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Relative Yield, Profit and Water Productivity of Crops in IGNP Stage-I

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Abstract: The choice of an appropriate crop and cropping systems is essential for achieving higher yield, profit and resource use efficiencies. Yield, returns and water productivity are important factors for determining suitability of crops and cropping systems in hot arid environment. A two-year (2012-13 and 2013-14) study was conducted in IGNP stage-I command area to determine productivity, profitability and water productivity of different crops and cropping systems. Yield, profit and water productivity varied markedly among different crops and cropping systems. The economic yield of crops varied from 1.6 Mg ha^{-1} to 4.2 Mg ha^{-1}; and biomass yield varied from 5.8 Mg ha^{-1} to 10.1 Mg ha^{-1}. The net return varied from Rs. 31421 ha^{-1} to Rs. 213680 ha^{-1}. The clusterbean had highest profit followed by cotton, wheat, barley and Indian mustard. Clusterbean and wheat was the most profitable crop of kharif and rabi season, respectively. Among the kharif season crops, the clusterbean was 1.4-times more water productive than cotton, and among rabi season crops, barley was 1.3- and 1.6-times more water productive than wheat and Indian mustard, respectively. Cotton–wheat cropping sytem had highest yield followed by cotton-barley, clusterbean-wheat, cotton-mustard, and clusterbean-mustard systems. The clusterbean based cropping systems were more profitable and water use efficiecnt than cotton based cropping systems.

Key words: Arid region, cropping system, IGNP command area, water productivity, yield.

Achieving sustainability in crop production will ultimately depend on the efficient use of natural resources. Land and water, the basic inputs of crop production are becoming scarce (Horrigan *et al*., 2002; Falkenmark and Rockstrom, 2004) due to increasing population and competition from industrialization and urbanization. In future, higher agricultural production must come from the natural resource base that is currently available. This requires a process of sustainable intensification by increasing land use and water use efficiency (FAO, 2005). The problem of ensuring an adequate supply of agricultural products and protecting natural resources is particularly acute in arid regions, which cover around 32% of world's land area and is home to about 21.2% of the human population (Safriel and Adeel, 2005). Identification of suitable crops/ cropping systems that make the best use of available resources and provide higher yields is important if the diverse needs of farming communities and environmental sustainability in arid regions are to be catered for (Joshi *et al*., 2009, Rathore *et al*., 2009, 2010). Comprehensive assessment of yield, profits and resource use efficiencies of different crops/cropping systems under existing crop management practices under given pedo-climatic condtions is pre-requisite for identifying suitable crop or cropping system diversification options (Rathore *et al*. 2014a). Water productivity along with profitability and productivity, are important criteria when comprehensively assessing crops/cropping systems. To date, very little information is available regarding the productivity, profitability and water productivity of contrasting irrigated crops/cropping systems in the IGNP stage-I command area of the hot arid region of India. The present study was conducted with the objective of assessing yields, returns, water productivity of different crops and cropping systems in IGNP stage-I command area.

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Materials and Methods

Study site

The study was undertaken during 2012-13 and 2013-14 in village Mainawali (74°20'34"-

74°20′60″E longitude and 28° 37′62″ N - 29° 21′39″ N latitude; 235 m a.s.l.) in district Hanumangarh, Rajasthan, India. The village had 28 farmer household with an area of 187 ha receiving water from a common water distributary of IGNP stage-I. The climate of experimental site is hot arid with an average annual precipitation of 281 mm; the mean maximum and minimum temperature are 43.0 and 5.1°C, respectively. More than 85% of the total annual rainfall is received during the south-west monsoon season (July to September). The soil has following key properties for the 0 to 15 cm layer: pH (soil/H_2O, 1:2.5): 8.1, organic carbon: 1.3 g kg^{-1} (Walkley-Black method), available NO_3-N: 20.2 kg ha^{-1}; available NH_4-N: 55.6 kg ha^{-1}; the texture was loamy sand, with sand (2000-50 µm), silt (50-2 µm) and clay (<2 µm) content: 678, 21 and 11 g kg^{-1} respectively.

