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Lemongrass (*Cymbopogon flexuosus*) productivity as affected by salinity of irrigation water, planting method and fertilizer doses on degraded calcareous soil in a semi-arid region of northwest India

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ABSTRACT

Traditional cropping being non-viable with existing saline underground waters especially on the degraded calcareous soils of arid and semi-arid regions of India, these usually remain uncultivated. Salt tolerant and low water requiring medicinal and aromatic plants can provide for viable alternative to effectively utilize these lands. Thereby, different experiments were conducted during 2005-08 with lemongrass (*Cymbopogon flexuosus* (Steud.) Wats) so as to standardize cultivation techniques including optimal irrigation and fertilizer requirements, appropriate method of planting and promising salt-tolerant cultivars on a sandy loam calcareous degraded soil using saline water (ECiw 8.6 dS/m). The average fresh foliage yield was found to be 12.0-13.0, 6.7-8.3 and 9.1-9.8 Mg/ha, respectively, when irrigated with water of low salinity (ECiw 4.0 dS/m), high salinity (ECiw 8.6 dS/m) and alternately with two waters. There was increase in yield with increase of frequency of irrigation particularly during second year. Similarly, increased nitrogen and phosphorus doses could increase the yield but significant response was only during second year. Furrow planting followed by flat method of planting were superior. Amongst the cultivars tested, RRL 16 and OD 58 showed better performance followed by Praman and Krishna. The overall results indicated the possibilities of raising lemongrass on degraded calcareous soil using saline water up to EC 8.6 dS/m without build up of soil salinity if normal rainfall occurs once in 3-4 years.

Key words: Aromatic and medicinal plants, Calcareous soil, *Cymbopogon flexuosus,* Irrigation schedule, Saline irrigation

Due to scarce and marginal quality of ground waters in many arid and semi-arid areas, these continue to be underutilized for raising arable crops. Especially where fresh water supplies are not available to support crop growth, the soils usually remain fallow. However, the recent research efforts have yielded valuable concepts and viable technologies for the sustained irrigation even with saline waters (Minhas 1996, Minhas *et al.* 1998, Bouwer 2002, Qadir *et al.* 2007, 2008). Amongst the various soil-crop-water management options, medicinal and aromatic plants offer viable alternative for utilizing these degraded lands (Patra and Singh 1995, Tomar and Minhas 2004 a, b, Dagar *et al.* 2004, 2006 a, b, 2008; Tomar *et al.* 2010). Several species of lemongrass like *Cymbopogon flexuosus* (Steud) Wats., *C. citratus* (DC.) Stapf., *C. pendulus* (Nees ex Steud) Wats. have been documented to be promising for cultivation using saline water for irrigation (Patra and Singh 1995, Weiss 1997, Joy *et al.* 2006, Dagar *et al.* 2008). Lemongrasses are tropical perennial plants which yield essential oils of commerce having strong lemon-like odour and are being cultivated for extraction of essential oils widely used for isolation of citral - starting material for the preparation of ionones which in turn used in flavours, cosmetics, perfumes, vitamin A, insect repellants and medicines. Leaves are also used as a source of cellulose in the manufacture of paper and card board. These also have medicinal properties reported to be used as a fever reducing especially where there is significant catarrh and applied as a poultice to ease pain and arthritis and leaf paste is smeared on patches of ringworm (Joy *et al.* 2006). A component of oil (Z-asarone) is used as anti-allergic compound and strengthens stomach, stimulates appetite, promotes digestion, regulates nervous system and is antiseptic, febrifuge, carminative, diuretic, anti-inflammatory, anti-diabetic and useful against rickets (CSIR 1986). The annual world production of lemongrass oil is around 1 000 tones from an area of about 16 000 ha. In India, it is cultivated in about 4 000 ha and the annual production is about 250 tonnes (Joy *et al.* 2006). Although it is established that lemon grass can be cultivated in the poor, marginal and degraded lands, its agronomic practices for maximizing benefits have not been standardized

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on these lands. Keeping this in view, experiments were undertaken on a degraded calcareous soil in a dry region where the only available source of irrigation water is saline.

