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Alternatives to rice-wheat cropping system under partially reclaimed sodic soils

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ABSTRACT

A field experiment was conducted during 2013–14 to 2015–16 at Central Soil Salinity Research Institute, Regional Research Station, Lucknow to find out the alternate to rice (*Oryza sativa* L.)- wheat (*Triticum aestivum* L.) cropping system under partially reclaimed sodic soils. Four cropping systems, viz. rice (*Oryza sativa* L.)- wheat (*Triticum aestivum* L.), sorghum (*Sorghum bicolor*)–berseem (*Trifolium alexandrinum*), sweet basil (tulsi) (*Ocimum basilicum L.)*–matricaria (*Matricaria chamomilla*) and chilli (*Capsicum* spp.)-garlic (*Allium sativum*) were evaluated in the light of sustainability, potentiality and profitability. Maximum rice equivalent yield (14.21 t/ha) and production efficiency (61.25 kg/ha/day) were recorded with sweet basil-matricaria cropping system whereas, highest land use efficiency (78.35%) was observed under sorghum–berseem fodder based cropping system. Highest water use efficiency (150.72 kg/ha cm) was recorded with chilli-garlic cropping system followed by sweet basil-matricaria, but the total amount of water used was more (125.65 cm) in rice-wheat system. The water requirements of sorghum-berseem, sweet basil-matricaria and chilli –garlic cropping systems were 8.0, 19.8 and 31.8% less than the rice-wheat cropping system. Among the cropping systems evaluated, maximum energy input (27.50 MJ/ ha) and output (314.46 MJ/ha) were analyzed in rice-wheat system. Whereas, maximum energy use efficiency (11.99) was found with sweet basil- matricaria followed by sorghum-berseem (11.91) cropping systems. Highest soil ameliorative potential was established with sweet basil -matricaria cropping system than rest of the cropping systems. Highest net return (₹ 63222/ha) and benefit: cost ratio of 2.74 was deliberated with medicinal and aromatic crop based sweet basil-matricaria cropping system.

Keywords: Cropping systems, Diversification, Equivalent yield, Energy use efficiency, Partially reclaimed sodic soils, Water use efficiency

About 6.73 million ha land which is about 2.1% of the geographical area of the country is suffering from salinity and sodicity problems in India of which about 1.37 million ha is in Uttar Pradesh (Mandal *et al.* 2009). During last three decades about 2.07 million ha sodic land has been reclaimed through various government as well as non government organizations in India (Thimappa *et al.* 2017). Rice-wheat is the predominant cropping system in the reclaimed sodic soils occupying about 60–70% area. Wide adoption of this system is due to high productivity and less element of risk. Though, it is very remunerative cropping system but sustainability of this system has been questioned with yield stagnation (Bhatt 2015), created many serious ecological problems such as atmospheric pollution (Singh *et al.* 2008), unattended intervening periods (Bhatt and Kukal 2015), declining underground water table (Humphreys *et al.* 2010, Bhatt *et al.* 2016). Moreover, the irrigation water is a costly and scares resource. The availability of water for agriculture is going down because of increasing demand for domestic and industrial uses. Due to continuous cultivation of rice-wheat cropping system in partially reclaimed sodic soils, the sustainability of the system is becoming questionable due to adverse effect on soil conditions, crop yield and factor productivity, increasing cost of production and more weed infestation in wheat crop (Singh *et al.* 2012). High crop response to N in sodic soil under rice-wheat cropping system further reduces the nitrogen pool of the soil (Swarup and Singh 1989, Singh *et al*. 2008). Rice-wheat cropping system (especially rice) has high water requirement and in area having shallow water table, intensification and expansion of salinity hazards have occurred. This is because irrigation water brings in additional salts and releases immobilized salt in the soil through mineral dissolution, weathering and losing water through evaporation and concentration of the dissolved salts in upper layer of soil (Abrol *et al.* 1990). Therefore, a field experiment was conducted to explore the possibility of highly remunerative alternate cropping system

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to traditional rice-wheat system for partially reclaimed sodic soils of UP.