Determination of yield

Out of total 28 farms of village, 15 farms were selected to determine the agronomic and economic performance of crops/cropping systems. Crop yields were determined at the maturity stage from five randomly selected 2 × 2 m^2 area (in case of cotton the 4 picking from selected area is used). Economic and straw yields were separated manually after harvesting. Sub-samples of economic yield and by-products (straw) were oven-dried to a constant weight at 70°C and expressed as kg ha^{-1}. Total biomass yields (BY) were measured by adding the economic yield (EY) and straw yields (SY) of the individual crops. Yield, returns and water productivity of cropping systems were determined following the procedure followed by Rathore *et al*. (2014b). Yields (EY and BY) of each cropping systems were measured by totalling yields (EY and BY) of kharif and rabi seasons crops of rotation in the year:

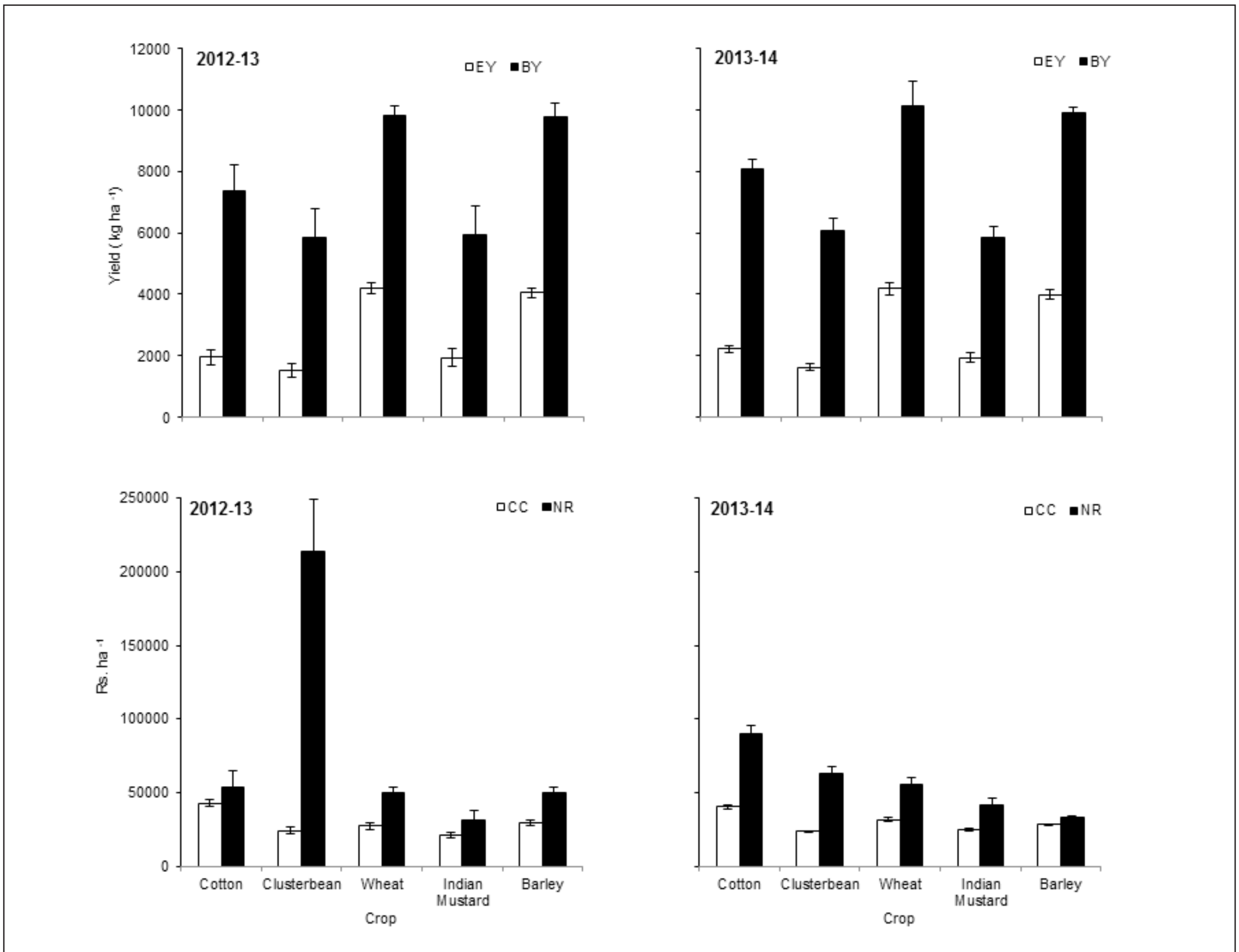

Fig. 1. Economic yield (EY), biomass yield (BY), cost of cultivation (CC) and net return (NR) of different crops in IGNP stage-I command area, Hanumangarh, Rajasthan, India during 2012-13 and 2013-2014.

$EY = EY_1 \ ha^{-1} + EY_2 \ ha^{-1}$

$BY = BY_1 \ ha^{-1} + BY_2 \ ha^{-1}$

where, EY is grain yield (kg ha^{-1}), the BY is biomass yield (kg ha^{-1}). The subscripts 1 and 2 represent the *kharif* and *rabi* seasons crops, respectively.

Determination of cost of cultivation and profits

Costs of cultivation (CC) and returns of crops were calculated on the basis of prevailing market prices for inputs and outputs. Net returns (NR) were calculated by subtracting production costs from the gross value of the produce (main and by-products) for each of the crops:

$NR = \{(EY) \ (Pe) + (SY) \ (Ps)\} - \{CC\}$