MATERIALS AND METHODS

The field study was carried out at Bir Forest, Hisar (29^0 10' N and 75^0 44' E with altitude of 215.2 m above MSL), in Haryana State in northwestern region of India, during the years 2005-06 to 2007-08. The climate at the experimental site is semi-arid monsoon type with an annual rainfall of 483 mm and open pan evaporation 1 964 mm (average of 18 years from 1991-2008, Fig 1). The annual rainfall during the study period, i e 2005, 2006, 2007 and 2008 was 599, 340, 493 and 576 mm, respectively (average 502 mm) and the most this 73, 92, 75, and 95 %, in respective years, occurring during June to September. The mean normal maximum and minimum daily temperatures were 31.3°C and 16.4°C, respectively. The annual and monthly rainfall, evaporation and temperature data of study years are shown in Fig 2a, b.

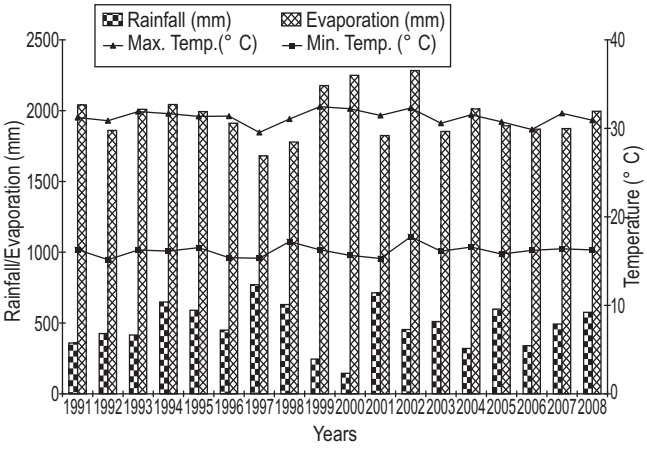

Fig 1 Climatic data of study site (Average of 18 years from 1991-2008)

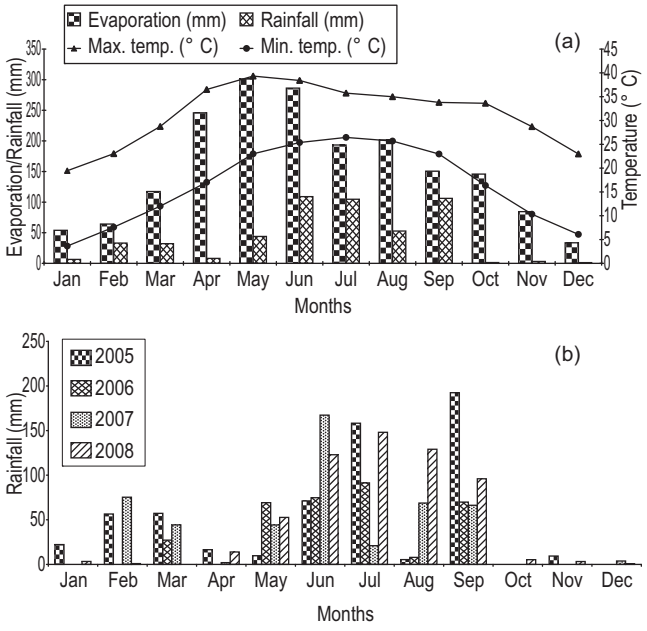

Fig 2 Climatic data during study period 2005-2008. (a) Monthly rainfall, evaporation and daily temperature (average of 4 years), (b) Monthly rainfall during 2005-2008.

Four different field experiments were conducted at Bir Forest site in Hisar, Haryana on a calcareous sandy loam soil during 2005-08 to standardize various agronomic practices of lemon grass with saline irrigation saline water. The chemical characteristics of the soil and two irrigation waters available at site in the form of tube wells are given in Table 1. The field experiments included optimizing irrigation schedules using waters of different salinity, optimizing doses of fertilizers nitrogen and phosphorus, suitable planting methods, and evaluation of promising varieties. The rooted slips (3 in number about 10-15 cm in length) were planted in plots of 4m × 4m size (at a distance of 45cm from plant to plant and 60cm from row to row; adjusting 63 plants in each plot) during August (rainy season) of 2005. The experiments were conducted in split plot design with 4 replications. The details of these experiments are as follows:

