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Medicinal Chamomile (*Matricaria recutita* Linn.): A Commercial Crop for Salt-affected Conditions in Semiarid Regions of India

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Abstract

Water availability is a major constraint for crop production in arid and semiarid regions. Saline groundwater is only alternative resource for irrigation to make productive utilization of the uncultivated barren land of these regions. However, very limited options are available on selection of suitable salt-tolerant crops. Chamomile (*Matricaria recutita* Linn.), an annual winter season medicinal crop of commercial importance, may be considered for cultivation on salt-affected lands and using saline groundwater for irrigation. To assess the production potential of Chamomile under above set of conditions, four experiments were carried out in field, micro-plots and pots. Two field experiments, consisted of three modes of saline (~5 and 10.2 dS m^{-1} and their alternate use) water irrigation and four irrigation regimes (0.2, 0.4, 0.6 and 0.8 ID/CPE) of saline (~5.0 dS m^{-1}) water, were conducted at Hisar (Haryana) in north-west India. While micro-plot and pot experiments were conducted, in variable soil alkalinity and calcareous soil using different salinity water for irrigation, respectively; at Central Soil Salinity Research Institute, Karnal. It was observed that 3.0 to 3.6 Mg ha^{-1} fresh and 0.6 to 0.8 dry flowers, which yield essential oil of commercial importance, were harvested when irrigated with low (EC_{iw} 5.0 dS m^{-1}) and high (EC_{iw} 10.2 dS m^{-1}) salinity water. Decreasing IW/CPE (0.8, 0.6, 0.4 and 0.2) irrigation regimes of EC_{iw} 5 dS m^{-1} water decreased fresh flower yield from 3.8 to 1.6 Mg ha^{-1}. The crop fresh flower yield increased from 4.8 to 6.1 Mg ha^{-1} with increasing alkalinity (pH) of the soil from 8.4 to 9.8. Irrigation water salinity tolerance limit was established at ~10-12 dSm^{-1}. Growth performance and nutrient compartmentation in different plant parts were also observed.

Key words: Chamomile, *Matricaria recutita*, Commercial crop, Growth performance, Saline irrigation, Sodic soil, Salinity tolerance limit

Introduction

In arid and semiarid regions scarcity of good quality water for irrigation is always constraint for agricultural production. Therefore, use of water from available saline underground aquifers employing appropriate technologies has been found a viable option, particularly in dry regions (Tomar and Minhas, 2002; Tomar *et al.,* 2010; Dagar *et al.,* 2013; Makrana *et al.,* 2017; Askari-Khorasgani *et al.,* 2018). Nevertheless, of late research developments have yielded in useful concepts and viable technologies for sustaining the production of variety of low water requiring crops with use of saline groundwater for irrigations (Minhas, 1996; Yadav *et al.,* 2003; Qadir *et al.,* 2007, 2008; Baghalian *et al.,* 2008, 2011; Dagar *et al.,* 2013, 2014, 2015, 2016; Yadav and Dagar, 2016). Amongst the various soil-crop-water management options, non-conventional crops such as medicinal/aromatic crops (Dagar *et al.,* 2004, 2005, 2006, 2011, 2012; Tomar *et al.,* 2010), forages (Tomar *et al.*, 2003; Yadav *et al.,* 2004, 2007; Makrana *et al.,* 2017), seed spices (Yadav *et al.,* 2014) and non-edible oil yielding crops (Dagar *et al.*, 2019) are suggested as viable alternatives for productive utilization of these degraded lands using saline irrigation. In general, non-conventional crops are more tolerant to stress and salinity as compared to arable crops. Since Chamomile also known as German Chamomile [*Matricaria recutita* Linn. syn *M. chamomilla* Linn., *Chamomilla recutita* (L.) Rauschert belonging to family Asteraceae], a winter season annual with medicinal value, has adaptability to wide range of climate and soil (Svab, 1992; Ram and Misra, 2004), so it can be considered as an economic substitute for field crops on dry lands under saline water irrigation conditions. The plant is native to southern and eastern Europe and can be found in North Africa, Asia, North and South America, Australia, and New Zealand (Evens, 1979) and also grown in Argentina, Egypt, Germany, Hungary, France, Russia, Yugoslavia, and Brazil. Hungary is the main producer of the plant biomass and the plant grows abundantly in poor soils and is a source of income to poor inhabitants of these areas. Flowers are exported to Germany in bulk for distillation of the oil (Svab, 1979) and in Germany alone about 4000 Mg flowers are consumed annually.

