Alternate options to rice (*Oryza sativa*)–wheat (*Triticum aestivum*) cropping system for partially reclaimed sodic soils of Uttar Pradesh

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A field experiment was conducted during 2003–04 to 2005–06 at the Central Soil Salinity Research Institute, Regional Research Station, Lucknow to find alternate options to the rice–wheat cropping system in partially reclaimed sodic soils. Four cropping systems, viz. rice–wheat (cereal-based), sorghum–berseem (fodder-based), sweet basil (tulsi)–matricaria (medicinal and aromatic crop-based) and chilli–garlic (spices-based) were evaluated in the light of sustainability, potentiality and profitability. Maximum rice equivalent yield (14.21 t ha^{-1}) was recorded with sweet basil–matricaria cropping system, whereas the highest production efficiency (61.25 kg ha^{-1} day^{-1}) was recorded with sweet basil–matricaria cropping system. Sorghum–berseem cropping system gave maximum (78.35%) land-use efficiency. Chilli–garlic cropping system recorded the highest water expense efficiency (150.72 kg ha^{-1} cm) followed by sweet basil–matricaria, but the total amount of water used was more (125.65 cm) in the rice–wheat system. The water requirement of sorghum–berseem, sweet basil–matricaria and chilli–garlic cropping systems was 8.0, 19.8 and 31.8% respectively, less than the rice–wheat cropping system. Among the cropping systems evaluated, energy input (27.50 MJ ha^{-1}) and output (314.46 MJ ha^{-1}) were maximum in the rice–wheat system. Energy use efficiency was maximum (11.99) with sweet basil–matricaria followed by sorghum–berseem (11.91). Reclaiming effect of sweet basil–matricaria cropping system on soil properties was higher than the rest of the cropping systems. Sweet basil–matricaria cropping system gave the highest net return (Rs 50,222 ha^{-1}) and benefit : cost ratio (2.74).

Keywords: Cropping systems, diversification, equivalent yield, sodic soils, water use efficiency.

IN India, about 6.73 mha area is subjected to salinity and sodicity problems, of which about 1.37 mha is in Uttar Pradesh (UP)[1]. During the last two decades about 0.53 mha sodic soil has been reclaimed through various government as well as non-government organizations[2]. 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 lesser risk. Though it is a remunerative cropping system, it has created many serious ecological problems such as exhaustion of underground water, resulting in the depletion of groundwater ranging from 15 to 80 cm every year[3]. Moreover, irrigation water is a costly and scarce 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 questionable due to adverse effect on soil conditions, crop yield and factor productivity, increasing cost of production and weed infestation in the wheat crop[4,5]. High crop response to N in sodic soil under rice–wheat cropping system further reduces the nitrogen pool of the soil[6]. The rice–wheat cropping system (especially rice) has high water requirement and in areas 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 dissolved salts in the upper layer of the soil[7]. Therefore, a field experiment was conducted to explore the possibility of a highly remunerative alternate cropping system to the traditional rice–wheat system for partially reclaimed sodic soils of UP.

The four times replicated field experiment was conducted at the Central Soil Salinity Research Institute, Regional Research Station, Experimental Farm, Lucknow during 2003–04 to 2005–06. The farm situated at an elevation of 120 m amsl, and extends from 26°47′ to 26°48′N lat. and 80°46′E long. 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 dSm^{-1} and organic carbon 0.10%. The experiment consisted of four cropping systems, viz. S_1, rice–wheat (cereal-based), S_2, sorghum–berseem (fodder-based), S_3, sweet basil (tulsi)–matricaria (German chamo-

Table 1. Initial properties of experimental soil

Soil parameter	Soil depth (cm) 0–15	15–30
pH_2	9.20	9.36
EC_2 (dSm^{-1})	1.43	1.52
Organic carbon (%)	0.10	0.15
CO_3 (meq l^{-1})	0.25	1.00
HCO_3 (meq l^{-1})	3.75	4.63
Na^+ (meq l^{-1})	26.19	79.60
Cl^- (meq l^{-1})	14.00	16.40
K (meq l^{-1})	0.12	0.13
Mg^{++} (meq l^{-1})	7.25	10.50
Ca^{++} (meq l^{-1})	0.75	1.25
Available N (kg ha^{-1})	186.72	102.02
Available P (kg ha^{-1})	16.87	8.24
Available K (kg ha^{-1})	116.20	139.62

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Table 2. Yield, water use and water expense efficiency of different cropping systems (mean data of 3 years)

