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Enhancement of productivity and profitability of small farmers through Bio intensive complimentary cropping systems

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Abstract
Farm efficiency has to be improved by introducing diversified cropping systems which may also help in improving the factor productivity and farm profitability. Hence identification of bio intensive complimentary cropping systems by inclusion of more hardy cereals and pulse crops in the system which are ecologically sustainable and more viable is very pertinent. A field experiment was conducted during 2016-17 at AICRP on Integrated Farming Systems, Professor Jayashankar Telangana Sate Agricultural University, Rajendranagar to identify bio-intensive complementary cropping systems under I.D conditions for light textured soils of Southern Telangana Zone. The experiment was laid out with twelve cropping systems as treatments in Randomized Block Design (RBD) with three replications. On system basis, among the twelve cropping systems tested, cotton + green gram (1:2) –maize for green cobs system recorded highest system productivity in terms of maize equivalent yield (11803 kg ha^{-1}) with Rs 78,820 ha^{-1} of net returns followed by *Bt* cotton + soybean (1:3) – sesame + groundnut (2:4) system (10155 kg ha^{-1}). Higher production efficiency (45.40 kg $ha^{-1}day^{-1}$), water productivity (21.46 (kg $ha^{-1}mm^{-1}$) and economic efficiency (303.15 Rs ha^{-1} day^{-1}), were also recorded with cotton + green gram (1:2) – maize for green cobs system. Employment generation (man days) was also higher with *Bt* cotton + soybean (1:3) – sesame + groundnut (2:4) system (151) followed by cotton + green gram (1:2) – maize for green cobs system (114).

Keywords: Cropping systems, system productivity, production efficiency, economic efficiency, water productivity, employment generation and profitability

1. Introduction
Natural resource management for sustainable agriculture development is important for India's food and nutritional security. Diversification of agriculture in favour 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) [4]. Crop diversification can be a useful means to increase farm output under different situations.

A cropping system consists of cropping pattern in terms of crop combination, spatial arrangement and sequences of cropping in addition to the resources, input management and technology attributed to involve in the production of the desired products through improving land productivity (Okigbo, 1981) [8]. 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) [5]. 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) [6]. 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 Southern 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) [13]. Cotton and maize are widely cultivated crops in the Southern Telangana Zone. Intensive cultivation of these crops resulted in slowdown in productivity of these crops due to deterioration of the soil physical conditions. Both being exhaustive, non-leguminous in nature the viability and sustainability is a matter of concern especially in the context of light textured soils of the region. Hence identification of bio intensive complimentary cropping systems by inclusion of more hardy cereals and pulse crops in the system which are ecologically sustainable and more viable is very pertinent.

Material and Methods

The study was conducted at research farm of All India Coordinated Research Project on Integrated Farming Systems, Professor Jayashankar Telangana Sate Agricultural University, Rajendranagr during 2016-17. The soil of the experimental field was a red chalka soil. The experiment was laid out with twelve cropping systems as treatments in Randomized Block Design (RBD) with three replications. The twelve combinations of bio-intensive complimentary cropping systems tested during *kharif* and *rabi* seasons were, T_1: Maize – sunflower (check), T_2: Pearl millet + soybean–potato, T_3: Maize-groundnut, T_4: Pearl millet + soybean (3:2) – sunflower + groundnut (2:3), T_5 : Maize + soybean (2:3) – potato, T_6: *Bt* cotton + soybean (1:3) – sesame + groundnut, T_7: Maize (Flat bed) + soybean (Raised Bed) – castor (F) + greengram (RB) (2:3), T_8: *Bt* cotton + greengram (1:3) - pearl millet, T_9 :Soybean – potato, T_{10}: *Bt* cotton + green gram (1:2) –sesame, T_{11}: Pearl millet – groundnut, T_{12}: Bt Cotton + green gram (1:2) –maize for green cobs. All the *kharif* crops were sown on 2.07.2016 and the 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 maize equivalent yield on price basis and calculated production efficiency, land use efficiency, water productivity and economic efficiency by using the following formula.

Production efficiency (PE)

Production efficiency was calculated by dividing the system productivity by total duration of the system and was expressed in kg MEY/ha/day.

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

Economic efficiency or Per Day Return or Monetary system efficiency (MSE): 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 percantage.

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

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.