In India, the plant was introduced in Punjab about 300 years ago during the Mughal period, whereas its cultivation started on alkali soils in Lucknow and Jammu about 200 years ago (Chandra *et al.,* 1968; Handa *et al.*, 1957). It is cultivated on limited scale in Jammu and Kashmir, Lucknow, Punjab, Solan and Assam. The research initiative for its cultivation was taken under Coordinated Project on Medicinal and Aromatic Plants in Solan and also introduced in southern India (Nidagundi and Hegde, 2007). There is no demand for blue oil as such at present in India; however, the flowers are in great demand. Presently, 2 firms, namely, M/s Ranbaxy Labs Limited, New Delhi and M/s German Remedies are the main growers of chamomile for its flowers.

Chamomile has been used in herbal remedies for thousands of years, known in ancient Egypt, Greece, and Rome (Issac, 1989). It is an ingredient of several traditional, Unani, and homeopathy medicinal preparations. As a drug, it finds use in flatulence, colic, hysteria, and intermittent fever and mainly used as an anti-inflammatory, antiseptic, antispasmodic and mildly sudorific (Mericli, 1990). Chamomile flower is an official drug in the pharmacopoeia of 26 countries (Pamukov and Achtardziar, 1986) including United States Pharmacopoeia (USP, 2004) and British Pharmacopoeia (2002). Essential oil content of its flowers varies from 0.3 to 1.5 percent; and in the improved varieties of chamomile, it can reach up to 3 per cent (Repèαk and Krausovα, 2009). Singh *et al.* (2011) have reviewed the pharmaceutical uses and active principals of chamomile drug in detail.

Chamomile has a reputation of adaptation to different edaphoclimatic conditions and tolerant to sodicity (Singh, 1970; Patra and Singh, 1996; Balak and Misra, 2004; Noori *et al.*, 2016) and salinity (Baghalian *et al.*, 2008; Noori *et al.*, 2016) and also to stress (Razmjoo *et al.,* 2008). Recently, many workers have investigated on various parameters of Chamomile irrigating with saline water of different salinity in isolation and in combination with canal water (Tomar and Minhas, 2002; Baghalian *et al.*, 2008, 2011; Askari-Khorasgani *et al.,* 2018) and found it to be a suitable commercial crop for dry ecologies in different regions of the world. Therefore, present investigation was undertaken to evaluate the potentials of Chamomile for its suitability as a commercial crop for calcareous degraded and sodic soils and irrigating with saline water in dry regions of northwest India.

Materials and Methods

Following field and controlled condition micro-lysimeters and pot-house studies were carried out to assess the potential of medicinal Chamomile under salt-affected conditions.

Field experiments

Site and climate description

The field studies were carried out at Bir Forest, Hisar (29°10′N and 75°44′E with altitude of 215.2 m above MSL) in Haryana state of India. The climate at the experimental site is semi-arid monsoonal with an annual rainfall of 499 ±165 mm and open pan evaporation 1930±177 mm (log-term average of 21 years from 1995–2015). The average annual rainfall during the study period of 3 years was ~500±201 mm and the most of this (79±11.4%) occurred during June to September. While about 40±5.6 mm rainfall occurred during crop growth period. The mean maximum and minimum daily temperatures were 31.3±0.8 °C and 16.4±0.8 °C, respectively.

Soil and water characteristics

The experimental site soil is sandy loam typical Ustipsamments and highly calcareous with 7.3 to 10.5% $CaCO_3$ in profile. The characteristics of the same are shown in Table 1.

Table 1. Initial physico-chemical properties of the experimental soil in upper 30 cm soil depth

Soil characteristics	Values
Sand (%)	62.0
Silt (%)	18.8
Clay (%)	19.2
Texture	Sandy loam
pHs	8.3
ECe (dS m^{-1})	2.5
Soluble Na (mg kg^{-1})	39
Available K (mg kg^{-1})	125
Available P (mg kg^{-1})	122
$CaCO_3$ (%)	8.5

Two tube wells, with different salinity groundwater, existed at the experimental site. The chemical characteristics of both qualities of water are shown in Table 2.

