INNOVARE JOURNAL OF AGRICULTURAL SCIENCE

Vol 10, Issue 3, 2022

ISSN - 2321-6832

Research Article

ALTERNATE OPTIONS TO RICE (*ORYZA SATIVA*) – WHEAT (*TRITICUM AESTIVUM*) CROPPING SYSTEM FOR PARTIALLY RECLAIMED SODIC SOILS

YASH PAL SINGH[1], VINAY KUMAR MISHRA[2], RAVINDRA KUMAR GUPTA[3]

ICAR-Central Soil Salinity Research Institute, Regional Research Station, Lucknow, Uttar Pradesh, India. E-mail: ypsingh.agro@gmail.com

Received: 18 January 2021, Revised and Accepted: 12 May 2021

ABSTRACT

Objectives: A field experiment was conducted during 2013–2014–2015–2016 at Central Soil Salinity Research Institute, Regional Research Station, experimental farm, Shivri, Lucknow to find out the alternate options to rice (*Oryza sativa* L.) – wheat (*Triticum aestivum* L.) cropping system in partially reclaimed sodic soils.

Methods: Four cropping systems, namely, rice (*O. sativa* L.) – Wheat (*T. aestivum* L.) (Cereal-based), sorghum (*Sorghum bicolor*) – berseem (*Trifolium alexandrinum*) (Fodder-based), sweet basil (tulsi) (*Ocimum basilicum* L.) – matricaria (*Matricaria chamomilla*) (medicinal and aromatic crop-based), and chilli (*Capsicum* spp.) – garlic (*Allium sativum* Linn.) (spices-based) were evaluated in the light of sustainability, potentiality, and profitability.

Results and Discussion: 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 expense 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 (Rs. 63,222/ha) and benefit: cost ratio of 2.74 was deliberated with medicinal and aromatic crop-based sweet basil–matricaria cropping system than rest of the cropping systems.

Conclusion: From the study, it is concluded that, diversification of rice–wheat cropping system with other highly remunerative crops such as sweet basil and chilli in kharif and matricaria and garlic in rabi 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.

Keywords: Cropping systems, diversification, equivalent yield, energy use efficiency, partially reclaimed sodic soils, production efficiency, water use efficiency.

 DOI: http://dx.doi.org/10.22159/ijags.2022v10i3.40829. Journal homepage: https://innovareacademics.in/journals/index.php/ijags

INTRODUCTION

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 Thimmappa *et al.* (2017) in India. 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. Although, it is very remunerative cropping system, sustainability of this system has been questioned with yield stagnation Bhatt *et al.* (2015), created many serious ecological problems such as atmospheric pollution Singh *et al.* (2008), un attended intervening periods Bhatt *et al.* (2015), and declining underground water table Humphreys *et al.* (2010) and Bhatt *et al.* (2016). Moreover, the irrigation water is a costly and scares resource. The availability of water for agriculture is going down due to 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 *et al.* (1989) and 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 the upper layer of soil Gupta *et al.* (1990). Therefore, a field experiment was conducted to explore the possibility of highly remunerative alternate cropping system to traditional rice–wheat system for partially reclaimed sodic soils of U.P.

METHODS

The 4 times replicated field experiment was conducted at Central Soil Salinity Research Institute, Regional Research Station, Experimental farm, Shivri, Lucknow during 2013–14–2015–2016. It is situated at an elevation of 120 m AMSL. It extends from 26° 47’ to 26° 48’ latitude and 80° 46’ longitude. 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, namely, 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 initial soil properties of the experimental field are given in Table 1. The 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 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. Total rainfall received during the year 2013–2014, 2014–2015, and 2015–2016 (January to December) was 905.8 mm, 790.3 mm, and 816.6 mm, respectively. The climatic water balance of the study area is given in Fig. 1. 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 observations on growth parameters of rice and wheat were recorded at 30 days interval; however, yield attributes and yield were recorded at harvest. Similarly in case of sweet basil, chilli, and matricaria, the plant height, number of branches were taken at 30 days interval and inflorescence weight/plant, fresh leaves weight/plant in sweet basil, length of fruit and fruit yield in case of chilli, size of bulb, and weight of bulbs in case of 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. 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 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 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 in to consideration.

