Environment and Ecology 40 (2C) : 838—844, April—June 2022
ISSN 0970-0420

Diversification of Rice-Rice Cropping System with Efficient Cropping Systems for Northern Telangana Zone of Telangana State

Firdoz Shahana, M. Goverdhan, Swapna Naguri, M. Venkatiah

Received 25 October 2021, Accepted 19 February 2022, Published on 12 June 2022

ABSTRACT

A field experiment was conducted during 2018-19 at AICRP on Integrated Farming Systems, Regional Sugarcane and Rice Research Station, Rudrur to diversify existing rice-rice cropping system with less water requiring crops under irrigated dry conditions for vertisols of Northern Telangana Zone. The experiment was laid out with twelve cropping systems as treatments in Randomized Block Design (RBD) with three replications. The twelve combinations of cropping systems tested during *kharif* and *rabi* seasons were rice – rice (check), maize + soybean (2:4) – tomato, maize + soybean (2:4) - rice, maize - sunflower + chickpea (2:4), maize - chickpea, *Bt* cotton + soybean (1:2) on broadbed – sesame + groundnut (2:4), *Bt* cotton - sesame + blackgram (2:4), soybean – wheat, soybean – sunflower + chickpea (2:4), turmeric – sesame, turmeric + soybean (1:2) on flat bed – bajra and turmeric + soybean (1:2) on broadbed – sesame + blackgram (2:4).Cropping system turmeric + soybean (1:2) (on BBF method) –sesame+ blackgram (2:4) was most productive with rice equivalent yield of 23413 kg ha^{-1} followed by sole turmeric-sesame (22597 kg ha^{-1}) and *Bt* cotton+soybean (1:2) (on BBF method) – sesame + groundnut (2:4) (22568 kg ha^{-1}) over rice-rice (14395 kg ha^{-1}). Cropping system turmeric-sesame and turmeric+soybean (1:2) on flatbed - Sesamum + Blackgram (2:4) on BBF were observed to be significantly profitable with system net returns of Rs 21516.35 ha^{-1} and Rs 21163.65 ha^{-1} but maize+soybean (2:4)-tomato (3.7) and sole *Bt*.cotton-sesame + blackgram (2:4) (3.6) and *Bt* Cotton + Soybean (BBF) (1:2)- sesame + groundnut (2:4) (3.6) recorded higher returns per rupee invested Rice-Rice (1.6) andturmeric-bajra (1.6) were least profitable cropping systems. Production efficiency was higher with turmeric+soybean (1:2) on BBF - Sesamum + Blackgram (2:4) (75.53) and *Bt* Cotton + Soybean (1:2) on BBF- sesame + groundnut (2:4) (75.23). System profitability was also higher with turmeric or *Bt*.cotton based cropping systems with higher value in turmeric-sesame (69.41) and turmeric+soybean (1:2) on BBF - Sesamum + Blackgram (2:4) (68.27) followed by *Bt* Cotton + Soybean (1:2)on BBF- sesame +groundnut (2:4) (63.75) and *Bt* Cotton- Sesame + Black gram (2:4) (62.09). cotton is next in area to rice in Telangana state indicating wider scope of diversing existing rice-rice cropping system with either *Bt* Cotton + Soybean (1:2) on BBF- sesame + groundnut (2:4) or *Bt* Cotton- Sesame + Black gram (2:4) cropping systems.

Keywords Cropping systems, System productivity, Net returns, Production efficiency, Economic efficiency and water productivity.

Firdoz Shahana*, M. Goverdhan, Swapna Naguri,.Dr M.Venkatiah
AICRP on Integrated Farming Systems, Sub Center: Regional Sugarcane and Rice Research Station, Rudrur 503188, Nizamabad, Telangana.
Email: shahanaagro34@gmail.com
*Corresponding author