	Cropping system	Yield (t ha^{-1}) Kharif crop	Yield (t ha^{-1}) Rabi crop	Rice equivalent yield (t ha^{-1})	Quantity of water used (cm)	Water expense efficiency (kg ha^{-1} cm)
S_1	Rice–wheat	4.04	3.33	7.74	125.65	61.59
S_2	Sorghum–berseem	29.62	36.85	9.28	115.65	80.24
S_3	Sweet basil–matricaria	0.074*	0.80*	14.21	100.65	141.18
S_4	Chilli–garlic	1.57	2.85	12.91	85.65	150.72
	CD (P = 0.05)	–	–	–	0.65	–

*Oil yield of sweet basil and dry flower yield of matricaria.
Sale price of produce: Rice @ Rs 540 q^{-1}, sorghum fodder @ Rs 70 q^{-1}, sweet basil oil @ Rs 500 l^{-1}, chilli @ Rs 800 q^{-1}, wheat @ Rs 600 q^{-1}, matricaria flower @ Rs 52.50 kg^{-1} and garlic @ Rs 2000 q^{-1}.

Table 3. Change in soil properties due to different cropping systems

	Cropping system	Soil pH_2	EC_2 (dSm^{-1})	Organic carbon (%)
S_1	Rice–wheat	8.95	0.60	0.12
S_2	Sorghum–berseem	9.01	1.01	0.12
S_3	Sweet basil–matricaria	8.86	0.41	0.13
S_4	Chilli–garlic	9.00	0.99	0.11
	Initial	9.20	1.43	0.10

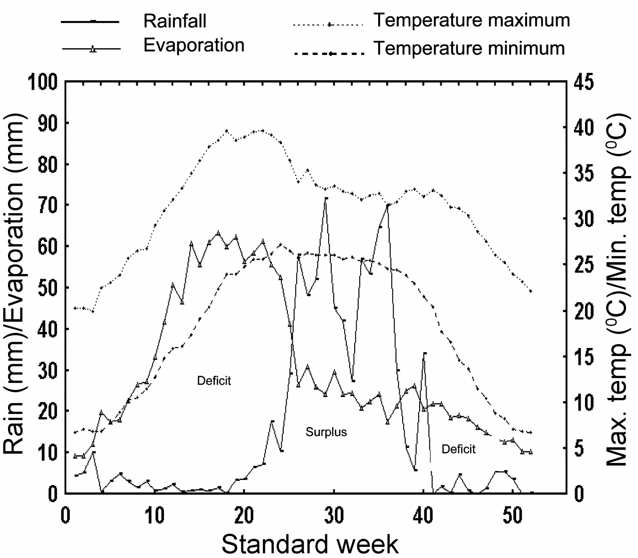

Figure 1. Climatic water balance of the study area.

mile; medicinal and aromatic crop-based) and S_4, chilli–garlic (spices-based). The initial soil properties of the experimental field are given in Table 1. Crops were raised with recommended package of practices. N, P and K were 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 the rest of the N was given according to 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. Total rainfall received during 2003–04, 2004–05 and 2005–06 (January–December) was 905.8, 790.3 and 816.6 mm respectively. The climatic water balance of the study area is given in Figure 1. During kharif, Pant 10, SSG-59-3, Sim somya and LCA-235 varieties of rice, sorghum, sweet basil and chilli and during rabi, PBW 343, JB-2, vallary and local varieties of wheat, berseem, matricaria and garlic were grown. Observations on growth parameters of rice and wheat were recorded at 30 days interval; however yield attributes and yield were recorded during harvest. Similarly, in the case of sweet basil, chilli and matricaria, plant height and number of branches were taken at 30 days interval, while inflorescence weight/plant, and weight of fresh leaves/plant in sweet basil, length of fruit and fruit yield in chilli and size and weight of bulbs in garlic were recorded at maturity. The sorghum and berseem fodder yields were calculated on the basis of two and four cuttings of these crops respectively. Irrigation and depth of water applied to the crop were monitored following the standard method. To study the changes in soil fertility after each cropping system, composite soil samples (0–15 cm) were collected and analysed for pH_2, EC_2 and organic carbon using standard methods. Land-use efficiency was calculated by dividing the total duration of crops (in individual cropping system) by 365, production efficiency values were calculated by dividing the total production in a system by the total duration of crops in it[8]. Water applied efficiency was worked out in terms of yield (kg ha^{-1} cm) of water used that included the irrigation water applied and effective rainfall. Energy input and output were calculated using the energy equivalents[9]. Prevailing market price of rice, wheat, sorghum, berseem, chilli and garlic was taken for economic analysis of different systems. However, for sweet basil and matricaria, the prevailing market price of sweet basil oil and matricaria flowers was taken into consideration.