Experimental details

Experiment 1. Performance of Chamomile under saline water irrigation

One experiment, consisting of three modes of irrigation treatments of variable salinity levels (LSW ~5.0 and HSW ~10.2 dS m^{-1} and their alternate use), was laid out in 4 m × 4 m plot size in randomized complete block design with three replications. Two-weeks old seedlings, raised in nursery, were planted at plant to plant and row to row distance of 20 and 30 cm, respectively in second week of November. Farm Yard Manure was applied (10 Mg ha^{-1}) with field preparation before start of experiment. Nitrogen and phosphorus were applied at the rate of 40 and 20 kg ha^{-1}, respectively. Half of the nitrogen and entire phosphorus were applied as basal dose while the rest half nitrogen applied after first picking of the flowers. In total 6 irrigations (each ~7cm depth) were applied.

The flowers were harvested four times till February end. In the end above ground biomass was harvested and weighed for fresh weight. Representative samples (separating into branches and leaves) were oven dried, at 70°C for 48 hours, for recording dry biomass. Root piths of 20 cm diameter were dug up to 30 cm depth, washed with water and dried in air and oven for dry biomass. Soil samples were collected from each replicate after the harvest of the crop. The soil was air dried and passed through a 2 mm mess sieve, stored in polythene bags and analysed in laboratory for different parameters.

Experiment 2: Performance of Chamomile under different schedules of saline water irrigation in calcareous soils

Second experiment was conducted to evaluate the performance of Chamomile at 0.2, 0.4, 0.6 and 0.8 Diw/CPE (ratio of depth of irrigation water and cumulative open pan evaporation) irrigation schedules of saline water (5 dS m^{-1}) at the same site. Rest materials, methods and procedures were the same as adopted in experiment 1.

Pot-house experiments

In control conditions, one experiment was conducted in micro-lysimeterss at Central Soil Salinity Research Institute, Karnal (latitude 29°43′ N, 76°58′ E, altitude 245 msl) in Haryana (India). The climate of the site is subtropical, semiarid, megathermic and monsoonal with the mean annual rainfall (measured at the institute meteorology observatory) of 782±31.6 mm; the maximum of which (78%) occurred during July to September. The actual rainfall during study period was about 60 cm. The mean maximum and minimum daily temperatures were 31.3 °C and 17.8 °C, respectively. The study was conducted in well-settled 12 micro-plots (each 6 m × 3 m × 0.9 m) filled with sodic soil brought directly from fields having soil in the range of ~four pH levels (Table 3). Four levels of soil alkalinity were arranged in RBD with 3 replications. Farm-yard manure and fertiliser doses were as in earlier experiments

Table 2. Chemical composition of the groundwater of two tube wells used for irrigation

Tube well	EC_{iw} (dS m^{-1})	Na (me l^{-1})	Ca + Mg (me l^{-1})	Cl (me l^{-1})	CO_3+HCO_3 (me l^{-1})	RSC (me l^{-1})	SAR (m mol l^{-1})
1.	~5.0±0.3	35±2.4	7±1.3	18±1.6	8.3±0.6	1.3±0.02	18.3±1.7
2.	~10.2±0.4	69±3.8	24±0.8	46±2.5	4.8±0.2	—	21.2±2.1

Table 3. Physico-chemical characteristics of soil (0-15 cm) in micro-plots (n=3)

Group	Sand (%)	Silt (%)	Clay (%)	pH_s		ESP		ECe (dS m^{-1})	
				Range	Mean	Range	Mean	Range	Mean
A	48.4	30.6	21.0	8.2-8.5	8.4	20-28	26	1.9-2.3	2.1
B	47.6	31.9	20.5	9.0-9.2	9.1	30-37	35	2.5-2.9	2.7
C	47.1	31.4	21.4	9.3-9.5	9.4	39-44	41	2.8-3.2	3.0
D	46.4	30.6	22.9	9.7-9.9	9.8	58-62	60	3.4-3.9	3.6

except that additional 10 kg ha^{-1} zinc was applied in the form of $ZnSO_4$.

Another pot experiment was conducted to assess the potential of Chamomile production under saline water irrigation conditions. The experiment comprised of five levels of irrigation water salinity [0.6 (control), 4, 8, 12 and 16 dS m^{-1} each with SAR ~10] arranged in CRD with four replications. The pots of 40 cm diameter and 40 cm height were filled with a mixture of normal calcareous soil (brought from Hisar field): sand and FYM (in 2: 1: 1 ratio). Fifteen days old two seedlings were planted in each pot and after establishment i.e. 15 days after transplanting only one seedling was retained in each pot. The saline (ECiw 4, 8, 12, 16 and 20 dS m^{-1} and SAR ~10) irrigation water was prepared in tap water using salts of NaCl, $MgSO_4$ and $CaCl_2$. The flowers were plucked as and when available and air-dried. The plants were carefully excavated with roots intact, using jet of water in the end of February after three and half month's growth, separated in to different parts, air dried, oven dried and used for different growth parameters.