Experiment I: This experiment consisted of combinations of 12 treatments comprising 3 irrigation waters, viz. LSW – irrigation with water of low salinity (~ EC_{iw} 4.0 dS/m) , HSW – irrigation with water of high salinity (~ EC_{iw} 8.6 dS/m) and LSW /HSW – alternate irrigation with LSW and HSW and 4 irrigation schedules based upon ratio of irrigation water applied (70mm) and cumulative open pan evaporation, i.e. IW:CPE of 0.2 , 0.4, 0.6 and 0.8, respectively.

Experiment II: This experiment consisted of combinations of 16 treatments comprising 4 levels of applied N, i e 0, 25, 50, and 75 kg N/ha and 4 levels of P, i e 0, 20 ,40, and 60 kg/ha.

Experiment III: This experiment consisted of 7 different planting methods, i e flat planting, planting on west, east,

Table 1 Physico- chemical properties of the experimental soil and irrigation water

Soil depth (cm)	Clay	Silt (%)	Sand	pH_2	ECe (dS/m)	$CaCO_3$ (%)
0-15	18.7	19.3	62.0	8.3	2.3	6.2
15-30	18.4	20.6	61.0	8.3	2.3	6.5
30-60	17.5	21.5	61.0	8.3	2.4	6.7
60-90	17.2	21.9	60.9	8.3	1.9	7.6
90-120	18.3	22.1	59.6	8.3	2.0	7.5
Chemical composition of the ground waters used for irrigation						
EC iw (dS/m)	pH	Na	Ca+Mg (meq/l)	Cl	HCO_3	RSC (mmol/l)$^{1/2}$	SAR
4.0*	8.4	34.8	7.3	17.9	7.8	1.0	18.2
8.6**	8.0	69.0	23.6	46.2	4.8	0.0	20.1

* Low saline water, ** high saline water

south and north side of ridge (about 15 cm height), planting on top of the ridge and planting in furrows.

Experiment IV: In this experiment, 8 promising varieties/ cultivars of lemon grass collected from different sources of India, viz. OD 58, OD 19, CKP 25, RRL 16, Pragati, Krishna, Nima and Praman were evaluated.

Cultivar OD 15 was planted in experiment I while OD 58 was planted in experiments II and III and irrigation water was HSW, i e ECiw 8.6 dS/m. Nitrogenous fertilizer (60 kg/ ha except in Experiment II) was applied in two split doses, i.e. half dose as basal and the remaining half after the first cutting during first year while during second year one during March while the second in August after second cutting. However, the entire dose of phosphorus (50 kg/ha) was applied as basal dose. In each year, the grass was cut four times, i e in first week of April, June, August and October and fresh biomass was recorded which was later pooled in the results. Lemon grass oil was extracted after each cutting during second year by distillation method by using glass assembly. The fresh leaves were collected, chopped and put into distillation apparatus containing distilled water. The oil floated on water and separated.

The soil samples were collected randomly from different depths initially from three different places and after harvest of second year three samples from each treatment were taken. After grinding the air-dried soil samples, these were passed through a 2 mm sieve and analyzed for electrical conductivity of the saturated extract (ECe) which was obtained by subjecting the soil paste to a vacuum pump as described by Richards (1954). The mechanical analysis of initial soil samples was done using the Pipette method (Piper 1966) and the soil pH was determined using a digital pH meter in a soil: water suspension (1:2). The water samples from the two tube wells of low and high salinity waters were collected every month and analyzed in laboratory for chemical analysis as described by Richards (1954) and mean values of three years are reported (Table 1). The Na and K were determined with the help of flame photometer (Richards 1954) while the Ca+Mg were determined as per standard procedure (Jackson 1967).

