e-planet **15** (2): 96-101 (December 2017)

Water productive and profitable dry season crops for tropical coastal region

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Date of receipt: 13.08.2017 Date of acceptance: 29.09.2017

ABSTRACT

Rice is the predominant crop in the coastal region during wet season (June-December). Dry season (December-May) cropping is constrained by limited availability of irrigation water. A study was undertaken to find out dry season crops, which are water productive and profitable in the coastal region of India. The crop evapotranspiration (ETc) during dry season was highest in case of sugarcane (11789 m^3 ha^{-1}), followed by dry season (boro) rice (6048 m^3 ha^{-1}) and eggplant (5072 m^3 ha^{-1}). Irrigation water productivity (WP) was highest in tomato (2.95 kg m^{-3}) followed by eggplant (2.41 kg m^{-3}) among vegetables and sunflower (1.77 kg m^{-3}) followed by maize (1.01 kg m^{-3}) among field crops. Cropping systems like rice-tomato, rice-maize, rice-potato, rice-sunflower, resulted in higher WP on net return basis (> `. 24 m^{-3}). The benefit cost ratio (BCR) was higher for rice-sunflower (3.2), rice-tomato, rice-eggplant (3.0) and 2.4 or more for rice-onion and rice-maize.

Key words: B:C ratio, coastal region, crop diversification, evapotranspiration, water productivity

INTRODUCTION

The cropping intensity and agricultural productivity in the coastal region of India is low in comparison to the inland areas mainly due to degraded soil and water quality, low adoption rate of improved package of practices on a system basis, constricted resource base together with climatic adversities. However, the region is endowed with bounty of natural resources like high precipitation, diverse soil types, flat topography and rich biodiversity. In spite of the vast resource potentials in the coastal region, the enhancement of the agricultural productivity of coastal land has been slow and much below the potential. Scarcities of good quality irrigation water and soil salinity are the major limiting factors for crop production as a result majority of cultivated land remain fallow during dry season.

Average productivity gain for rice in the eastern India is only 36 kg ha^{-1} against the 44 kg ha^{-1} in India during 1970-71 to 2003-04 (Naik et al., 2008). Wet season rice yield in the coastal saline region of eastern India is as low as 1.0 to 1.5 t ha^{-1} owing to erratic rainfall, abiotic stresses viz. salinity, drought, submergence and natural calamities like storms and cyclones (Sen et al., 2009). Average land holding of most farmers (> 80%) in the coastal area is marginal (<1 ha), land is fragmented in to multiple parts and in majority cases the holding size is even below 0.5 ha. Hence to raise the income of the farming community, it looks imperative to diversify the mono cropping of rice with other farming options (Sarangi et al., 2014a). The cropping intensity in the eastern coast of India is only 134%, with predominance of dry season rice, which is irrigation water intensive. There is need to increase cropping intensity and ensure food and economic security in the coastal saline areas. Therefore efforts must be focussed on developing diversified rice-based cropping systems by including low water-requiring, salt-tolerant non-rice crops (Mahata et al., 2009). Appropriate technologies with need based cropping pattern with respect to available resources are essential to overcome the problems in these areas. One of the major impediments to cropping system intensification in coastal region of India is lack of availability of good quality irrigation water during dry season. Avenues to improve cropping intensity and crop production include, adopting cropping systems which make maximum use of available water and result in higher economic returns to the farmers. Growing of non-rice crops during dry season by conserving the excess rainwater of wet season in on-farm reservoirs is possible in the coastal areas. Shift from rice to non-rice crops could also help enhance land and water productivity, crop diversification and farmer's income and reduce the risk of yield losses due to shortage of irrigation water during the grain filling of rice (Singh et al., 2006). Keeping these facts in view, the present investigation was carried out to find out water efficient rice based cropping systems for coastal region of India.