where, EY is economic yield (kg ha^{-1}), the SY is straw yield (kg ha^{-1}), Pe is price of economic product (Rs. kg^{-1}), Ps is price of straw (Rs. kg^{-1}) and CC is cost of cultivation (Rs ha^{-1}). Net return on the rotation basis was calculated as:

$NR = NR_1 + NR_2$

The subscripts 1 and 2 represent the kharif and rabi seasons crops, respectively.

Determination of water productivity

The water productivity was measured in terms of yield per unit of total water applied (kg m^{-3}) and return per unit of water applied (Rs. m^{-3}). The amount of irrigation application was measured by using V notch weir. For individual crop, WP was determined by dividing yields (EY, BY) and returns by the amount of water applied (rainfall + irrigation) as follows:

$WP = Y \ (EY) \text{ or } NR/TW$

where, Y is the yield (EY or BY in kg ha^{-1}), NR is net return (Rs. ha^{-1}) and TW is the total water applied (irrigation + rainfall, m^3) to crop.

Water productivity on the rotation basis was calculated as:

$WP = WP_1 + WP_2$

The subscripts 1 and 2 represent the kharif and rabi seasons crops, respectively.

Results and Discussion

Productivity and profitability of crops

The EY (economic yield) and BY (biomass yield) varied considerably amongst studied crops (Fig. 1). Amongst kharif crops, the EY varied from 1532 kg ha^{-1} to 2212 kg ha^{-1}; and BY varied from 5844 kg ha^{-1} to 8077 kg ha^{-1}. Averaged across years, cotton recorded 32% higher EY and 29% higher BY than that of clusterbean. Amongst rabi season crops the EY varied from 1936 kg ha^{-1} to 4182 kg ha^{-1}, and BY varied from 5844 kg ha^{-1} to 10128 kg ha^{-1}. Wheat had highest yield (EY: 4180 kg ha^{-1}, BY: 9981 kg ha^{-1}) followed by barley (EY: 4021 kg ha^{-1}, BY: 9861 kg ha^{-1}) and Indian mustard (EY: 1938 kg ha^{-1}, BY: 5898 kg ha^{-1}). Yields of crops varied substantially, and among kharif season crops cotton recorded higher yields than clusterbean; and bread wheat recorded higher yields than other *rabi* season crops.