RESULTS AND DISCUSSION

Irrigation with high salinity water adversely affected the growth and performance of lemon grass with higher build up in soil salinity (Table 2 and 3). The overall yield reduction equaled 38% when compared with low salinity water. Alternate irrigation with low and high salinity improved the yield but still the yield obtained equaled 79% of that obtained with low salinity water. There was gradual improvement in yield with frequency y of irrigation. Yields obtained during the two years were 15.21, 18.45, 21.00 and 23.89 Mg/ha when irrigations were schedules at IW/CPE of 0.2, 0.4, 0.6 and 0.8, respectively. The impacts were more visible during the second year. However, the interactive effects of salinity of irrigation water and their schedules remained non-significant during the two years. However, the yield reduction with high salinity water when irrigations were schedules at IW/CPE of 0.2, 0.4, 0.6 and 0.8 were 60, 40, 35 and 30%, respectively while counter values with alternate irrigation were 25, 28, 23 and 19% indicating the advantage of the latter. These observations differ from Singh and Anwar (1985) and Patra and Singh (1995) who reported that there was no adverse effect on herbal biomass when irrigated with water up to 10 dS/m. However, the similar results were obtained for oil yield where no effect of salinity was observed (0.73-0.75%). Under saline conditions, irrigation is recommended to meet both the water requirements of crops and the leaching requirements to maintain a favorable salt balance in the root zone (Shalhevet 1984, Rhoades *et al.* 1992). However, in dry areas, where sufficient supplies are not available to meet leaching requirements, the increased frequency of irrigation rather adds to salinity in soils and thereby showing little impacts (Minhas 1996). Under the present situation where the lemon grass responded to irrigation water supplies up to 0.8 times their evapo-transpirational needs, was mainly due the fact that salt leaching was occurring with monsoon rains and the major build up occurred only during post-rainy period. That is why there are little differences were observed in soil salinity monitored at the end of the experiment (Table 3).

Table 2 Effect of different salinity waters and irrigation schedules on fresh yield* (Mg/ha) of lemon grass

ECiw	Irrigation schedule (IW/CPE ratio)				
(dS/m)	0.2	0.4	0.6	0.8	Mean
		2006-07			
Low (4.0)	10.83	11.06	12.95	13.18	12.01
Low/High	8.01	8.26	9.39	10.83	9.12
High (8.6)	3.39	6.99	8.13	8.11	6.66
Mean	7.41	8.77	10.16	10.71	
LSD (P=0.05)	ECw 2.59	IW/CPE	NS	ECw × IW/CPE	NS
		2007-08			
Low (4.0)	10.88	12.80	13.10	15.38	13.04
Low/High	7.28	9.00	10.55	12.23	9.76
High (8.6)	5.23	7.25	8.88	11.95	8.32
Mean	7.80	9.68	10.84	13.18	
LSD (P=0.05)	ECw 2.14	IW/CPE	0.98	ECw × IW/CPE	NS

Table 3 Build up in soil salinity (ECe) as affected by salinity of irrigation water and their schedules

Water salinity	ECe (0.3 m soil, dS/m) with irrigation scheduled at IW/CPE ratio of			
	0.2	0.4	0.6	0.8
Low	3.8	4.1	4.3	5.1
Low/High	4.0	5.0	5.1	5.5
High	4.3	5.2	5.9	6.4

Table 4 Impact of nitrogen and phosphorus fertilizers on fresh yield (Mg/ha) of lemon grass with saline irrigation during 2006-07 and 2007-08

Applied P (kg/ha)	Applied N (kg/ha)				
	0	25	50	75	Mean
			2006-07		
0	17.30	18.86	18.61	17.30	18.02
20	17.60	20.63	20.28	19.55	19.51
40	18.84	20.28	20.93	19.67	19.93
60	20.73	19.57	21.87	23.76	21.48
Mean	18.62	19.84	20.42	20.07	
LSD (P=0.05)	Applied N NS		Applied P NS		Interaction NS
			2007-08		
0	18.80	21.33	22.35	26.13	22.15
20	24.53	27.33	29.10	31.25	28.05
40	26.15	28.90	29.28	32.53	29.22
60	26.38	28.35	30.95	33.23	29.73
Mean	23.96	26.48	27.92	30.78	
LSD (P=0.05)	Applied N 1.25		Applied P 1.79		Interaction 4.68