MATERIALS AND METHODS

Field experiments were conducted at three locations viz. Haldia (22°05' N, 88°04' E), Paradip (20°10' N, 86°25' E) and Visakhapatnam (17°46' N, 83°22' E) in the eastern coast of India during 2010-12 to find out suitable rice based cropping systems. Soil is heavy textured, low to medium saline (electrical conductivity of saturation extract varied from 1.6 to 4.3 dS m^{-1}) with acidic to neutral pH (5.1-7.4), low in available nitrogen, medium in phosphorus and potassium. Rice is the predominant crop in the study sites during wet season (*kharif*/ June to December) and majority of land remains fallow in the subsequent dry season (*rabi/boro*/ December to May) with limited area planted to field

Table 1. Crops and their varieties used in the field experiments during dry season

Crop	Botanical name	Variety	Duration (days)
Field crops			
Summer/*boro* rice	*Oryza sativa* L.	MTU 1010	125
Sunflower	*Helianthus annuus* L.	PAC 36	100
Lathyrus/Grass pea	*Lathyrus sativus* L.	Nirmal	120
Green gram/ Mung bean	*Vigna radiata* (L.) R. Wilczek	Local cultivar	80
Sugarcane	*Saccharum officinarum* L.	Co 6907	300
Sesame	*Sesamum indicum* L.	Local cultivar	90
Horse gram	*Macrotyloma uniflorum* (Lam.) Verdc.	Local cultivar	110
Maize	*Zea mays* L.	Hybrid	120
Vegetables			
Potato	*Solanum tuberosum* L.	Kufri Jyoti	110
Brinjal/Eggplant	*Solanum melongena* L.	Utkal Madhuri	105*
Chilli	*Capsicum annuum* L.	Utkal Rashmi	135*
Ladies' finger/Okra	*Abelmoschus esculentus* (L.) Moench	Utkal Gaurav	50*
Tomato	*Solanum lycopersicum* L.	BT 1	105*
Onion	*Allium cepa* L.	Local cultivar	120

* Duration to first harvest

crops like *boro* rice, lathyrus, green gram, horse gram and some vegetables. In the present study, promising *rabi* crops and their varieties were selected (Table 1) on the basis of suitability to the soil and weather conditions as well as local market demand. These crops were evaluated for higher yield, irrigation water productivity and profitability.

The volume of irrigation water applied to each crop was measured from the discharge rate of the pump and the time of pumping. Weather data for 2010-2012 were collected from agro-meteorological observatories located at these sites for computation of reference evapotranspiration (ET_0) by modified Penman method as given below.

$$ET_0 = c[W.Rn + (1-W).f(u).(ea-ed)] \text{ mm per day}$$

Where: ET_0 = reference crop evapotranspiration in mm per day for the month considered,

W = Temperature related weight factor,

Rn = Net radiation equivalent to evaporation in mm per day,

f(u) = Wind related function = 0.27(1+U/100),

U = 24-h wind run in km per day at 2 m height,

ea-ed = Difference between the saturation vapour pressure at mean air temperature and the mean actual vapour pressure of the air, both in mbar,

c = Adjustment factor to compensate for the effect of day and night weather conditions.

Appropriate data for W, ea, ed and c were obtained from Doorenbos and Pruitt (1977). The ET_0 data was used for calculation of crop evapotranspiration (ET_c). To account for the effect of the crop characteristics on crop water requirements, crop coefficients (Kc) were used to relate ET_0 to ET_c by the following formula.

$$ET_c = K_c \times ET_0$$

The Kc values for different crops at different locations were found out taking into account crop characteristics, time of sowing, stages of crop development and general climatic conditions. Yield data of various crops were collected from on-farm experiments conducted during 2010-11 and 2011-12 with three farmers at each location. Mean of three farmers at each location was considered as one replicate; hence data of four locations was used as replicates in randomized block design. At harvest, grain yield was recorded from a net area of 30 m^2 (6 m × 5 m) marked at the middle of each plot and converted to t ha^{-1}. Yield of each crop was converted into rice grain equivalent yield (REY) by following formula.

$$REY = \frac{\text{Yield of a particular crop} \times \text{price of that crop}}{\text{Grain price of rice crop}}$$

Irrigation water productivity (WP) of each crop and cropping system was calculated by using the following formula.