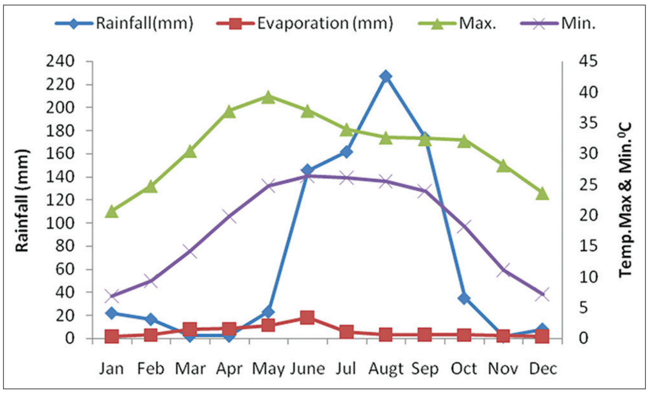

Fig. 1. Mean monthly weather parameters during study period

Table 1: Initial properties of experimental soil

Soil parameters	Soil depth (cm)	
	0–15	15–30
pH_2	9.20	9.36
EC_2 (dSm^{-1})	1.43	1.52
O.C. (%)	0.10	0.15
CO_3 ($meql^{-1}$)	0.25	1.00
HCO_3 ($meql^{-1}$)	3.75	4.63
Na^+ ($meql^{-1}$)	26.19	79.60
Cl^- ($meql^{-1}$)	14.00	16.40
K ($meql^{-1}$)	0.12	0.13
Mg^{++} ($meql^{-1}$)	7.25	10.50
Ca^{++} ($meql^{-1}$)	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

RESULTS AND DISCUSSION

Crop yields

From the data, it is revealed that rice–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-based cropping system recorded the highest fodder yields of 29.62 t/ha and 36.85 t/ha, respectively (Table 2). 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 due to high market price of sweet basil oil (Rs. 500/lit) and matricaria flowers (Rs. 52.50/kg) for medicinal and aromatic uses. Although, a good yield of sorghum (29.62 t/ha) and berseem (36.85 t/ha) was obtained from fodder-based cropping system, 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 time 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 3). It is due to higher rice equivalent yield of sweet basil–matricaria than the other cropping systems.

Water use efficiency

Different cropping systems consumed varied quantity of irrigation water (Table 4). 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 $ha^{-1 cm}$), 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

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

Cropping systems	Yield (t ha^{-1})		Rice equivalent yield (t ha^{-1})	Quantity of water used (cm)	Water expense efficiency (kg ha^{-1}cm)
	Kharif crop	Rabi crop			
Rice–wheat	4.04	3.33	7.74	125.65	61.59
Sorghum–berseem	29.62	36.85	9.28	115.65	80.24
Sweet basil–matricaria	0.074*	0.80*	14.21	100.65	141.18
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

Table 3: Changes in soil properties due to different cropping systems

Cropping systems	Soil pH_2	EC_2 (dSm^{-1})	O.C (%)
Rice–wheat	8.95	0.60	0.12
Sorghum–berseem	9.01	1.01	0.12
Sweet basil–matricaria	8.86	0.41	0.13
Chilli–garlic	9.00	0.99	0.11
Initial	9.20	1.43	0.10

Table 4: Total energy ($MJ\times10^3$/ha) input and output of different cropping systems (mean data of 3 years)

Cropping systems	Human labour	Diesel	n	P_2O5	K_2O	Seeds	Irrigation	Total input	Energy out put	Energy efficiency
Rice–wheat	4.26	5.12	11.41	1.33	0.44	2.42	2.52	27.50	314.46	11.43
Sorghum–berseem	5.80	4.34	7.63	1.11	0.30	1.18	1.68	22.04	262.62	11.91
Sweet basil–matricaria	7.68	3.14	9.42	1.21	0.42	0.52	1.34	23.73	284.63	11.99
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 systems	Net return (Rs ha^{-1})	Benefit: cost ratio	Production efficiency (Kg ha^{-1} day^{-1})*	Land use efficiency (%)
Rice–wheat	39,861	2.14	32.25	65.75 (240)
Sorghum–berseem	61,000	2.32	32.44	78.35 (286)
Sweet basil–matricaria	63,522	2.74	61.25	63.56 (232)
Chilli–garlic	42,500	2.42	54.93	54.38 (235)

*Calculated on rice equivalent basis

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 4). In general, nitrogen accounted for single largest share of energy input followed by diesel and human labor. 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). Although, 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 the 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 (Rs. 63,522 ha^{-1}) was obtained from sweet basil–matricaria medicinal and aromatic crop-based cropping system followed by sorghum–berseem (Rs. 61,000/ha) fodder-based, chilli–garlic (Rs. 42,500/ha), and rice–wheat (Rs. 39,861/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 5).