In the second experiment, the lemon grass did not respond either to application of nitrogen or phosphorus while the yields increased with both N and P application during the second year (Table 4). While the yields continued to improve with additional doses of nitrogen up to 75 kg/ha, the response to applies P was observed only up to 20 kg/ha. The overall improvement in yield by adding 25, 50 and 75 kg N/ha was 18, 22 and 27% over control (no N application) while response to applied P at 29, 49 and 60 kg/ha equaled 8.7, 13.5 and 17.0% over control. Significant interaction during the second year indicates toward better response to added nitrogen when phosphorus was applied simultaneously. Increasing levels of P mitigates the adverse effects of salinity especially when chlorides are the dominant anions (as is true in present case) in the saline water have earlier been reported by Chauhan *et al.* (1991). Pareek *et al.* (1981) observed in palmarosa (*Cymbopogon martini*) grass that application of N, P and K increases the herbage yield both singly or in combination and on an average palmarosa requires 75 kg N, 40 kg P and 40 kg K/ha. But from this experiment, it is evident that lemon grass requires only nominal dose of N (50-75 kg/ha) and P (20 kg/ha).

One of the alternatives proposed for getting for desired yields under saline conditions is the planting practices, which would ensure suitable environment in the rooting zone of crops. Amongst the alternative methods tried, furrow planting method was observed to be superior to the other methods (Table 5) and this was followed by flat planting. The fresh biomass (average of two years) was 9.10 and 5.74 Mg/ha under furrow and flat methods, respectively while it ranged between 4.02-4.35 Mg/ha for planting on the side of ridges and was minimum (3.13 Mg/ha) when planted on the top of ridges. Latter was due to the accumulation of salts in the top soil of ridges. Since irrigation was done in furrows and even the rainwater infiltrated through these to leach the accumulated salts and also better water regimes were maintained in furrows, these better salt and water regimes create niches for better growth of crops (Minhas and Gupta 1992).

Table 5 Impact of different methods of planting on fresh yield of lemon grass

Method of planting slips	Fresh yield* (Mg/ha)		
	First year	Second year	Mean
In furrows	7.78	10.42	9.10
On a flat bed	4.23	7.25	5.74
On the top of ridges	2.85	3.41	3.13
Eastern side of N-S ridges	3.40	4.65	4.02
Western side of N-S ridges	3.88	4.50	4.19
Northern side of E-W ridges	3.80	4.26	4.03
Southern side of E-W ridges	3.98	4.72	4.35
LSD (P=0.01)	1.02	1.24	1.13

Amongst the various cultivars screened for their performance under saline irrigated conditions (Table 6), the cultivar RRL 16 gave the best performance (25.7 Mg/ha) followed by OD 58 (23.7 Mg/ha), Praman (15.5 Mg/ha), Krishna (10.0 Mg/ha) and OD 19 (8.7 Mg/ha). The other varieties were very sensitive to salinity and their performance remained very poor (< 2.0 Mg/ha).

Table 6 Performance of some different varieties of lemon grass under saline water irrigation

Varieties	Survival (%)	Average number of tillers/plant	Fresh yield* (Mg/ha)	Oil content (%)
RRL 16	83	41	23.8	0.89
OD 58	75	38	19.2	0.76
Praman	64	39	13.5	0.72
Krishna	38	34	8.3	0.95
OD 19	54	17	7.9	0.60
Pragati	12	25	4.1	0.66
Nima	13	25	1.7	0.63
CKP 25	7	5	1.2	0.68
LSD (P=0.05)	23	17	3.2	0.67
RRL 16	76	58	27.6	0.87
OD 58	70	51	28.3	0.75
Praman	54	46	17.4	0.74
Krishna	32	38	11.7	0.97
OD 19	47	19	9.6	0.58
Pragati	08	23	1.9	0.68
Nima	08	19	0.8	0.65
CKP 25	2	7	0.5	0.67
LSD (P=0.05)	18	21	4.5	0.72

CONCLUSIONS

The experimental evidences show the potential of cultivating the aromatic lemon grass in dry regions with saline irrigation. The furrow planting method was superior and the herbage biomass improved with increased frequency of irrigation. It is low fertilizer requiring crop and a dose of 50-75 kg nitrogen and 20 kg phosphorus per ha seems sufficient. The cultivars/varieties RRL 16, OD 58 and Praman were most promising with saline water.

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