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

Results and Discussion

The performance of different crops in terms of maize equivalent yield during *kharif* indicated that *Bt* cotton intercropped with soybean at 1:3 ratio (T_6) gave significantly higher maize equivalent yield (7516 kg ha^{-1}) over other crops evaluated in different cropping systems. However it was found at par with *Bt* cotton intercropped with greengram at 1:3 row ratio (7474 kg ha^{-1}) or *Bt* cotton intercropped with greengram at 1:2 row ratio (6945 kg ha^{-1}). Sree rekha *et al*. (2010) [10] reported that cotton hybrid, Bunny and variety, Narsimha inter cropped with soybean recorded 28 and 29 per cent more seed cotton yield, respectively, over corresponding sole crops. Regarding net returns, due to higher price of greengram *Bt* cotton intercropped with greengram at 1:3 (T_8) recorded significantly higher net returns (Rs 48676 ha^{-1}) followed by *Bt* cotton intercropped with soybean at 1:3 row ratio (Rs 46345 ha^{-1}) and *Bt* cotton intercropped with greengram at 1:2 (Rs. 43425 ha^{-1}). Undie *et al*. (2012) [12] investigated productivity of maize and soybean as sole crops and as additive mixtures (100:100) at Akamkpa, Nigeria. It revealed that intercrops were 64, 66 and 63 percent in 2007 and 43, 57 and 65 percent in 2008, more productive than the sole crops at 2:2, 1:2 and 1:1 arrangements, respectively. Yogesh *et al*. (2014) [14] conducted a field experiment at University of Agricultural Sciences, Dharwad (Karnataka) and found that, among all the cropping systems tested, highest net return and B:C ratio (3.57) were obtained with maize intercropped with soybean in 2:6 paired row. Mandal *et al*. (2014) [7, 11] found that the grain and stover yield of maize were significantly higher in case of pure stand of maize than either of its intercropping systems with legumes while the cob yield was highest in maize with soybean (1:2) intercropping system and it was statistically at par with the yield obtained in sole maize. However, the maize equivalent yield of the system was highest in maize with soybean intercropping (1:2) followed by maize with groundnut (1:2), maize with groundnut (2:4) and maize with soybean (2:4) intercropping. Banik *et al*., (2009) [1] also reported that cereal-legume intercropping systems were superior to mono cropping.

During *rabi*, potato in soybean-potato cropping system (T_9) recorded significantly highest MEY of 5260 kg ha^{-1} over other treatments followed by maize for green cobs in *Bt* cotton + greengram (1:2) – maize for green cobs system (5173 kg ha^{-1}) and Potato in pearlmillet + soybean-potato system (4852 kg ha^{-1}). Potato 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, pulses or oilseeds. The high profitability of potato as a cash crop makes it an economically viable enterprise for the small and marginal farmers and has contributed to increasing equity among farmers (Gulati *et al*., 2007) [3]. Regarding net returns, maize for green cobs in *Bt* cotton + greengram (1:2) – maize for green cobs system (T_{12}) recorded significantly higher net returns (Rs 39684 ha^{-1}) over other treatments.

Amongst the twelve cropping systems tested, cotton + green gram (1:2) –maize for green cobs system recorded highest system productivity in terms of maize equivalent yield (11803 kg ha^{-1}) with Rs 78,820 ha^{-1} of net returns followed by *Bt* cotton + soybean (1:3) – sesame + groundnut (2:4) system (10155 kg ha^{-1}). In two year cotton-legume-corn rotation, an yield increase to the tune of 11 per cent was recorded as compared to continuous cotton grown without legumes (Sankaranarayanan *et al*., 2010) [9]. 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).

Production efficiency (PE) refers to per day productivity of entire cropping system under particular treatment. PE was higher in cotton + green gram (1:2) –maize for green cobs system (45.40 kg $ha^{-1}day^{-1}$) due to higher prices for green cobs in the market and favorable effect of greengram on the productivity of succeeding crops of the system. Highest economic efficiency (303.15 Rs ha^{-1} day^{-1}) was also recorded with cotton + green gram (1:2) –maize for green cobs system.