Soil and plant analysis

After grinding the air-dried soil samples (brought from field, taken from micro-plots and pots), these were passed through 2 mm sieve and analysed for different soil parameters. The physical parameters were determined as described by Piper (1967). The soil saturated extract was obtained by subjecting the soil saturation paste on the vacuum pump. The pHs was measured in soil saturation paste with digital pH meter and electrical conductivity (ECe) in the extract with electrical conductivity meter. The ESP was calculated after measuring the cation exchange capacity (CEC) following method as described by Richards (1954). Sodium adsorption ratio (SAR) in water was determined by using the values of Na, Ca and Mg. In plant samples, the Na^+ and K^+ were determined with the help of Flame Photometer (Richards, 1954), while Ca^{2+} and Mg^{2+} were determined by AAS method as per standard procedures (Jackson, 1973) and automatic titration method was used for chloride determination (Adriano and Doner, 1982). Essential oil was extracted by hydro distillation of chopped flowers kept in distillation apparatus with distilled water and using glass assembly.

Statistical analysis

All the growth and yield and nutrients contents parameters recorded in different experiments were subjected to statistical analysis by employing an appropriate method of analysis of variance (ANOVA) for respective statistical designs using SAS 9.2 software (SAS Institute, 2001) and pair wise comparison of the means of treatments effect was made using Turkey's test at $p \leq 0.05$.

Results and Discussion

Field experiments

Performance of Chamomile under different modes of variable salinity water irrigation

The shoot and root biomass production reduced by 11.8 and 6% under continuous irrigation with HSW and alternate irrigations using LSW/HSW, respectively in comparison to regular irrigation with LSW. These differences were at par with one another among all modes of saline irrigation. Although adverse effect on fresh flower yield reduced by 20 and 7% under HSW and alternate irrigations of LSW/HSW but dry flower yield decreased only insignificantly i.e. 7 and 2%, respectively as compared to that obtained with consistent irrigation using LSW.

Table 4. Growth parameters of Chamomile under different modes of saline water irrigation using water of low, high and alternate irrigations of low and high salinity water

Irrigation water	Plant height (cm) ± sd	Root weight (kg ha^{-1}) ± sd	Shoot dry weight (kg ha^{-1}) ± sd	Flower weight (kg ha^{-1}) ± sd		Essential oil (%)
				Fresh	Dry	
LSW(5.0 dS m^{-1})	46.4±4.2	840±125	1660±235	3654±251	845±62	0.58±0.06
AlternateLSW/HSW	42.4±3.6	806±62	1564±150	3256±189	831±75	0.62±0.04
HSW(10.2 dS m^{-1})	38.6±4.0	785±85	1485±105	3046±210	789±57	0.54±0.07
LSD (p≤0.05)	NS	NS	125	148	85	NS

sd=standard deviation from mean NS=not significant

Tomar and Minhas (2002) earlier reported 3.5 Mg ha^{-1} flower yield when irrigated with water of 4-5 dS m^{-1} as compared to 4.2 Mg ha^{-1} with fresh water irrigation. They did not observe any significant yield reduction with alternate irrigations of fresh and saline water. Our observations are also consistent with results reported by Prasad *et al*. (1997). Baghalian *et al.* (2008) also reported non-significant effect of salinity level of irrigation water even up to 16 dS m^{-1} on dry flower weight, while fresh flower yield decreased with increasing salinity and it was higher in control (fresh water) compared to others. The results clearly advocate that there is no significant effect of irrigation with high salinity (up to 16 dS m^{-1}) water on dry flower yield which are used commercially. Reaffirmation of the earlier reports in our study confirms the economic viability of this crop on highly degraded calcareous soil of dry ecologies practicing irrigation with available saline water up to ECiw 10-12 dS m^{-1} or even higher.