The rice–wheat traditional cropping system gave 7.37 t ha^{-1} grain yield. Sweet basil–matricaria cropping

Table 4. Total energy (MJ × 10^3 ha^{-1}) input and output of different cropping systems (mean data of 3 years)

	Cropping system	Human labour	Diesel	N	P_2O_5	K_2O	Seeds	Irrigation	Total input	Energy out put	Energy efficiency
S_1	Rice–wheat	4.26	5.12	11.41	1.33	0.44	2.42	2.52	27.50	314.46	11.43
S_2	Sorghum–berseem	5.80	4.34	7.63	1.11	0.30	1.18	1.68	22.04	262.62	11.91
S_3	Sweet basil–matricaria	7.68	3.14	9.42	1.21	0.42	0.52	1.34	23.73	284.63	11.99
S_4	Chilli–garlic	6.09	2.89	8.43	1.31	0.48	1.69	1.21	22.10	213.52	9.66

Table 5. Economics, land-use and production efficiency of different cropping systems (mean data of 3 years)

	Cropping system	Cost of cultivation (Rs ha^{-1})	Net return (Rs ha^{-1})	Benefit : cost ratio	Production efficiency (kg ha^{-1} day^{-1})*	Land-use efficiency (%)
S_1	Rice–wheat	25,978	29,861	2.14	32.25	65.75 (240)
S_2	Sorghum–berseem	19,837	30,377	2.32	32.44	78.35 (286)
S_3	Sweet basil–matricaria	28,778	50,222	2.74	61.25	63.56 (232)
S_4	Chilli–garlic	22,800	32,510	2.42	54.93	54.38 (235)

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

system yielded 0.074 t ha^{-1} oil and 0.80 t ha^{-1} flower. Sorghum–berseem fodder-based cropping system recorded the highest fodder yield of 29.62 and 36.85 t ha^{-1} respectively (Table 2). Maximum rice equivalent yield (14.21 t ha^{-1}) was recorded with sweet basil–matricaria cropping system followed by chilli–garlic (12.91 t ha^{-1}) and sorghum–berseem (9.28 t ha^{-1}), with the lowest (7.74 t ha^{-1}) in the rice–wheat system. The higher rice equivalent yield in sweet basil–matricaria cropping system was because of high market price of sweet basil oil (Rs 500 l^{-1}) and matricaria flowers (Rs 52.50 kg^{-1}) for medicinal and aromatic uses. Though a good yield of sorghum (29.62 t ha^{-1}) and berseem (36.85 t ha^{-1}) was obtained from the fodder-based cropping system, it was not economical. Sweet basil–matricaria cropping system had the highest potential to give better return[10]. Chilli–garlic cropping system in partially reclaimed sodic soils was found to be highly remunerative compared to the rice–wheat cropping system.

The 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%) systems. This is primarily due to the longer duration of winter crops. Berseem crop during winter season produced fodder for a longer time followed by wheat, garlic and matricaria. Production efficiency was the highest (61.25 kg ha^{-1} day^{-1}) in sweet basil–matricaria cropping system followed by chilli–garlic (54.93 kg ha^{-1} day^{-1}), sorghum–berseem (32.44 kg ha^{-1} day^{-1}) and rice–wheat (32.25 kg ha^{-1} day^{-1}; Table 3). This is because of higher rice equivalent yield of sweet basil–matricaria than the other cropping systems.

Different cropping systems consumed varied quantities of irrigation water (Table 4). Maximum water (125.65 cm) was applied in the rice–wheat cropping system and minimum (85.65 cm) in the chilli–garlic system. However, the highest water expense efficiency (150.72 kg ha^{-1} cm) was recorded with chilli–garlic cropping system followed by sweet basil–matricaria (141.18 kg ha^{-1} cm), sorghum–berseem (80.24 kg ha^{-1} cm) and rice–wheat (61.59 kg ha^{-1} cm). The water requirement of sorghum–berseem, sweet basil–matricaria and chilli–garlic cropping systems is about 8.0, 19.8 and 31.8% respectively, less than that of the rice–wheat system.