$$WP\ (kg\ m^{-3}) \text{ based on REY} = \frac{REY\ (kg\ ha^{-1})}{\text{Amount of irrigation water applied } (m^3\ ha^{-1})}$$

$$WP\ (`.\ m^{-3}) \text{ on gross/net return basis} = \frac{\text{Gross/Net return } (`.\ ha^{-1})}{\text{Amount of irrigation water applied } (m^3\ ha^{-1})}$$

The benefit cost ratio (BCR) was calculated as gross return accrued divided by total variable cost. Total variable cost was calculated by taking into account the costs of inputs, human labour, hiring power tiller for land preparation and an irrigation pump. Gross return was calculated by multiplying the amount of produce by its corresponding market price (during 2011-12) at harvest. Net return was the gross return minus total variable costs. The data were analyzed by using the Statistical Tool for Agricultural Research software developed by the International Rice Research Institute, Philippines (http://bbi.irri.org). Treatment means were compared using the least significant difference tests and compared at p=0.05 level of significance (Gomez and Gomez, 1984). Since the interaction between year and locations for different characters studied in this experiment were non-significant, hence mean data of three farmers, three locations and two years (18 data points) are presented.

RESULTS AND DISCUSSION

Crop evapotranspiration (ET_c), irrigation water productivity and yield

Among the dry season field crops, highest ET_c was observed in sugarcane (11789 m^3 ha^{-1}) followed by *boro* rice (6048 m^3 ha^{-1}), whereas lowest ET_c was for lathyrus (1439 m^3 ha^{-1}). Among vegetables, eggplant (5072 m^3 ha^{-1}) and ladies' finger (3991 m^3 ha^{-1}) are the crops with higher ET_c (Table 2). Irrigation water productivity was computed on the basis of rice grain equivalent yield (REY), which was highest for sunflower (1.77 kg m^{-3}) and maize (1.01 kg m^{-3}) among field crops. In vegetables WP varied from 0.90–2.95 kg m^{-3} lowest in ladies finger and highest in tomato. Water consumption by crops varies substantially, reflecting differences in cropping density, crop choice, soil characteristics, irrigation availability and agricultural management as well as climatic drivers of evapotranspiration (Brauman et al., 2013). The choice of suitable crop is likely to contribute substantially towards water saving without affecting food production, where water resources are scarce. Studies at West Bengal, India suggests farmers particularly with small and marginal holding size (< 1 ha) are interested for crop diversification towards vegetable crops and are interested to invest on water and inputs to achieve greater returns from crops other than rice (Chatterjee et al., 2013). Since, irrigation water is a precondition for successful cropping during dry season in coastal areas, every drop of precious water could be used effectively by choosing water productive crops and cropping patterns, which not only increase food production through increased cropping intensity but also reduce the pressure on natural resources.

Table 2. Crop evapotranspiration (ET_c) and irrigation water productivity (WP) of crops in the coastal region

Crop	ET_c (m^3 ha^{-1})	Irrigation water applied (m^3 ha^{-1})	REY*(t ha^{-1})	WP based on REY (kg m^{-3})
Sunflower	2860	4175	7.4	1.77
Maize (grain)	3053	6430	6.5	1.01
Lathyrus	1439	2225	1.7	0.76
Sugarcane	11789	17228	14.0	0.08
Green gram	1537	2455	1.4	0.57
Boro rice	6048	12445	4.5	0.36
Sesame	2229	2465	1.4	0.57
Horse gram	2887	1854	1.5	0.81
Kharif rice	5958	-	2.1	-
Tomato	2437	5225	15.4	2.95
Potato	2448	6440	13.4	2.08
Chilli	3476	7174	11.5	1.60
Onion	2767	4465	8.8	1.97
Eggplant	5072	5970	14.4	2.41
Ladies finger	3991	5125	4.6	0.90
LSD (p=0.05)	7	7	0.2	0.04