Figures in parentheses are total duration of crops in that system.

Soil improvement

Among the cropping systems tested in the experiment, maximum reduction in soil pH_2 after 3 years of experimentation was recorded with sweet basil–matricaria cropping system followed by rice–wheat, chilli–garlic, and sorghum–berseem (Table 3). It is because, matricaria absorbs higher amount of cations, especially sodium at a faster rate Mishra (1987). The organic carbon status in the soil has also improved slightly higher with sweet basil–matricaria cropping system over the traditional rice–wheat system.

CONCLUSION

From the study, it is 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 such as sweet basil and chilli in kharif and matricaria and garlic in rabi 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.

ACKNOWLEDGMENT

The authors are grateful to Dr. D. K. Sharma, Former Director, ICAR-Central Soil Salinity Research Institute for providing the necessary facilities to conduct the research work on this very important aspect.

REFERENCES

Bhatt R, Kukal SS, Busari M, Arora S, Yadav M. Sustainability issue on rice-wheat cropping system. Int Soil Water Conserv Res 2016;4:64-74.
Bhatt R, Kukal SS. Soil temperature, evaporation and water tension dynamics at upper vadose zone during intervening period. Trends Biosci 2015c;8:795-800.
Bhatt R. Soil Water Dynamics and Water Productivity of Rice-wheat System under Different Establishment Methods [PhD Thesis]. Ludhiana: Submitted to Punjab Agricultural University; 2015.
Gupta RK, Abrol IP, Abrol IP. Salt affected soils their reclamation and management for crop production. Adv Soil Sci 1990;11:223-88.
Humphreys E, Kukal SS, Christen EW, Hira GS, Singh B, Yadav S, *et al.* Halting the groundwater decline in north-west India-which crop technologies will be winners? Adv Agron 2010;109:156-99.
Mandal AK, Sharma RC, Singh G. Assessment of salt affected soils in India using GIS. Geocarto Int 2009;24:437-56.
Mishra PN. German chamomile. In: Khoshoo, T.N. Eco-development of Alkaline Land: A Case Study TN. NBRI; 1987. p. 80.
Mittal VK, Mittal JP, Dhawan KC. Research Digest on Energy Requirements

in Agricultural Sector (in) Energy Requirement Scheme Report. New Delhi: Indian Council of Agricultural Research; 1985.

Singh A, Kaur R, Kang JS, Singh G. Weed dynamics in rice-wheat cropping system. Glob J Biol Agric Health Sci 2012;1:7-16.

Singh B, Shah YH, Beebout J, Singh Y, Buresh RJ. Crop residue management for low land rice based cropping systems in Asia. Adv Agron 2008;98:117-99.

Singh YP, Raju R. Reclamation of sodic soils in India: An economic impact assessment. In: Arora S, Singh AK, Singh YP, editors. Bioremidiation of Salt Affected Soils: An Indian Perspective. Berlin: Springer; 2017.

Singh YP, Singh R, Gautam AK. Effect of nitrogen levels on yield and nutrient uptake by salt tolerant rice and wheat cultivars in gypsum amended sodic soils. J Indian Soc Soil Sci 2008;56:86-91.

Subbiah P, Gopalsundaran P, Palaniappan. Energetics and energy use efficiency of intensive cropping systems. Indian J Agron 1995;40:398-402.

Swarup A, Singh KN. Effect of 12 years rice- wheat cropping and fertilizer use on soil properties and crop yields in a sodic soil. Field Crops Res 1989a;21:277-87.

Thimmappa K, Singh YP, Raju R. Reclamation of sodic soils in India: An economic impact assessment. In: Arora S, Singh AK, Singh YP, editors. Bioremediation of Salt Affected Soils: An Indian Perspective. Berlin: Springer; 2017.

Tomar SS, Tiwari AS. Production potential and economics of different cropping systems. Indian J Agron 1990;35:30-5.