INTRODUCTION

The modernization and industrialization of Agriculture, which are necessary to increase food production, are thought to be the main causes of the preferential sole cultivation of several species. Nowadays the intercropping procedure is being reevaluated due to advantages pointed previously (Oliveira *et al.* 2005). Considering that the productivity of a crop is limited by the amount of resources and is mainly determined by how efficiently the crop can use them, the species composing an intercropping should be contrasting in some of their agrobotanical characteristics, such as size, architecture, cycle, growth rate, demand for nutrients, demand for light. Natural resource management for sustainable agriculture development is important for India's food and nutritional security. Diversification of agriculture in favor of commercial crops leads to greater market orientation of farm production. Crop diversification is intended to give a wider choice in the production of variety of crops in a given area. Depending on just one crop can have grave consequences and leave small farmers open to unnecessary hazards. Crop diversification in India is viewed as a shift from traditionally grown less remunerative crops to more remunerative crops (Hazara 2000) . Crop diversification can be a useful means to increase farm output under different situations. The goal of sustainable intensification is to increase food production from existing farmland while minimizing pressure on the environment. It is a response to the challenges of increasing demand for food from a growing global population, in a world where land, water, energy and other inputs are in short supply, over exploited and used unsustainably. Any efforts to 'intensify' food production must be matched by a concerted focus on making it 'sustainable.' Failing to do so will undermine our capacity to continue producing food in the future substitution of non-traded inputs in favor of purchased inputs (Joshi *et al.* 2002). Increasing diversification of cereal cropping systems by alternating crops such as oilseed, pulse and forage crops is another option for managing plant disease risk (Krupinsky *et al.* 2002). It is a climate-smart agriculture strategy for food security, mitigation and adaptation. Both intensification and diversification of cropping systems may allow improving the productivity and sustainability of agricultural production in the Northern Telangana Zone of Telangana state but the choices to be made require integrated assessment of various cropping systems. The farmers for concerning higher per hectare production and income per unit area in a time frame can be overcome by adopting a cropping system which is profitable and economically viable. In the era of shrinking resource base of land, water and energy, resource use efficiency is an important aspect for considering the sustainability of a cropping system (Yadav 2002).

Rice followed by rice is the predominant cropping followed in vertisols of Northern Telangana Zone, Telangana, India . During cultivation of rice, soil undergoes drastic changes, i.e., aerobic to anaerobic environment, leading to several physical and electro-chemical transformations. Crop diversification shows lot of promises in alleviating these problems besides, fulfilling basic needs for cereals, pulses, oilseeds and vegetables and regulating farm income, withstanding weather aberrations, controlling price fluctuctuation, ensuring balanced food supply, conserving natural resources, reducing the chemical fertilizer and pesticide loads, ensuring environmental safety and creating employment opportunity (Gill and Ahlawat 2006) . Rice, which is high water requiring crop is affected due to less water availability and frequent dry spells during cropping season due to precarious rainfall situation for past few years coupled with depleting ground water resources. Avoiding resource depleting crop and identifying most productive, remunerative crops with less water requirement is necessary. Cropping system is one of the very important tool to augment the agricultural production. The approach involves sequential as well as intercropping and mixed cropping system aimed at efficient utilization of natural and man made resources of production.

MATERIALS AND METHODS

A field experiment was conducted during 2016-17 at AICRP on Integrated Farming Systems, Regional Sugarcane and Rice Research Station. Rudrur to diversify existing rice-rice cropping system with less water requiring crops under irrigated dry conditions for vertisols of Northern Telangana Zone. The experiment was laid out with twelve cropping systems

as treatments in Randomized Block Design (RBD) with three replications. The twelve combinations of cropping systems tested during *kharif* and *rabi* seasons were rice – rice (check), maize + soybean (2:4) – tomato, maize + soybean (2:4) - rice, maize - sunflower + chickpea (2:4), maize - chickpea, *Bt* cotton + soybean (1:2) on broadbed – sesame + groundnut (2:4), *Bt* cotton - sesame + blackgram (2:4), soybean – wheat, soybean – sunflower + chickpea (2:4), turmeric – sesame, turmeric + soybean (1:2) on flat bed – bajra and turmeric + soybean (1:2) on broadbed – sesame + blackgram (2:4).