The cost of cultivation (CC) of crops varied from Rs. 21524 ha^{-1} to Rs. 43118 ha^{-1} (Fig. 1). Averaged across years the cultivation of cotton incurred highest cost (Rs. 41799 ha^{-1}) followed by wheat (Rs. 29836 ha^{-1}), barley (Rs. 29062 ha^{-1}), clusterbean (Rs. 24105 ha^{-1}) and Indian mustard (Rs.23272 ha^{-1}). The cotton incurred 40, 44, 73 and 80% higher CC compared to wheat, barley, clusterbean and Indian mustard, respectively. The higher labor, irrigation and seed costs for cotton compared to clusterbean was responsible for higher CC of cotton. The higher CC of wheat is attributed to higher labor and irrigation costs compared to Indian mustard.

The profitability of crops measured in terms of net return (gross return-cost of cultivation) varied from Rs. 31421 ha^{-1} to Rs. 213680 ha^{-1} (Fig. 1) Averaged across both the years, the clusterbean had highest NR (Rs. 138566 ha^{-1}) followed by cotton (Rs. 72002 ha^{-1}), wheat (Rs. 53103 ha^{-1}), barley (Rs. 42157 ha^{-1}) and Indian mustard (Rs. 36703 ha^{-1}). Amongst the kharif season crops, cotton recorded 1.9 times higher profit than clusterbean. Amongst rabi season crops, wheat was more profitable, and it recorded 1.3 and 1.4 folds higher net return than barley and Indian mustard, respectively.

Water use and water productivity of crops

The total amount of water applied for different crops varied from 315 mm to 726.7 mm, being highest for cotton, followed by wheat, barley, clusterbean and Indian mustard

(Fig. 2). The amount of irrigation water applied had range: 92-470 mm. Averaged across both the years, the mean amount of irrigation water applied were highest for wheat (461 mm) followed by cotton (402 mm), barley (307 mm), Indian mustard (252 mm) and clusterbean (92 mm). Amongst the kharif season crops, the amount of irrigation water applied for cotton was 4.4 folds higher than that for clusterbean. In case of rabi season crops, the amount of irrigation water applied for wheat were 1.5 and 1.8 times higher than for barley and Indian mustard, respectively.

The water productivity of total water applied measured in terms of economic yield (WP_{TWY}) varied from 0.27 kg m^{-3} to 1.00 kg m^{-3} (Fig. 2). Averaged across the years, the WP_{TWY} for cotton, clusterbean, Indian mustard, wheat and barley were 0.31, 0.45, 0.62, 0.75, 0.98 kg m^{-3}, respectively. Thus, considering WP_{TWY}, the clusterbean was 1.4-times more water productive than cotton, and among rabi season crops, barley was 1.3- and 1.6-times more water productive than wheat and Indian mustard, respectively. The water productivity of total water applied measured in terms of return (WP_{TWR}) varied from Rs. 7.4 m^{-3} to Rs. 52.7 m^{-3}. Averaged across the years, the WP_{TWR} for cotton, clusterbean, Indian mustard, wheat and barley were 10.9, 36.4, 12.0, 9.5 and 10.3 kg m^{-3}, respectively. Thus, considering WP_{TWR}, the clusterbean was 3.3-times more water productive than cotton, and among rabi season crops, Indian mustard was 1.2- and 1.3-times more water productive than barley and wheat, respectively. Thus, considering WP measured for total water applied in terms of economic