Mineral contents

Mineral nutrition of plants is mainly affected by salinity of growing medium and lead to ionic imbalance and nutrition problems (Baghalian *et al.*, 2008). Actually, salinity alters the ion transport and contents of elements such as Na^+, K^+, Ca^{2+}, Mg^{2+} and Cl^- as some of these show antagonistic effect on uptake of the other (Cramer and Schmidt, 1995). In this study, all the mineral contents, except K^+, were affected significantly and in flowers showing the maximum accumulation when irrigated with water of high salinity. This was followed by accumulation in stem. Surprisingly, the least accumulation was in leaves, whereas K^+ was the maximum in roots. Chloride content was the maximum in flowers but in other parts it varied among different treatments but remained quite high in roots (Fig. 1).

It is worth noting that concentration of both Na^+ and Cl^- was higher in stem than roots. This was also observed by Baghalian *et al*. (2008) in the same plant. Dagar *et al.* (2005) observed the highest K^+ content in all the parts of periwinkle (*Catharanthus roseus*) followed by sodium. The Na^+ accumulation was the maximum in root followed by shoot while the K^+ was equally high in leaves and pods. The Ca^{2+} and Mg^{2+} were highest in leaves and shoots. The studies conducted by Gururaja Rao *et al*. (1999) in halophyte *Salvadora persica* indicated that after absorption of ions (particularly Na^+) by roots these reached to stem and finally accumulated in leaves facilitating the dilution of salt within tissues. Probably it is the reason that, after absorbing minerals, roots transports these quickly to different parts to dilute the contents in the tissue and finally lock into flowers which contribute good biomass. The difference in plant response to a given level of salinity is dependent upon the genotype as well as the concentration and composition of the ions in solution (Greenway and Munus, 1980). Tomar *et al.* (2010) in psyllium (*Plantago ovata*), Dagar *et al.* (2013) and Lal *et al.* (2013) in lemon grass, Yadav *et al.* (2006) in different forages and Askari-Khorasgani *et al.* (2017) in *Matricaria recutata* found different behaviour to salinity tolerance and economic yield as well as accumulation of mineral contents in different plant parts.

Essential oils

Saline water irrigation had no significant effect on oil content. Baghalian *et al*. (2008) have also

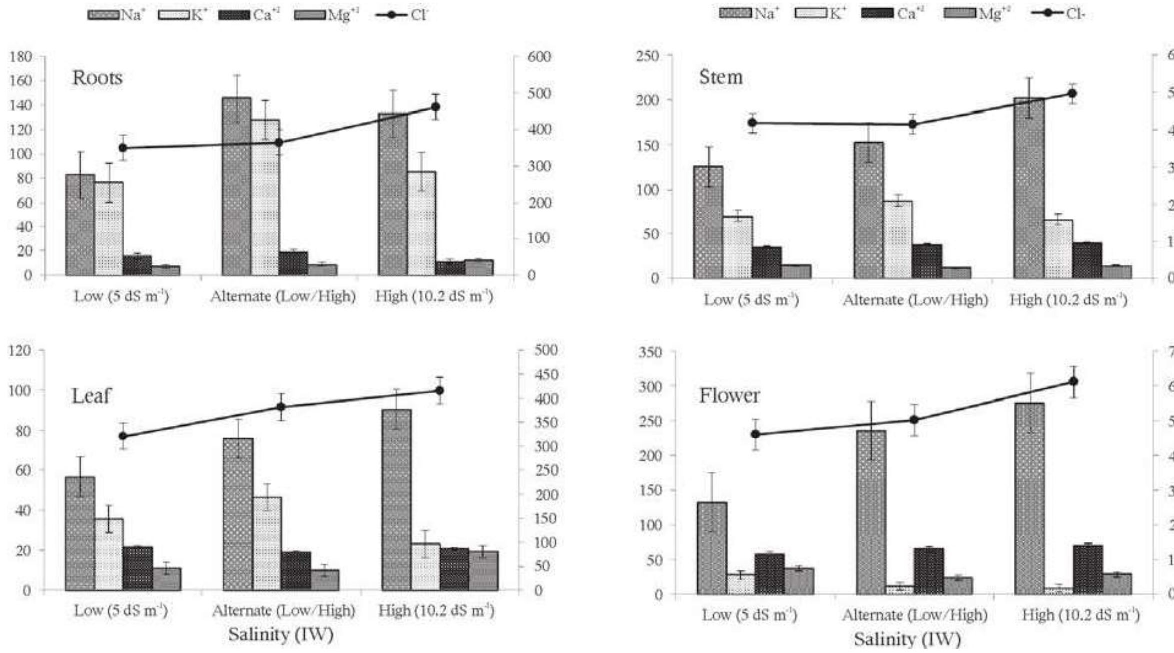

Fig. 1 Nutrient contents (mg g^{-1}) accumulated in different parts of the plant when irrigated with water of low, high and alternately with low and high salinity waters. Chloride contents are shown on right axis