All *kharif* crops were sown during last week of June after receipt of wetting rainfall and following sequence crops during *rabi* were taken up as and when the preceding *kharif* crops were harvested in the respective plots. Economic yield and stover/straw/stalk yield were recorded individually for all the crops in cropping systems. For comparison of different crop sequences, the yields of all the crops were converted in to rice equivalent yield on price basis. Production efficiency (PE) was calculated by dividing the system productivity by total duration of the system and was expressed in kg MEY/ha/day.

$$PE = \frac{\text{Total productivity of the system (kg/ha)}}{\text{Duration of the crops in the system (Day)}}$$

System profitability or Per Day Return: This is called as income per day and can be obtained by dividing the net return of the cropping system with total duration of the crops in the system (days).

$$\text{MSE (Rs ha}^{-1}\text{ day}^{-1}) = \frac{\text{Net return of the cropping system per ha}}{\text{Duration of the crops in the system (Day)}}$$

Land use efficiency: LUE of the cropping system was obtained by taking the total field duration of the crops in individual cropping system divided by 365 days and expressed as percentage.

$$\text{LUE (\%)} = \frac{\text{Total field duration of the crops in individual cropping sestem}}{365} \times 100$$

Water productivity total water use was worked out by the sum of the irrigation water applied and effective rainfall during the crop growing period. Total water use efficiency of cotton crop (TWUE) or water productivity under different treatments was calculated from the following relationship.

$$\text{Wayter productivity (kg ha}^{-1}\text{ mm}^{-1}) = \frac{\text{System productivity (kg ha}^{-1})}{\text{Total water use (mm)}}$$

RESULTS

Productivity analysis

The performance of different crops in terms of rice uivalent yield (REY) during *kharif*, indicated that higher productivity in terms of rice equivalent yield (19632 kg ha^{-1}) was recorded with sole turmeric. However it was found to be at par with turmeric +soybean (1:2) on broad bed (BBF) (16819 kg ha^{-1}) and (turmeric +soybean (1:2) on flat bed)(16128 kg ha^{-1}) The lowest productivity was recorded with sole maize (5197 kg ha^{-1}) and rice (5952 kg ha^{-1}) (Table 1). During *rabi* 2016, tomato crop raised after maize+ soybean (2:4), recorded significantly highest REY of 15992 kg ha^{-1} over other tested crops or cropping systems. However cropping systems Sesame + Groundnut (2:4) raised after *Bt* cotton +soybean (1:2) on BBF (10954 kg ha^{-1}),Sunflower + Chickpea (2:4) raised after sole maize (10695 kg ha^{-1}) and Sunflower + Chickpea (2:4) raised after sole soybean (10410 kg ha^{-1}) followed closely. Rezende *et al.* (2005) observed that, in the intercropping of tomato and lettuce, the productivity of tomato was not reduced by lettuce in any of the times when intercropping was established (transplanting lettuce at 0, 14, 28 and 42 DAT tomato). Tomato being nontraditional crop provides excellent opportunities in raising the income of the farmers as it has capacity to yield 5-10 times more than cereals.

Cropping system turmeric + soybean (1:2) (on BBF method) –sesame + blackgram (2:4) was most productive with rice equivalent yield of 23413 kg ha^{-1} followed by sole turmeric-sesame (22597 kg ha^{-1}) and *Bt* cotton + soybean (1:2) (on BBF method) – sesame +groundnut (2:4) (22568 kg ha^{-1}) over rice-rice (14395 kg ha^{-1}).

Table 1. Productivity of crops under different cropping systems during 2018-19 (1a). *Kharif* Treatments T1 Rice T2 Maize T3 Maize + Soybean T4 *Bt* Cotton T5 Soybean T6 *Bt* Cotton + Soybean (BBF) T7 Soybean T8 Turmeric T9 Maize T10 Turmeric + Soybean T11 Maize + Soybean T12 Turmeric + Soybean (BBF). *Rabi* Treatments T1 Rice T2 Sunflower + Chickpea T3 Rice T4 Sesamum + Blackgram T5 Sunflower + Chickpea T6 Sesamum + Groundnut (BBF) T7 Wheat T8 Sesamum T9 Chickpea T10 Bajra T11 Tomato T12 Sesamum + Blackgram (BBF).

