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Improving water and land use efficiency of fallow-wheat system in shallow Lithic Calciorthid soils of arid region: Introduction of bed planting and rainy season sorghum–legume intercropping

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ABSTRACT

In arid regions of India, wheat is conventionally planted in narrow spaced rows irrigated through flooding mostly with poor quality water followed by fallowing. To utilize these fallows for rainy season cropping and improving water use efficiency, a field experiment was carried out for three consecutive years (2009–2012) in arid zone. The experiment was laid out in split plot design with two planting systems i.e. bed planting and conventional planting in main plots and five rainy season cropping systems in sub plots viz., sorghum intercropped with *Sesbania* (green manuring/brown manuring), green gram and cowpea in 2:2 ratio and sole sorghum replicated thrice. In the succeeding wheat crop, each plot was further sub divided into two for applying two levels of nitrogen i.e. 90 and 120 kg ha^{-1}. The irrigation water for wheat was slightly saline (4.1 dS m^{-1}). Bed planting significantly improved yield of intercropped pulses i.e. green gram and cowpea by 31.8% and 27.5% over conventional planting while, yield of sorghum decreased by 13.7%. During winter season, bed planting improved number of grains $spike^{-1}$ and 1000 grain weight (43.3 g) that had compensated the decrease in spike density of wheat (19.2%). Bed planting saved 19–24% of irrigation and hence water productivity improved by 30%. Marked improvement in soil physical properties, dry root mass (81.5%) and nutrient status of soil i.e. soil organic carbon, available N and P was observed under this system. Salinity built up during winter season was below the threshold level for wheat and almost all the accumulated salts leached down during succeeding rainy season. Significant improvement in yield attributing characters of sorghum was observed under sorghum + green gram/cowpea intercropping system. Rainy season sorghum–legume intercropping had marked residual effect on succeeding wheat crop with maximum 19.1% yield increase being under sorghum + *Sesbania* (green manuring) treatment. During third crop cycle, this treatment saved 25% fertilizer nitrogen to wheat and significantly increased soil organic carbon status. However, highest system productivity and net returns were recorded under sorghum + green gram–wheat system (8265 kg ha^{-1} wheat grain equivalent yield). This was at par with sorghum + cowpea–wheat system. From the present study, it may be concluded that the productivity and water use efficiency of traditional fallow–wheat system could be increased by utilizing wheat fallow for growing sorghum + green gram/cowpea intercrops in 2:2 ratio under bed planting system.

1. Introduction

Arid and semi arid regions constitute one quarter of the total area of the world and yet home to about one sixth of the world's total population. Arid lands are fragile ecosystems suffering from various problems like scarce fresh water resources, shallow top soils, poor fertility, lower biomass productivity, overexploitation and inadequate irrigation facilities leading to salinization and land degradation. These problems often occurs in combination. With the burgeoning population and enhanced purchasing power of people, agriculture in these regions has been under great pressure to produce more. This could be achieved either by putting more area under cultivation or to increase the productivity through irrigation, cropping intensity and soil fertility enhancements. Conventional irrigation methods and cropping systems result in poor water use efficiency which is unsustainable in arid regions. In areas where irrigation is available farmers take winter season crops like wheat, mustard etc. and follow poorly efficient irrigation method like flood irrigation. Where water quality is poor, farmers keep the land fallow during rainy season for leaching of salts (Dhir, 1977) and to improve

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soil fertility. This results in loss of rainy season cropping. For higher returns, these fallows need to be cultivated during rainy season also without sacrificing the benefits of fallowing and water productivity enhancements.

It has now been established that bed planting is one of the most important resource conservation technologies of recent times. Research conducted under varying climatic conditions indicated the benefits of bed planting as saving of irrigation water by 20–40%, reduced seed rate, opportunities for mechanical weeding, improved fertilizer placement, reduced lodging, while maintaining the same or higher levels of productivity with reduced operational cost compared to conventional flat planting (Aggarwal and Goswami, 2003; Aquino, 1998; Fahong et al., 2004; Hobbs, 2001; Hobbs and Gupta, 2003a,b; Jat et al., 2005; Jani et al., 2008; Limon et al., 2000; Ram et al., 2005; Sayre, 1999; Sayre and Hobbs, 2004; Sayre and Moreno Ramos, 1997).