Table 5. Soil salinity development and mineral composition in soil under irrigation using water of different salinity

Salinity and mineral components	Irrigation water	Initial	After experiment
ECe (dS m^{-1})	Low salinity	2.4	3.5
	Alternate (Low/High salinity)	2.6	3.9
	High salinity	2.0	4.2
Soluble Na (mg kg^{-1})	Low salinity	40.0	43.8
	Alternate (Low/High salinity)	43.0	48.0
	High salinity	34.5	53.4
Available K (mg kg^{-1})	Low salinity	130	135
	Alternate (Low/High salinity)	140	148
	High salinity	126	139
Available P (mg kg^{-1})	Low salinity	20	32
	Alternate (Low/High salinity)	31	46
	High salinity	18	21

observed that even medically important constituents, such as α-bisabololoxide B, α-bisabolon-oxide A, chamazulene, α -bisabolol oxide A, α-bisabolol and trans-β-farnesene; were also not affected by level of salinity in irrigation water. However, these results are not consistent with the observations of Ram *et al.* (1999) and Prasad *et al*. (2006) who reported that increasing sodium ions significantly affects oil content and composition. Dagar *et al.* (2013) also investigated in lemon grass (*Cymbopogon flexuosus)* that increase in salinity in irrigation water does not affect oil content and quality so is the case in *Matricaria recutata*.

Soil salinity development

There was gradual increase in soil salinity, mineral contents and electrical conductivity of soil. It is quite natural that more salinity will be developed when irrigated with water of higher salinity (Table 5). As Chamomile is winter crop, hence most of this salinity will be leached in lower soil depths during following rainy season as reported earlier by Dagar *et al.* (2013) and the same will be further lowered down with more frequency of irrigation water despite of irrigation with water of high salinity. In long-term experiments at the same site (Dagar *et al*., 2008, 2016), it was concluded that one normal rainfall year in 3 to 4 years will take care of leaching of the salts, developed in soil profile due to saline water irrigation available at site, in deeper layers.

Performance of Chamomile under different schedules of saline water irrigation in calcareous soils

There was gradual improvement in yield with increasing frequency of saline water irrigation. All parameters i.e. the plant height, shoot and root biomass and fresh and dry flower biomass increased with increasing frequency schedules i.e. IW/CPE 0.2, 0.4, 0.6 and 0.8 of irrigation (Table 6). Under saline conditions, irrigation is recommended to meet both the water requirements of the crops and as well as the leaching requirements to maintain a favourable salt balance in the root zone (Shalhevet, 1984; Rhoades *et al*., 1992). However, in dry areas, where sufficient supplies of good quality water or rainfall are not available to meet leaching requirements, the increased frequency of irrigation rather adds to salinity in soils and thereby, show little impacts (Minhas, 1996; Tomar *et al.,* 2010). The lemon grass responded to irrigation water supplies up to 0.8 times of its evapo-transpirational needs, because of the fact that salt leaching was occurring with monsoon rains and the major build up occurred only during post-rainy period (Dagar *et al.,* 2013). That is why only little differences were observed in soil salinity monitored at the end of the experiment (data not given). In present case the salinity development and mineral accumulation affecting the salinity was nominal because of two reasons, one the salinity of the irrigation water was low and second the adaptability of the crop is more as compared to other tested crops (evident from Table 5, hence data not included). This nominal development in salinity is taken care by the proceeding monsoonal rains after this crop as was the case in other cropping systems at the site (Dagar *et al*., 2013, 2016).

Pot-house Experiments

Growth performance of Chamomile on alkali/sodic soil of different pH

Chamomile plant height, shoot biomass and flower yield increased gradually with increasing soil pH from 8.4 to 9.1 and further to 9.4. But further increase in soil pH to 9.8 caused reduction in these plant growth parameters as compared to pH 9.4. Although the flower yield at the highest pH of 9.8 was lower than pH 9.4 but it was more than pH 9.1 and 8.4. It showed the preference of the plant to sodicity adaptation (Table 7). Similar trend was also observed in cultivation of other salt-tolerant winter cut-flowers like *Chrysanthemum indicum* and *Calendula officinalis* (Dagar *et al*., 2009). However, in many other medicinal plants, it was also found that the yield though decreased gradually but not significantly with increase in pH up to 9.2 which suggests their suitability of cultivation on alkali soils up to this pH (Dagar *et al*., 2004, 2005, 2006).