		Kharif				*Rabi*			
		Grain yield (kg ha^{-1})		Straw/ Stover yield kg ha^{-1})		Grain yield (kg ha^{-1})		Straw/Stalk/ Stover yield (kg ha^{-1})	
Treatments		Main	Inter	Main	Inter	Main	Inter	Main	Inter
Kharif	*Rabi*	crop	crop	crop	crop	crop	crop	crop	crop
T1	T1	5539	0	5865	0	4866	0	3865	0
T2	T2	5101	0	7870	0	1713	870	2616	965
T3	T3	5314	376	5607	760	4993	0	3733	0
T4	T4	4985	0	9034	0	431	822	731	947
T5	T5	2474	0	1765	0	1667	892	2573	927
T6	T6	4108	926	5105	942	593	1722	779	1694
T7	T7	2514	0	2077	0	3915	0	1707	0
T8	T8	5072	0	3599	0	484	0	971	0
T9	T9	5236	0	7079	0	1816	0	2226	0
T10	T10	3686	892	1937	1095	2320	0	3175	0
T11	T11	5386	516	7214	736	16525		2287	0
T12	T12	3854	951	2885	977	478	829	970	849
SEm ±		128.82	10.50	185.96	51.84	217.90	26.97	46.43	34.46
CD (p=0.05)		380.25	30.98	548.91	153.01	643.21	79.62	137.04	101.74

Table 1. Continued.

		Rice equivalent yield (kg ha^{-1})				Productivity (REY - kg ha^{-1})		
		Kharif		*Rabi*				
Treatments								
Kharif	*Rabi*	Grain	Straw	Grain	Straw	*Kharif*	*Rabi*	System
T1	T1	5573	378	5128	499	5952	8443	14395
T2	T2	4689	508	7065	62	5197	10694	15770
T3	T3	5626	386	5325	482	6012	8713	14725
T4	T4	12929	0	4340	61	12929	6604	19756
T5	T6	4867	57	6878	60	4924	10410	15425
T6	T6	12526	30	6969	328	12556	10954	22568
T7	T7	4947	67	4383	110	5014	6741	11427
T8	T8	19632	0	1656	0	19632	2484	22597
T9	T9	4814	457	5155	144	5271	7950	13156
T10	T10	16092	35	2133	205	16128	3508	19568
T11	T11	5966	489	10661	0	6456	15992	22390
T12	T12	16788	32	4521	55	16819	6867	23413
SEm±		350.52	5.630	204.27	4.33	350.62	205.52	413.45
CD (p=0.05)		1034.67	16.62	602.97	12.78	1034.98	606.68	1220.42

Profitability analysis

Sole turmeric recorded significantly higher net returns of Rs 184300 ha^{-1} followed by sole *Bt* cotton (Rs 160397 ha^{-1}). Due to higher productivity recorded with turmeric net returns were also higher any how lower cost of production with *Bt* cotton compared to turmeric has contributed for higher returns per rupee invested net returns from sole *Bt* cotton (2.9) and Bt Cotton + Soybean on BBF (1:2) (2.5) over sole turmeric (1.2). Cultivation of rice or turmeric intercropped with soybean (1:2) on flat or broadbed were observed to be least profitable as they recorded B.C ratio less than one. During *rabi* net returns was significantly higher for tomato raised after maize+ soybean (2:4) (Rs 1134390 ha^{-1}) and also recorded

Table 2. Economic analysis of cropping systems during 2018-19.