The total energy input in different cropping systems ranged from 22.04 to 27.50 × 10^3 MJ ha^{-1} (Table 4). In general, nitrogen accounted for the single largest share of energy input followed by diesel and human labour. The energy input through seeds, phosphatic and potassic fertilizers and irrigation was lower. Sweet basil–matricaria cropping system gave the highest energy use efficiency (11.99), while the lowest was observed in the chilli–garlic (9.66) system. The total energy output was high in the rice–wheat (314.46 × 10^3 MJ ha^{-1}) cropping system as well as the total energy input (27.50 × 10^3 MJ ha^{-1}), resulting in lower energy use efficiency. Similar observations were made by Subbiah *et al.*[11].

As the experiment was conducted with different cropping systems consisting of crops diverse in nature, it is worthwhile to compare the systems on the basis of gross return, net return and benefit : cost ratio. The economics of different cropping systems was analysed, which revealed that the highest cost of cultivation (Rs 28,778 ha^{-1}) was incurred in the sweet basil–matricaria cropping system because of higher labour requirement for picking the matricaria flowers followed by the rice–wheat (Rs 25,978 ha^{-1}), chilli–garlic (Rs 22,800 ha^{-1}) and sorghum–berseem (Rs 19,837 ha^{-1}) systems. However, maximum net return (Rs 50,222 ha^{-1}) was obtained from the sweet basil–matricaria cropping system followed by chilli–garlic (Rs 32,510 ha^{-1}), rice–wheat (Rs 29,861 ha^{-1}) and sorghum–berseem (Rs 30,377 ha^{-1}) systems. Analysis of benefit : cost ratio (net return : cost of cultivation) revealed that maximum (2.74) was obtained from sweet basil–matricaria followed by chilli–garlic (2.42), sorghum–berseem (2.32) and rice–wheat (2.14) cropping systems (Table 5). These results confirm the findings of Roy Bardhan *et al.*[12].

Among the cropping systems tested in the experiment, maximum reduction in soil pH_2 after three years of experimentation was recorded with sweet basil–matricaria followed by rice–wheat, chilli–garlic and sorghum–berseem (Table 3). This is because matricaria absorbs higher amount of cations, especially sodium at a faster rate[13]. The organic carbon status in the soil was slightly higher in the sweet basil–matricaria cropping system over the traditional rice–wheat system.

From this study it is concluded that in partially reclaimed sodic soils, cultivation of rice–wheat cropping system for a longer period may not be an 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 may be adopted by the farmers to get higher returns per unit area and to save the natural resources.

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Elemental oxides analysis of the medieval period glazed ware from Gogha, Gulf of Khambhat, Gujarat, India

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During an inter-tidal zone exploration in the Gulf of Khambhat region, a large number of glazed and non-glazed sherds were recovered along with stone anchors dating back to the late medieval period. Four representative specimens were analysed for elemental oxides using scanning electron microscope and energy dispersive spectrum. The results indicate that silicon oxide content of the glazed sherds varies between ~73 and 77%, forming three-fourths of the total composition, while it ranges from 42 to 47.5% in non-glazed sherds. Its content is more than half that in the ordinary sherds. It is difficult to understand the origin of these sherds on the basis of chemical analysis, as this study focuses only on the Gogha area. Therefore, similar studies from different regions in the Gulf of Khambhat will help to understand the origin and divergence in the manufacturing techniques used.

Keywords: Elemental oxides, glazed ware, medieval period, stone anchors.

GENERALLY pottery with a glossy layer is termed as glazed ware. The glaze is primarily composed of fine glass-forming oxides, mostly silica (SiO_2), which on vitrification melt and fuse to form an impermeable glassy layer over the surface of a vessel. The oxides found in glazes have a unique role in determining the final properties such as texture and colour on fired ware. Excavations and explorations at different locations on the Indian subcontinent have yielded a variety of glazed ceramics from various time-periods.

The earliest examples of glazed ware were reported at Mohenjo-Daro[1] and Desalpur[2]. Excavations at a Kushana Period site in Shah-Ji-Ki-Dheri near Peshawar[3], yielded an inscription over which a glaze coating was observed. Similar studies at another Kushana Period site in Harwan near Srinagar, revealed a pavement of glazed tiles.

During the medieval period use of glazed ware increased manifold with several variations and decorations, and many sites of the medieval period in India yielded the remains of glazed ware[4]. A few important sites among these are Hastinapur, Fatehpur Sikri, Purana Qila, Adilabad, Ujjain, Atranjikhera, Nevasa, Sanghol, Qila-ri-Pithora, Ropar, Chirand and Kurukshetra. Glazed ware is also re-

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