*REY = Rice equivalent yield

Economic water productivity of cropping systems

The economic water productivity though blurred by fluctuations in market prices, still preferable and is more appropriate indices for comparing different crops (Droogers et al., 2003). In the coastal regions of eastern India, rice-vegetable, rice-oilseeds and rice-pulses were found to be remunerative cropping systems for getting higher WP. Highest WP on gross return basis was observed in rice-tomato (`. 78 $m^{-3}$) and rice-potato (`. 66 m^{-3}) followed by rice-maize (`. 54 $m^{-3}$). However, on net return basis rice-maize (`. 32 m^{-3}) was second best after rice-tomato (`. 52 m^{-3}). Introduction of water productive crops and their suitable varieties could lead to substantial improvement in the cropping intensity, land and water productivity. Diversification of crops should be for higher profits to farmers, sustainability of resources as well as for mitigating risks. Crop diversification in areas, where continuous cropping of rice-rice is in vogue, has been advocated as one of the effective options for minimizing the second-generation problems (over-mining of soil nutrients, decline in factor productivity, reduction in profitability, lowering of ground water tables, ingress of sea water into the ground aquifers in coastal areas and build up of pests including weeds, diseases and insects) and to make a breakthrough in productivity and profitability (Gangwar and Prasad, 2005).

Table 3. Economic water productivity of different cropping systems

Cropping systems	WP* on gross return basis (`. m^{-3})	Cost of cultivation* (`. m^{-3})			WP on net return basis (`. m^{-3})	BCR
		kharif rice	*rabi* crop	Total		
Rice-sunflower	36	4.2	7.2	11.4	24.6	3.2
Rice-maize	54	4.2	18.0	22.2	31.8	2.4
Rice-horse gram	12	4.2	1.8	6.0	6.0	2.0
Rice-green gram	18	3.0	6.0	9.0	9.0	2.0
Rice-sesame	12	4.2	2.4	6.6	5.4	1.8
Sugarcane	12	-	-	7.2	4.8	1.7
Rice-lathyrus	18	4.2	7.2	11.4	6.6	1.6
Rice-rice	12	3.6	4.8	8.4	2.4	1.4
Rice-tomato	78	3.0	22.8	25.8	52.2	3.0
Rice-eggplant	36	3.0	9.0	12.0	24.0	3.0
Rice-chilli	42	3.6	14.4	18.0	24.0	2.3
Rice-onion	42	3.0	13.8	16.8	25.2	2.5
Rice-potato	66	3.6	33.6	37.2	28.8	1.8
Rice-ladies' finger	18	3.6	6.0	9.6	8.4	1.9
LSD (p=0.05)	6	-	1.2	1.2	6.6	0.5

Benefit cost analyses

Economic viability of a system depends on higher return per unit of investment. The data (Table 3) indicated that highest BCR of about 3 was observed in rice-sunflower, rice-tomato, rice-eggplant cropping systems followed by rice-onion (2.5), rice-maize (2.4) and rice-chilli (2.3). Highest BCR of > 3 in rice-sunflower cropping system is due to relatively lower cost of cultivation of sunflower than other crops like tomato and eggplant (Mishra et al., 2014). Sugarcane is a labour intensive crop; about 76% of cost of cultivation is incurred on labour charges and rest on materials (Babu and Rama Rao, 2011). Though vegetables are also labour intensive, but have economic advantage with highest net return and benefit cost ratio (Manjunath et al., 2010). Lower BCR (1.4) in rice-rice cropping system is due to less gross income and higher cost of cultivation. The cost of cultivation is higher during the dry season because of the high cost of irrigation water (Sarangi et al., 2014b).

CONCLUSION

Availability of sufficient good quality irrigation water is the major constraint for dry season cropping in the coastal areas of India. Therefore selection of suitable crops justifying water productivity is essential for efficient use of limited quantity of irrigation water. Growing of vegetable crops like tomato, potato, onion, eggplant, and chilli in the rice fallows in the eastern coast of India produced higher net income per unit of irrigation water applied. Among field crops, maize and sunflower may be introduced depending upon location. Diversification of dry season rice with water use efficient crops not only save precious water resources, but also help to increase the cropping intensity by bringing in additional area under cultivation through conserved water.

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