Treatment		*Kharif*				*Rabi*		
Kharif	*Rabi*	Cost of cult. Rs. ha^{-1}	Gross returns Rs. ha^{-1}	Net returns Rs. ha^{-1}	Re. ha^{-1}	Cost of cult Rs. ha^{-1}	Gross returns Rs. ha^{-1}	Net returns Rs. ha^{-1}
Rice	Rice	45000	92252	47252	0.9	48000	87219	39219
Maize	Sunflower + Chickpea (2:4)	30000	80553	50553	1.4	31000	108357	77357
Maize+Soybean (2:4)	Rice	35500	93190	57690	1.3	48000	90004	42004
Bt Cotton	Sesame + Black gram (2:4)	40000	200397	160397	2.9	28750	69081	40331
Soybean	Sunflower + Chickpea	27500	76327	48827	1.3	31000	107255	76255
Bt Cotton + Soybean (BBF)(1:2)	Sesame + Groundnut (2:4)	46750	194618	147868	2.5	29250	101822	72572
Soybean	Wheat	27500	77712	50212	1.4	22550	66261	43711
Turmeric	Sesame	120000	304300	184300	1.2	23750	29203	5453
Maize	Chickpea	30000	81694	51694	1.3	22550	80282	57732
Turmeric + Soybean (1:2)	Bajra	125500	249981	124481	0.8	21500	35152	13652
Maize + Soybean	Tomato	35500	100062	64562	1.4	30000	164390	134390
Turmeric + Soybean (BBF) (1:2)	Sesame + Black gram (2:4)	45000	260701	133901	0.9	28750	67337	38587
	SEm ±	-	5433.67	5433.67	0.28	-	2667.80	2667.80
	CD (p=0.05)	-	16039.24	16039.24	0.84	-	7874.88	7874.88

Table 2. Continued.

Treatment		*Rabi*			
Kharif	*Rabi*	Net Returns Rs Re^{-1}	System gross returns Rs. ha^{-1}	System Net returns Rs. ha^{-1}	Rs. Re^{-1}
Rice	Rice	. 0.8	11579.00	11579.00	1.6
Maize	Sunflower + Chickpea (2:4)	2.5	12187.67	12187.50	2.8
Maize + Soybean (2:4)	Rice	0.9	11818.67	11818.67	1.9
Bt Cotton	Sesame + Black gram (2:4)	1.4	17385.67	17385.77	3.6
Soybean	Sunflower + Chickpea	2.5	11844.00	11844.00	2.8
Bt Cotton + Soybean (BBF) (1:2)	Sesame + Groundnut (2:4)	2.5	19125.33	19125.33	3.6
Soybean	Wheat	1.9	9288.667	9288.66	2.5
Turmeric	Sesame	0.2	21516.33	21516.33	2.0
Maize	Chickpea	2.6	10450.00	10450.00	2.7
Turmeric + Soybean (1:2)	Bajra	0.6	18395.67	18395.67	1.6
Maize + Soybean	Tomato	4.5	17061.33	17061.33	3.7
Turmeric + Soybean (BBF)	Sesame + Black gram (2:4)	1.3	21163.67	21163.67	1.8
	SEm+	0.09	6409.59	14206.95	0.074
	CD (p=0.05)	0.28	18920.01	41936.45	0.218

Table 3.. System productivity and system profitability of different cropping systems.

Treatment			Total duration of the system (days)	System productivity (kg ha^{-1}day^{-1})	Land use efficiency (%)	System profitability (Rs ha^{-1}day^{-1}	Total water use of the system (mm)	Water productivity (kg ha^{-1}mm^{-1})
	Kharif	*Rabi*						
T1	Rice	Rice	255	56.45	69.86	45.41	1950	7.38
T2	Maize	Sunflower + Chickpea (2:4)	300	52.57	82.19	40.63	550	28.67
T3	Maize + Soybean (2:4)	Rice	240	61.35	65.75	49.24	1550	9.50
T4	*Bt* Cotton	Sesame + Black gram (2:4)	280	70.56	76.71	62.09	850	23.24
T5	Soybean	Sunflower + Chickpea	285	54.12	78.08	41.56	400	38.56
T6	*Bt* Cotton + Soybean (BBF) (1:2)	Sesame + Groundnut (2:4)	310	75.23	84.93	63.75	950	23.76
T7	Soybean	Wheat	225	50.79	61.64	41.28	350	32.65
T8	Turmeric	Sesame	340	72.89	93.15	69.41	1600	14.12
T9	Maize	Chickpea	210	62.65	57.53	49.76	400	32.89
T10	Turmeric + Soybean (1:2)	Bajra	360	59.30	98.63	55.74	1650	11.86
T11	Maize + Soybean (2:4)	Tomato	330	66.84	90.41	50.93	1100	20.35
T12	Turmeric + Soybean (BBF) (1:2)	Sesame + Black gram (2:4)	340	75.53	93.15	68.27	1600	14.63