Green manuring with *Sesbania aculeate* is a widely investigated practice for amelioration of salinity and improving soil fertility. It is found beneficial not only for realizing potential yields but also for economizing nitrogen use in succeeding crops (Shah. et al., 2003; Sharma and Behera, 2009; Singh et al., 1991). However, it could not become popular amongst farmers because of poor economics and loss of one cropping season. To rectify this problem, intercropping *Sesbania* with sorghum (at 50% plant population) could be an option so that cost of cultivation of green manure as well the fodder requirement of arid zone farmer could be met. The researchable issue was whether this substituted *Sesbania* population would benefit intercropped sorghum as well as succeeding wheat crop. Few studies indicated a positive response (Birather, 2008; Kurdali, 2009; Kurdali et al., 2003, 2007). An operational problem envisaged in *Sesbania* + sorghum intercropping system was the incorporation of *Sesbania* in mixed crop stand. To resolve this issue 'brown manuring' was tested which includes knocking down of *Sesbania* by a selective herbicide like 2,4 D at 30–50 days after sowing (DAS). This has been reported successful in paddy fields (Anitha and Jose Mathews, 2010). However, this was not tested in upland crops like sorghum. To improve the economics further, another option could be to grow pulses such as green gram (*Phaseolus radiata*) and cowpea (*Phaseolus unguiculata*) that provide economical produce like seed and also improve soil fertility through atmospheric nitrogen fixation. In various studies under diverse climatic conditions, intercropping of these pulses with sorghum enhanced the dry matter accumulation as well as grain yield of sorghum (Rao et al., 2009; Singh and Ahuja, 1990). In this study, a combination of options viz., bed planting, intercropped green/brown manuring, pulses intercropping etc. were tested to arrive at an economically viable and sustainable solution to low water productivity and cropping intensity in arid zone.

2. Materials and method

2.1. Experimental site

The field experiments were conducted at Central Arid Zone Research Institute, Regional Research Station, Pali—Marwar, Rajasthan, India (24°45′N, 75°50′E; 225 m a s l.) from2009 to 2012. The experimental soil was fine sandy clay loam in texture, mixed hyper–thermic belonging to the family Lithic Calciorthids having shallow depth of 25–45 cm and underlying dense layer of *murrum* (highly calcareous weathered granite fragments coated with lime) up to 10–15 m depth. The soil at the beginning of experiment had pH 7.5 (of soil extract), 0.37% organic carbon, 77 mg kg^{-1} available N, 12.9 mg kg^{-1} Olsen's extractable P and 102 mg kg^{-1} exchangeable K content in 0–30 cm layer. A complete description of the soil at the beginning of experiment is presented in Table 1. Weather parameters including minimum and maximum temperature, rainfall and pan evaporation recorded during the crop growth period for 3 years are mentioned in Fig. 1.

2.2. Experimental details

The experiment was conducted for 3 years during the rainy (*kharif*) and winter (*rabi*) seasons from 2009 to 2012. Treatments comprised of two planting systems i.e. bed planting and conventional planting in main plot and five cropping systems in sub plot during *kharif* season in split plot design (Table 2). During *rabi* season each plot of *kharif* was further sub divided into two for the application of two levels of nitrogen i.e. 90 and 120 kg ha^{-1} representing 75% and 100% of recommended dose of nitrogen for wheat crop in a split–split plot design. An extra treatment of fallow–wheat (conventional planted) was taken as control. All the treatments were replicated thrice.

During *kharif* season, field was prepared by tilling once with disc harrow (10–12.5 cm depth) followed by two runs of cultivator and planking. Conventional sowing was carried out with a seed cum fertilizer drill at a row spacing of 45 cm. A tractor drawn seed cum fertilizer bed planter was used for making 37.5 cm wide and 15 cm high beds and 30 cm wide furrows. The crops were sown in two rows on the shoulders of each bed in 2:2 proportions as per treatment. Under green manuring treatments, *Sesbania aculeata* Pers. was cut and incorporated manually into the soil at 40 DAS and in brown manuring treatment, it was knocked down by the spray of 2.4 D at 0.5 l ha^{-1}. During *rabi* season, fresh beds were prepared but with the same layout and each original plot was subdivided into two for applying nitrogen treatments. For conventional sowing, wheat was sown at a row spacing of 22.5 cm through seed cum fertilizer drill. Under bed planting system three rows of wheat were sown on the top of beds by bed planter. Full dose of phosphorus as di-ammonium phosphate and 60 kg N ha^{-1} were applied as basal and remaining dose of nitrogen was applied in two equal splits at second and third irrigation through urea with doses as per treatment. Fertilization for bed planting was applied in the furrows, and uniformly applied over the surface for conventional planted wheat. Seven irrigations were given at critical crop growth stages of wheat i.e. crown root initiation, tillering, jointing, booting, flowering, milking and dough corresponding to Z20, Z29, Z36, Z51, Z61, Z71 and Z83 of Zadocks stages (Zadocks et al., 1974). Qualitatively, the irrigation water applied was slightly saline in nature (Table 3). The amount of irrigation water applied to flat plots was based on the amount required to fully flood them,

Table 1
Physico-chemical properties of the experimental soil at the onset of experiment during *kharif* 2009.

Depth (cm)	Soil texture (%)				pH	Organic carbon (%)	Bulk density (g cm^{-3})	Field capacity (%)	Wilting point (%)	ECe (dS m^{-1})
	Fine sand	Coarse sand	Silt	Clay						
0–10	29.7	16.6	35.8	17.9	7.6	0.37	1.42	17.2	7.1	0.16
10–22	28.0	15.9	36.4	19.7	7.8	0.37	1.39	17.2	7.3	0.16
22–34	23.9	14.1	35.8	26.2	7.8	0.42	1.36	20.6	10.1	0.15
34–44	22.1	16.0	33.9	28.0	7.8	0.42	1.39	18.7	9.1	0.15
45–100	Gravelly clay loam with weathered granite fragments coated with powdery lime									