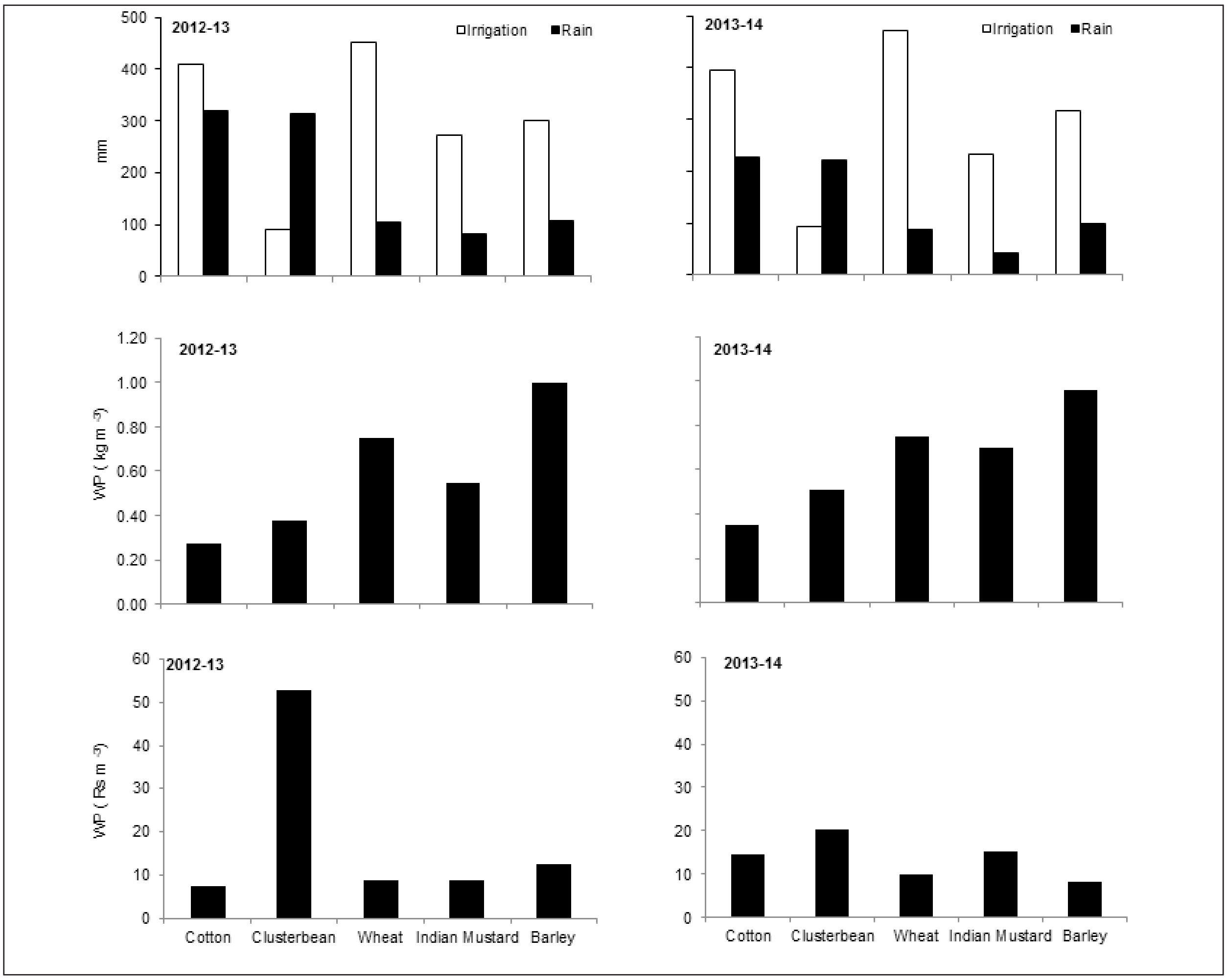

Fig. 2. Total amount of water applied (irrigation and rainfall), water productivity measured in terms of yield per unit of water applied (kg m⁻³) and net return per unit of water applied (Rs. m⁻³) of different crops in IGNP stage-I command area, Hanumangarh, Rajasthan, India during 2012-13 and 2013- 2014.