significantly higher returns per rupee invested (4.5) indicating wider scope for shifting towards vegetable cultivation during *rabi* cropping systems Sunflower + Chickpea (2:4) raised after sole maize (Rs77357 ha^{-1}) , Sunflower + Chickpea (2:4) raised after soybean (Rs776255 ha^{-1}) and Sesame + Groundnut (2:4) raised after *Bt*. cotton + soybean (1:2) (BBF) (Rs72527 ha^{-1}) were next best profitable option as they all recoded returns per rupee invested ratio of 2.5 and over other cropping systems. Bajra raised after turmeric+soybean (1:2) and sesame raised after turmeric were least profitable with net returns of Rs13652 ha^{-1} and Rs 15453 ha^{-1} respectively.

Cropping system turmeric-sesame and turmeric+soybean (1:2) on flatbed - Sesamum + Blackgram (2:4) on BBF were observed to be significantly profitable with system netreturns of Rs 21516.35 ha^{-1} and Rs21163.65 ha^{-1} but maize+soybean (2:4)-tomato (3.7) and sole *Bt* cotton-sesame +blackgram (2:4) (3.6) and *Bt* Cotton + Soybean (BBF) (1:2)- sesame +groundnut (2:4) (3.6) recorded higher returns per rupee invested. Rice-Rice (1.6) and turmeric-bajra (1.6) were least profitable cropping systems. In two year cotton-legume-corn rotation, an yield increase to the tune of 11% was recorded as compared to continuous cotton grown without legumes (Sankara-narayanan *et al.* 2010) Studies of CICR on six Bt cotton based double cropping systems viz., two millets, two pulses and two oilseed crops also indicated *Bt* cotton – maize was most profitable, productive and sustainable system (CICR 2009-10).

Efficiency of cropping systems

Production efficiency was higher with turmeric+soybean (1:2) on BBF - Sesamum + Blackgram (2:4) (75.53) and *Bt* Cotton + Soybean (1:2) on BBF- sesame +groundnut (2:4) (75.23).System profitability was also higher with turmeric or *Bt* cotton based cropping systems with higher value in turmeric-sesame (69.41) and turmeric+soybean (1:2) on BBF - Sesamum + Blackgram(2:4) (68.27) followed by Bt Cotton + Soybean 1:2 on BBF- sesame + groundnut (2:4) (63.75) and Bt Cotton- Sesame + Black gram (2:4)(62.09) (Tables 2-3). Land use ef-

ficiency higher for turmeric based cropping systems with higher value of 98.63 in Turmeric + Soybean (1:2) on flatbed –bajra cropping system followed by turmeric-sesame (93.15) and turmeric+soybean (1:2) on BBF - Sesamum + Blackgram (2:4) (93.15). Maize + Soybean (2:4)-tomato also recorded LUE of 90.41. Soybean-sunflower +chickpea (2:4) cropping system utilized water efficiently with water productivity of 38.56 kg ha^{-1} mm^{-1} followed by maize-chickpea (32.89 kg $ha^{-1}mm^{-1}$) and soybean-wheat (32.65 kg $ha^{-1}mm^{-1}$). Existing rice-rice cropping system was least water efficient with WUE of 7.38 kg ha^{-1} mm^{-1}. Water is the most crucial input and must be used rationally and these results consolidate the scope for immediate shift to the high water efficient and productivity cropping systems as stated above.