Table 6. Growth performance of Chamomile under different irrigation schedules using saline water of ECiw 5 dS m^{-1}.

Irrigation schedule (Diw/CPE)	Plant height (cm) ± sd	Dry shoot biomass (kg ha^{-1}) ± sd	Root biomass (kg ha^{-1}) ± sd	Flower yield (kg ha^{-1}) ± sd	
				Fresh	Dry
0.2	35.2±4.0	814±202	402±105	1614±410	362±125
0.4	40.7±5.8	1239±95	635±85	2835±211	605±105
0.6	53.5±8.4	1509±105	772±34	3642±275	790±85
0.8	56.0±9.4	1784±125	828±45	4064±175	1025±115
LSD ($p \leq 0.05$)	4.8	215	134	545	124

sd=standard deviation from mean

Table 7. Growth parameters of Chamomile on different pH soil

Soil group (Average pHs)	Plant height (cm) ± sd	Shoot biomass (kg ha^{-1}) ± sd	Flower biomass (kg ha^{-1}) ± sd	
			Fresh	Dry
A (8.4)	49.5±5.6	508±27	4790±215	998±84
B (9.1)	53.7±8.1	925±125	4876±148	1083±65
C (9.4)	62.7±4.9	1293±38	6175±146	1372±86
D (9.8)	58.1±6.4	1217±45	5345±178	1126±48
LSD (p ≤ 0.05)	54.6	28	137	69

sd=standard deviation from mean

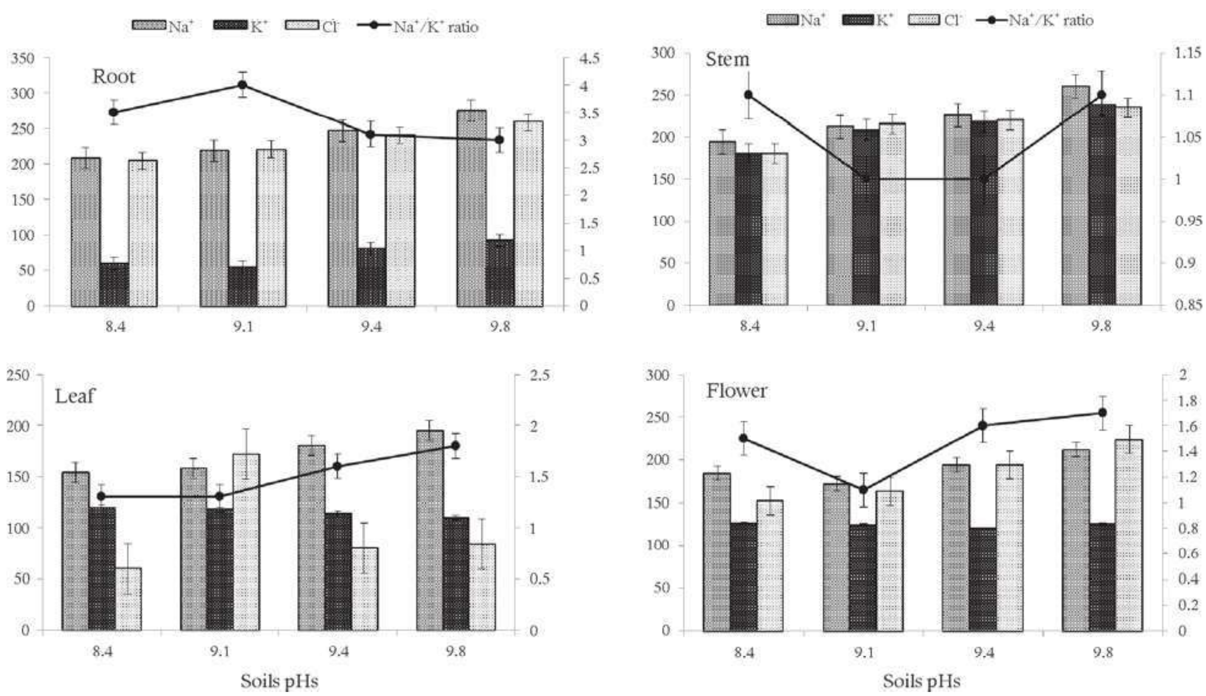

Fig. 2 Sodium, potassium and chloride contents (mg g^{-1}) accumulated in different parts of the plant when grown in soil of different pH and Na+/K+ ratio (shown on right hand axis)