yield and return the clusterbean was more water use efficient than cotton. Among the rabi season crops, barley had greatest WP $_{TWY}$ and, Indian mustard had greatest $WP_{TWR.}$

Productivity and profitability of cropping systems

The cropping systems varied considerably in terms of yields (Fig. 3). The EY varied from 3548-6390 kg ha^{-1} and BY varied from 11796-18205 kg ha^{-1}. Averaged across both the years, cotton-wheat had highest EY (6259 kg ha^{-1}) followed by cotton-barley (6100 kg ha^{-1}), clusterbean-wheat (5751 kg ha^{-1}), cotton-mustard (4017 kg ha^{-1}) and clusterbean-mustard (3509 kg ha^{-1}). The cost of cultivation of cropping systems had range: Rs. 45910-72521 ha^{-1}. Averaged across the experimentation years, the cotton-wheat had greatest cost of cultivation (Rs. 71494 ha^{-1}) followed by cotton-barley (Rs. 70713 ha^{-1}) cotton-mustard (Rs. 64923 ha^{-1}), clusterbean-wheat (Rs. 53947 ha^{-1}) and clusterbean-mustard (Rs. 47336 ha^{-1}). The cotton based cropping systems incurred higher cost of cultivation than that of clusterbean based cropping systems. The clusterbean-wheat was the most profitable cropping systems followed by clusterbean-mustard, cotton-wheat and cotton-barley. Averaged across the two years, the clusterbean based cropping systems had two times higher profit than cotton based cropping systems.

Water use and water productivity of cropping systems

The physical WP of cropping systems measured in terms of economic yield had range: 0.36-0.66 kg m^{-3} and that BY had range: 1.34-2.02 kg m^{-3} (Fig. 4). The clusterbean-wheat system had greatest physical WP measured in terms of economic yield (0.63 kg m^{-3}) followed by cotton-barley (0.56 kg m^{-3}), clusterbean-mustard (0.53 kg m^{-3}), cotton-wheat (0.51 kg m^{-3}) and cotton-mustard (0.41 kg m^{-3}) cropping