Discussion

Among twelve cropping systems studied, system productivity interms of rice equivalent yield was higher in turmeric and cotton based cropping systems and it ranged from 70.56 kg ha^{-1} day^{-1} to 75.5389 kg ha^{-1} day^{-1}. Similarl was the trend for system profitability with 69.41 Rs ha^{-1} day^{-1} to 62.09 Rs ha^{-1} day^{-1} This was due to increased proportion of net returns in relation to cost of cultivation. Similar results were also observed by Singh *et al*. (2011).These cropping systems also recorded higher water use efficiency indicating that water requirement of these crops match prevailing monsoon and irrigation facilities in Telangana state meeting critical water need of crops unlike rice cultivation where mostly crop moisture sensitive stage –flowering is often coincided with moisture deficit in most frequent situations of early withdrawal of monsoon with poor ground water recharge. It is pertinent to mention that turmeric is cultivated in limited districts of the state as traditional crop but cotton is next in area to rice in Telangana state indicating wider scope of diversing existing rice-rice cropping system with either *Bt* Cotton + Soybean (1:2) on BBF- sesame +groundnut (2:4) or *Bt* Cotton- Sesame + Black gram (2:4) cropping systems. Inclusion of legumes in these cropping systems also has advantage of nitrogen accumulation in soil.

CONCLUSION

Rice- Rice cropping adopted by majority of farmers is less productive and economically inferior indicating wider scope of diversifying existing rice- rice cropping system with high productive, economically viable cropping systems for irrigated conditions of Northern Telangana Zone.

REFERENCES

CICR. Annual report (2009-2010) Central Institute for Cotton Research, Nagpur (2010).

Fageria NK, dos Santos AB (2008) Yield physiology of dry bean. *J Pl Nutr* 31:983–1004

Gill MS, Ahlawat IPS (2006) Crop diversification - its role towards sustainability and profitability. *Ind J Fert* 2 (9): 125-138, 150.

Hamzei J, Seyyedi M (2016) Energy use and input–output costs for sunflower production in sole and intercropping with soybean under diferent tillage systems. *Soil Res* 157 : 73–82, https://doi.org/10.1016/j.still.2015.11.008

Hazara CR (2000) Expert consultation on crop diversification in the Asia-Pacific region. FAO Country Report, India. FAO Corporate Documents Repository.[E-book], Available: http://www.fao.org.

Joshi PK, Ashok G, Birthal PS, Laxmi T (2002) Nature and Speed of Agricultural Diversification in South Asian Countries. Paper Presented at the ICRIER ICAR IFPRI Conference on Economic Reforms and Food Security. The Role of Trade and Technology, New Delhi, India.

Krupinsky JM, Bailey KL, McMullen MP, Gossen BD, Turkington TK (2002) Managing plant disease risk in diversified cropping systems. *Agrono J* 94:198-209.

Modhavadia MM, Solanki RM, Nariya JN, Vadaria KN, .Rathod AD (2012) Effect of different levels of nitrogen, phosphorus and potassium on growth, yield and quality of *Bt* cotton hybrid under irrigated conditions. *J Cotton Res Dev* 26(1): 47-51.

Nawlakhe SM, Mankar DD, Rananavare PK (2010) Response of rainfed cotton to different sources of nutrients and fertilizer levels. *PKV Res J* 34(1): 90-94

Oliveira fl de, Ribas rgt, Junqueira rm, Padovan mp, Guerra gm, almeida dl deM ribeiro r de ld (2005) Desempenho do consórcio entre repolho e rabanete com pré-cultivo de crotalária, sob manejo orgânico. Horti Bras 23: 184–188.

Rezende bla, canato ghd, cecílio filho ab (2005) Influência das Épocas de Cultivo e do estabelecimento do consórcio na pro dução de tomate e alface consorciado. Cienc Agrotecnol 29: 77–83.

Sankaranarayanan K, Praharaj CS, Alayini P, Bandyopadhya KK, Gopalakrishnan N (2010) Legumeas companion crop for cotton. *J Cotton Res* Development. 24(1):115-126.

Singh Ummed, Singh SR, Saad AA, Khanday BA, Singh JK (2011) Yield advantage, reciprosity functions and energy budgeting of lentil (*Lens culinaris*) + oat (*Avena sativa*) intercropping under varying row ratio and phosphorus management. The *Ind J Agric Sci* 81 (3) :219–25.

Yadav JSP (2002) Agricultural resource management in India: The challenges. *J AgricWater Manag* (1):61-69.