
T_7	0.585	0.6	0.351	0.242	0.823	0.702	0.656	0.45	0.33	0.9

Crude Protein

Amongst the varieties CG Lemongrass^{-1} performed best followed by Krishna and Pragati in both the conditions of cultivation irrespective of treatments. Amongst the treatments T_4 was found to be superior. Joshua *et al.* (2012) [5] found the similar result in context of protein content (17.5%) in lemongrass leaves (*Cymbopogon citratus*).

Table 10: Pooled average data of Effect of Nutrient management on Crude Protein under rainfed and irrigated condition in different varieties

	Rainfed					Irrigated				
	Krishna	**Pragati**	**Neema**	**Kaveri**	**Cg Lemongrass^{-1}**	**Krishna**	**Pragati**	**Neema**	**Kaveri**	**Cg Lemongrass^{-1}**
T_1	3.003	2.846	1.252	1.086	4.789	3.592	3.385	2.012	1.453	5.005
T_2	3.672	3.014	1.715	1.169	4.919	3.612	3.425	2.079	1.499	5.032
T_3	3.453	2.977	1.88	1.202	4.949	3.645	3.482	2.122	1.549	5.075
T_4	3.536	3.193	1.95	1.246	5.002	3.665	4.022	1.969	1.599	5.112
T_5	3.365	3.176	1.841	1.189	4.912	3.562	3.565	2.105	1.441	5.032
T_6	3.206	2.949	1.782	1.212	4.956	3.595	3.692	2.152	1.495	5.042
T_7	3.459	3.13	1.852	1.242	4.982	3.609	3.722	1.915	1.559	5.072

Ash Content

The overall ash content of leaves was significantly higher in irrigated condition as compared to rainfall condition. The overall ash content in rainfed as well as in irrigated condition was highest in variety Krishna and treatment T_4 was significantly effective in enhancing ash content in rainfed as well as in irrigated condition over other treatments.

Table 11: Pooled average data of Effect of Nutrient management on Ash Content under rainfed and irrigated condition in different varieties

	Rainfed					Irrigated				
	Krishna	**Pragati**	**Neema**	**Kaveri**	**Cg Lemongrass^{-1}**	**Krishna**	**Pragati**	**Neema**	**Kaveri**	**Cg Lemongrass^{-1}**
T_1	3.66	3	3	3.275	3.66	3.33	3.22	3.33	3.553	3
T_2	4.66	3.22	3.997	4.327	4.66	4.55	4.107	3.997	4	3.663
T_3	4.66	3.773	4.275	4.33	4.107	4.44	3.883	4.33	4.052	3.22
T_4	5.44	4.44	4.66	4.773	4.717	5.22	4.66	4.55	4.66	4.44
T_5	4.55	3.387	3.55	3.66	3.883	4.55	4.107	3.66	3.883	4.052
T_6	4.44	4.553	4.44	3.66	4.22	4.44	4.55	4.385	4.275	4.107
T_7	5	4.33	4.55	4.44	4.55	4.883	4.66	4.33	4.55	4.553
	32.41	26.703	28.472	28.465	29.797	31.413	29.187	28.582	28.973	27.035

Conclusion

The preset study showed that morpho-physiological parameters were significantly higher in irrigated condition under the treatment T_4 and variety Krishna perform better as compared to other varieties in both the conditions of cultivation *i.e.*, rainfed and irrigated. The biochemical analysis were significantly higher in variety CG Lemongrass-1 as compare to other varieties under both the cultivation practices. Whereas, there were no significant impact of treatments in biochemical parameters. Specific leaf weight and proline content was higher in rainfed condition of cultivation.

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