Sodium, potassium and chloride contents in plant parts

The contents of sodium, potassium and chloride in different plant parts indicated that the maximum sodium and chloride contents were recorded in roots followed by stem, flowers and leaf, while potassium content was the maximum in stem followed by flowers, leaf and roots (Fig. 2). Na^+/K^+ ratio was also the maximum in roots but in other parts it is almost same. In many other plants also sodium and chloride showed same pattern of absorption and accumulation but potassium did not show any set pattern (Dagar *et al.*, 2009). Gururaja Rao *et al.* (1999) found sink of salt accumulation in bark and leaves in halophyte *Salvadora persica*.

Production when irrigated with water of different salinity

Chamomile plant height, shoot biomass, number of flowers per plant and flower weight decreased as the salinity of irrigation water increased except no reduction in flower yield at 4 dS m^{-1} (Table 8). There was about 16, 34 and 55% reduction in dry flower yield at EC 8, 12 and 16 dS m^{-1}, respectively. Askari-Khorasgani *et al*. (2012) compared 3 cultivars of Chamomile and noted decrease in yield and increase in soil salinity, sodium and available phosphorus when irrigated with water of increasing EC from 6, 9 and 12 dS m^{-1}. In present study also there was consistent increase in salinity and mineral contents in soil when irrigated with water of higher salinity (Fig. 3). As

Table 8. Performance of Chamomile in pots when irrigated with water of different salinity

Salinity of irrigation water (dS m^{-1})	Plant height (cm)± sd	Dry shoot weight (g pot^{-1}) ± sd	Number of flowers per plant± sd	Dry flower yield (g pot^{-1}) ± sd
Tap water (0.6)	45.5±2.5	29.0±3.5	224±14	12.5±2.6
4	46.0±2.7	27.8±4.0	218±21	13.0±1.4
8	39.8±3.4	22.4±3.0	161±9	10.5±2.2
12	34.5±3.0	18.6±2.8	137±11	8.2±1.8
16	28.6±3.2	14.2±2.5	126±17	5.6±2.0

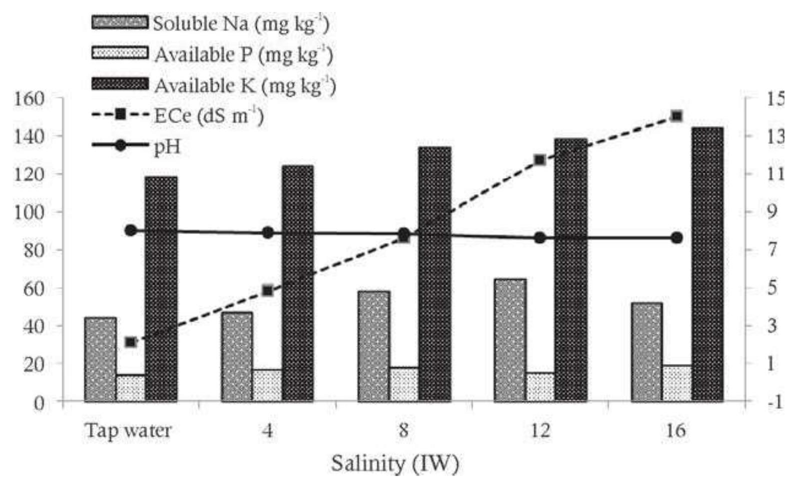

Fig. 3 Soil salinity and pH (right hand axis) and soil mineral contents (on left axis) when irrigated with water of different salinity and measured after experiment

the experiment was in controlled conditions hence there was no scope of leaching of the salts.

Conclusions

In arid and semiarid regions underlain with saline aquifers and scarcity of good-quality water for irrigation, Chamomile (*Matricaria recutita*), a winter annual, proved as an ideal crop yielding flowers of commercial value. It can be cultivated successfully by irrigating with saline water up to 12 dS m^{-1} and also in sodic soils having pH up to 9.8. The most interesting feature was that its performance in high pH soils has been found better than normal soils. This can be an alternative high value winter crop for sodic soils.

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