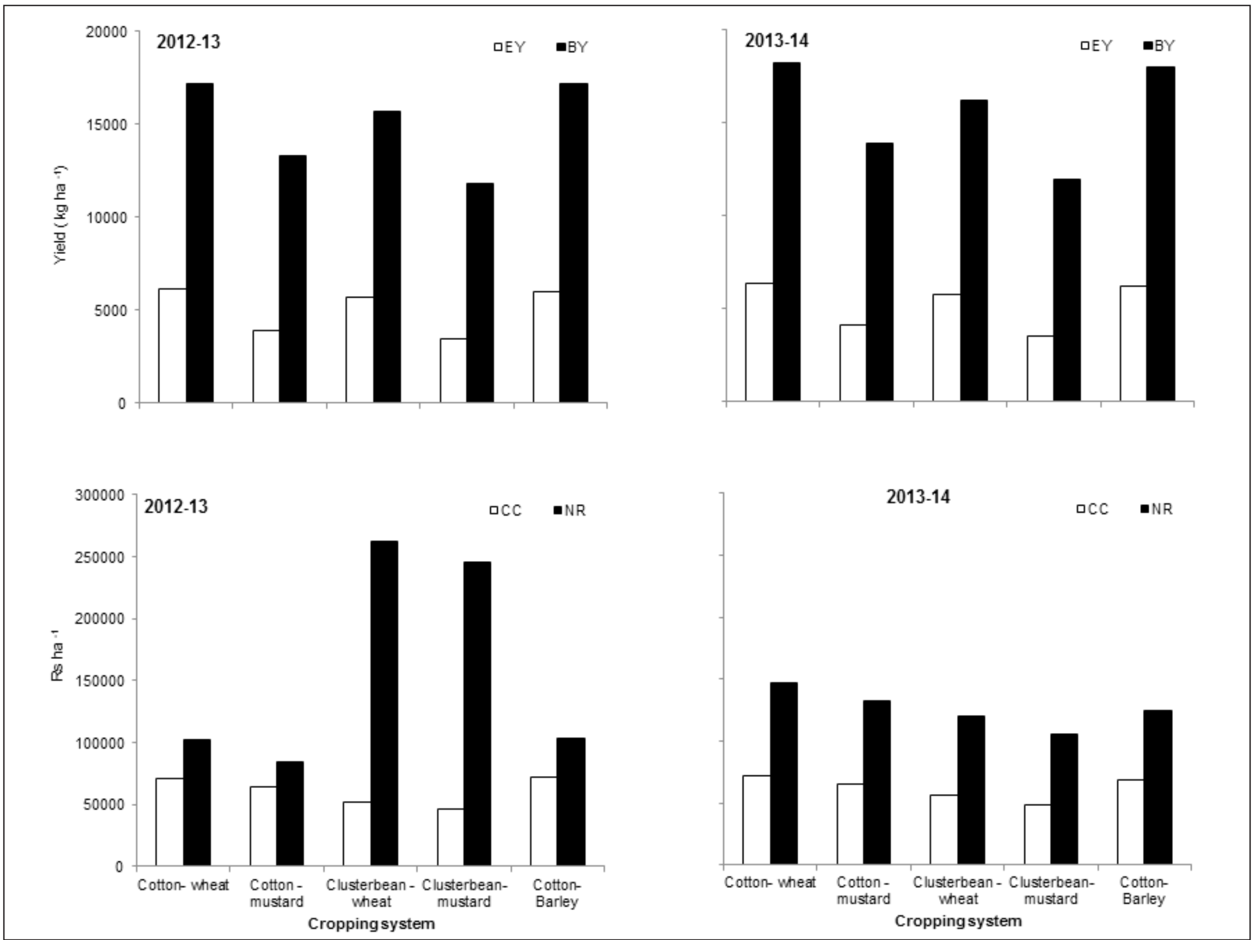

Fig. 3. Economic yield (EY), biomass yield (BY), cost of cultivation (CC) and net return (NR) of different cropping systems in IGNP stage-I command area, Hanumangarh, Rajasthan, India during 2012-13 and 2013-2014.