MATERIALS AND METHODS

The four times replicated field experiment was conducted at Central Soil Salinity Research Institute, Lucknow during 2013–14 to 2015–16 situated at an elevation of 120 m AMSL. It extends from 26^0 47' to 26^0 48' latitude and 80^0 46' longitude. The climate is semi-arid, subtropical and monsoonic receiving an average annual rainfall of 817 mm. The mean maximum and mean minimum temperatures were recorded as 39 and 7.1^0C in the month of May and January correspondingly, that indicate a seasonal climate. The mean annual temperature during the study period varied and was recorded as 24.6^0C. Total rainfall received during the year 2013–14, 2014–15 and 2015–16 (January–December) was 905.8 mm, 790.3 mm and 816.6 mm, respectively. The soil of the experimental farm is classified as typic Natrustalfs. The experiment was conducted on a partially reclaimed sodic soil having pH_2 9.2, EC_2 1.43 dS/m and organic carbon 0.10%. The experiment consisted of four cropping systems viz. rice–wheat (cereal based), sorghum-berseem (fodder based), sweet basil (tulsi) – matricaria (*German chamomile*) (Medicinal and aromatic crop based) and chilli-garlic (spices based). The crops were raised with recommended package of practices. N, P and K was applied through urea, single super phosphate, and muriate of potash, respectively. Full dose of P and K and half dose of N were applied as basal and rest of the N was given as per the recommendation for the individual crop. Pre-sowing irrigation was applied after the harvest of rainy season crops to ensure good germination of winter crops. During *kharif*, CSR 43, SSG-59-3, Sim Somya and LCA-235 varieties of rice, sorghum, sweet basil and chilli and in *rabi* KRL 210, JB-2, Vallary and local variety of wheat, berseem, matricaria and garlic, respectively were grown. The sorghum and berseem fodder yields were calculated on the basis of two and four cuttings of the respective crops. The number of irrigations and depth of water applied to the crop were measured following standard methods. To study the changes in soil fertility after each cropping system, composite soil samples (0-15 cm) were collected and analyzed for pH_2 (1:2 soil: water ratio), EC_2 and organic carbon through standard methods. Land use efficiency values were calculated by taking total duration of crops (in individual cropping system) divided by 365 and production efficiency values were calculated taking total production in a system divided by total duration of crops in a system (Tomar and Tiwari 1990). Water use efficiency was worked out in terms of yield (kg/ha cm) of water used that included the irrigation water applied and effective rainfall. Energy input and output was calculated using the energy equivalents (Mittal *et al.* 1985). Prevailing market price of rice, wheat, sorghum, berseem, chilli and garlic were taken for economic analysis of different systems. However, for sweet basil and matricaria, prevailing market price of sweet basil oil and matricaria flowers were taken into consideration.

RESULTS AND DISCUSSION

Crop yields: *R*ice-wheat traditional cropping system gave 7.37 t/ha grain yields. Sweet basil- matricaria cropping system yielded 0.074 t/ha oil and 0.80 t/ha of flower, respectively. Sorghum–berseem fodder cropping system recorded the highest fodder yields of 29.62 t/ha and 36.85 t/ha, respectively (Table 1). Maximum rice equivalent yield (14.21 t/ha) was recorded with sweet basil-matricaria cropping system followed by chilli–garlic (12.91 t/ha) and sorghum-berseem (9.28 t/ha) and the lowest (7.74 t/ha) with rice-wheat system. The higher rice equivalent yield in sweet basil -matricaria cropping system was because of high market price of sweet basil oil (₹ 500/litre) and matricaria flowers (₹ 52.50/kg) for medicinal and aromatic uses. Though, a good yield of sorghum (29.62 t/ha) and berseem (36.85 t/ha) was obtained from fodder based cropping system but it was not economical. Sweet basil-matricaria, cropping system got highest potentiality to give better return. Chilli-garlic, spices based cropping system in partially reclaimed sodic soils also found highly remunerative than rice-wheat cropping system.

Land use and production efficiency: Sorghum-berseem cropping system achieved the highest land use efficiency (78.35%) followed by rice-wheat (65.75%), chilli-garlic (564.38%) and sweet basil-matricaria (63.56%). It is primarily due to the longer duration of winter crops. Berseem crop during winter season produced fodder for a longer period followed by wheat, garlic and matricaria. Production efficiency was the highest (61.25 kg/ha/day) in sweet basil-matricaria cropping system followed by chilli-garlic (54.93 kg/ha/day), sorghum-berseem (32.44 kg/ha/day) and rice-wheat (32.25 kg/ha/day) (Table 1). It was because of higher rice equivalent yield of sweet basil-matricaria than the other cropping systems.

Table 1 Yield, water use, water expense and energy efficiency of different cropping systems (mean data of 3 years)

Cropping system	Yield (t/ha)		Water use efficiency (kg/ha-cm)	Total input (MJ×10^3/ha)	Energy out put (MJ×10^3/ha)	Energy efficiency
	Kharif crop	Rabi crop				
Rice-Wheat	4.04	3.33	61.59	27.50	314.46	11.43
Sorghum-Berseem	29.62	36.85	80.24	22.04	262.62	11.91
Sweet basil-Matricaria	0.074*	0.80*	141.18	23.73	284.63	11.99
Chilli-Garlic	1.57	2.85	150.72	22.10	213.52	9.66

* Oil yield of sweet basil and dry flower yield of matricaria.

Water use efficiency: Different cropping systems consumed varied quantity of irrigation water (Table 1). Maximum water (125.65 cm) was applied with rice-wheat cropping system and minimum (85.65 cm) in chilli–garlic. However, highest water expense efficiency (150.72 kg/ha cm) was recorded with chilli-garlic cropping system followed by sweet basil-matricaria (141.18 kg/ha cm), sorghum-berseem (80.24 kg/ha cm) and rice-wheat (61.59 kg/ha cm). The water requirements of sorghum-berseem, sweet basil-matricaria and chilli-garlic cropping systems are about 8.0, 19.8 and 31.8% less than the water requirement of rice-wheat cropping system.

Energetics: The total energy input in different cropping systems ranged from 22.04 to 27.50 × 10^3 MJ/ha (Table 1). In general, nitrogen accounted for single largest share of energy input followed by diesel and human labour. The energy input through seed, phosphatic and potassic fertilizers and irrigation was of lower magnitude. Sweet basil–matricaria cropping system gave the highest energy use efficiency (11.99) while the lowest was observed in chilli-garlic (9.66). Though, the total energy output was high in rice-wheat (314.46×10^3 MJ/ha) cropping system, the total energy input was also higher (27.50×10^3 MJ/ha) resulting in lower energy use efficiency. Similar findings were observed by Subbiah *et al.* (1995).

Economics: As the experiment was conducted with different cropping systems, consisting of crops having diverse in nature, it is worthwhile to compare cropping systems on the basis of gross return, net return and benefit:cost ratio. Economics of different cropping systems were analyzed which revealed that the maximum net return (₹ 63522/ha) was obtained from sweet basil-matricaria medicinal and aromatic crop based cropping system followed by sorghum-berseem (₹ 61000/ha) fodder based, chilli-garlic (₹ 42500/ha) and rice-wheat (₹ 39861/ha). Analysis of benefit: cost ratio (net return: cost of cultivation) revealed that, maximum benefit: cost ratio (2.74) was obtained from sweet basil-matricaria followed by chilli–garlic (2.42), sorghum-berseem (2.32) and rice–wheat (2.14) (Table 2).

Soil improvement: Among the cropping systems tested in the experiment, maximum reduction in soil pH_2 (8.86) after three years of experimentation was recorded with sweet basil-matricaria cropping system followed by rice-wheat (8.95), chilli-garlic (9.00) and sorghum-berseem (9.01) over the initial value of 9.20. It was because, matricaria absorbs higher amount of cations, especially sodium at a faster rate (Mishra 1987). The organic carbon status in the soil was slightly higher with sweet basil -matricaria cropping system (0.13%) over the traditional rice-wheat system (0.12%) over the initial value of 0.10%.

It was concluded that, in partially reclaimed sodic soils cultivation of rice-wheat cropping system for a longer period may not be economically viable proposition. Diversification of rice-wheat cropping system with other highly remunerative crops like sweet basil and chilli in *kharif* and matricaria and garlic in *rabi* was is an alternate highly remunerative medicinal and aromatic and spices based cropping systems which may be adopted by the farmers to get higher returns per unit area and to save the natural resources.

Table 2 Economics, land use and production efficiency of different cropping systems (Mean data of 3 years)

Cropping system	Cost of cultivation (₹/ha)	Net return (₹/ha)	Benefit: cost ratio	Production efficiency (kg/ha/day)*	Land use efficiency (%)
Rice-Wheat	45441	39861	2.14	32.25	65.75 (240)
Sorghum-Berseem	80520	61000	2.32	32.44	78.35 (286)
Sweet basil-Matricaria	110528	63522	2.74	61.25	63.56 (232)
Chilli-Garlic	60350	42500	2.42	54.93	54.38 (235)

*Calculated on rice equivalent basis, Figures in parentheses are total duration of crops in that system.

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