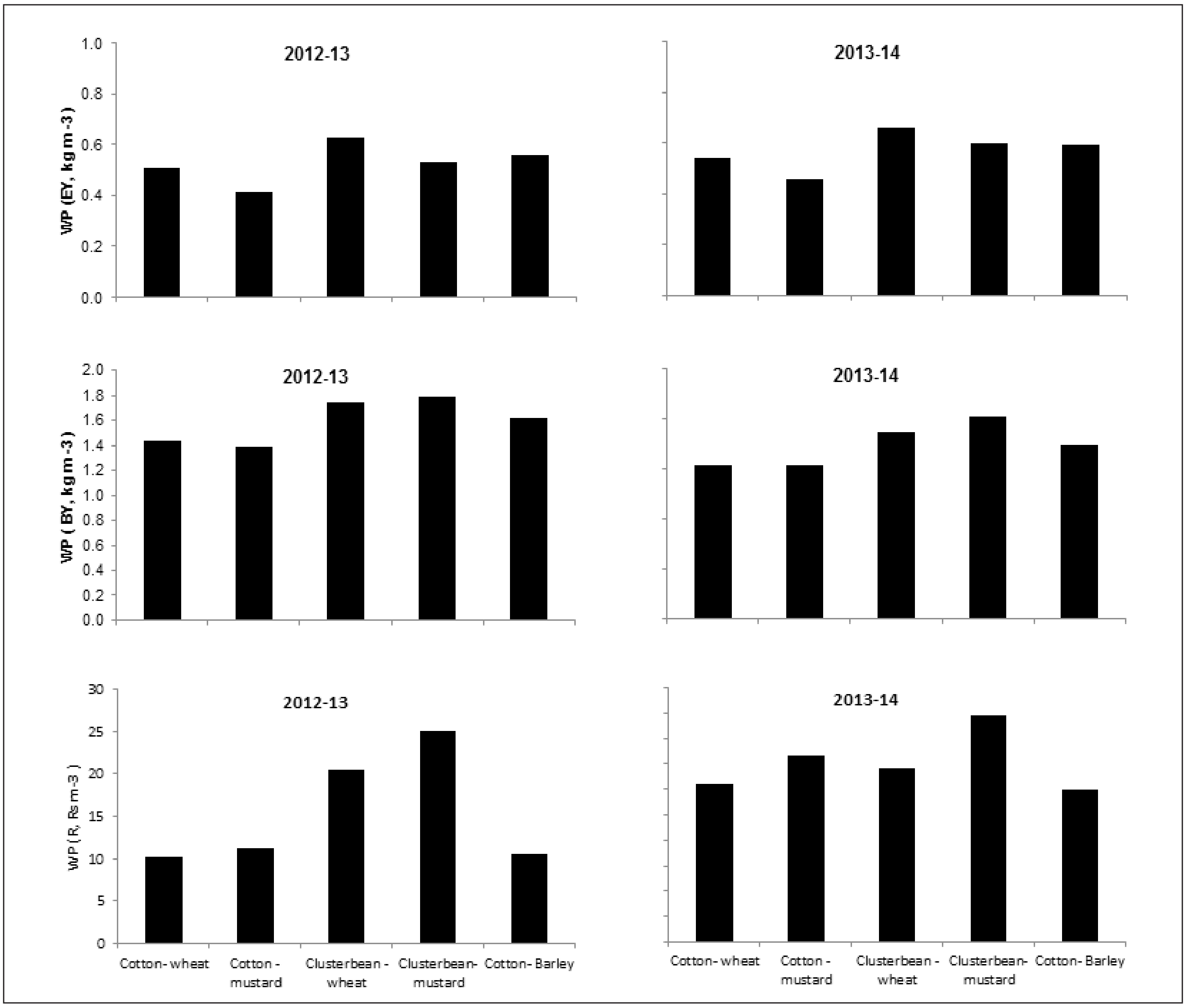

Fig. 4. Water productivity measured in terms of economic yield per unit of water applied (EY kg m^{-3}), biomass yield per unit of water applied (BY, kg m^{-3}) and net return per unit of water applied (R., Rs. m^{-3}) of different cropping systems in IGNP stage-I command area, Hanumangarh, Rajasthan, India during 2012-13 and 2013-2014.

systems. The WP measured in terms of net return varied from Rs. 7.8 m^{-3} to 32.3 m^{-3}. The average water productivity measured in terms of net return was highest for clusterbean-mustard (Rs. 25.1 m^{-3}) followed by clusterbean-wheat (Rs. 20.5 m^{-3}) , cotton-mustard (Rs. 11.3 m^{-3}), cotton-barley (Rs. 10.6 m^{-3}), and cotton-wheat (Rs. 10.2 m^{-3}). Thus, results suggest that clusterbean based cropping systems were more water productive in terms of yield and monetary return than cotton based cropping systems.

Conclusions

The study demonstrates that the existing crops and cropping systems varied markedly with respect to yield, cost of cultivation, profit and water productivities. Under prevailing crop-management practices and price of inputs and crop products, the clusterbean based production system is more profitable and water use efficient compared to cotton based cropping systems. The less requirement of labour, capital are the additional advantage offered by clusterbean.

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