The Land use efficiency of Maize (Flat) + Soybean (Raised Bed) – Castor (F)+ Green gram (RB) (2:3) system was higher over other cropping systems, which may be attributed to long duration of soybean and castor crops. *Bt* cotton + soybean (1:3) – sesame + groundnut (2:4) system showed a great performance and saved 136.3 mm of water with a water productivity of 18.46 kg ha^{-1} mm^{-1}. High water use efficiency is apparently attributed to efficient use of water and adoption of appropriate cropping system. However, Cotton + green gram (1:2) –maize for green cobs system also used equally less water than maize – sunflower system with water productivity of 21.46 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 productivity cropping systems as stated above. Employment generation (man days) was also higher with *Bt* cotton + soybean (1:3) – sesame + groundnut (2:4) system (151) followed by cotton + green gram (1:2) – maize for green cobs system (114).

Table 1: Performance of crops under bio-intensive complementary cropping systems

Treatments		*Kharif*		*Rabi*		Maize Equivalent Yield (kg ha^{-1})				Productivity		
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})	*Kharif*		*Rabi*		(MEY -kg ha^{-1})		
						Grain	Straw	Grain	Straw	*Kharif*	*Rabi*	*System*
T1	Maize – Sunflower (Check)	4812	8952	752	976	4812	656	2176	0	5468	2176	7644
T2	Pear millet + Soybean (3:2) - Potato	1037 389	1287 442	2649	847	1773	102	4852	0	1875	4852	6727
T3	Maize - Groundnut	5187	8721	882	1081	5187	639	2727	245	5826	2972	8798
T4	Pear millet + Soybean (3:2) – Sunflower + Groundnut (2:3)	887 401	1153 391	323 704	484 892	1650	92	3111	202	1742	3313	5055
T5	Maize + Soybean (2:3) – Potato	3562 435	6982 463	2573	801	4414	520	4712	0	4934	4712	9646
T6	Bt cotton + Soybean (1:3) – Sesame + Groundnut	2150 487	3439 512	185 582	409 714	7507	9	2477	162	7516	2639	10155
T7	Maize (Flat) + Soybean (Raised Bed) – Castor (F)+ Green gram (RB)(2:3)	3721 410	7234 431	952 307	1921 527	4524	538	3616	80	5062	3696	8758
T8	Bt cotton + Greengram (1:3) - Pearl millet	2031 337	4732 680	1308	2531	7375	100	1274	193	7474	1468	8942
T9	Soybean - Potato	1252	1132	2872	957	2454	21	5260	0	2474	5260	7734
T10	Bt cotton + Green gram (1:2) –Sesame	1987 234	4710 452	356	894	6878	66	1304	0	6945	1304	8249
T11	Pearl millet – Groundnut	1302	1532	934	1056	1269	112	2888	239	1381	3127	4508
T12	Bt Cotton+ Green gram (1:2) –Maize for green cobs	1905 218	3975 397	14837	11624	6572	58	4322	852	6630	5173	11803
S Em+										270.9	154.8	
CD (0.05)										799.7	456.9	
CV (%)										9.97	7.91	

Kharif: Sale price for Grain (kg^{-1}) : Maize = Rs 13.65, Pearl millet = Rs 13.30, Soybean = Rs 27.75, Bt Cotton = Rs 41.60, Greengram = Rs 52.25 Sunflower = Rs 39.50, Groundnut = Rs 42.20, Sesame = Rs 50.00, Castor = Rs, 35.00, Potato = Rs 25.00 Sale price for stover (kg^{-1}) : Maize = Rs 1.00, Pearl millet = Rs 1.00, Soy4bean = 0.25, Greengram = Rs 2.00, Groundnut Rs 3.00, Rabi: Sale price for grain (kg^{-1}) : Maize (green cobs)= Rs 5/kg, Pearl millet = Rs 13.30, Soybean = Rs 27.75, Bt Cotton = Rs 41.60, Sunflower = Rs 39.50, Groundnut = Rs 42.20, Sesame = Rs 50.00, Castor = Rs 35.00, Potato = Rs 25.00; Sale price for stover (kg^{-1}) : Maize = Rs 1.00, Pearl millet = Rs 1.00, Greengram Rs 2.00, Groundnut Rs 3.00

Table 2: Economics of crops under the bio-intensive complementary cropping systems

Treatment		*Kharif*				*Rabi*				System	
Kharif-Rabi		Cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns		Cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns		Net returns	
				Rs. ha^{-1}	Rs. Re^{-1}			Rs. ha^{-1}	Rs. Re^{-1}	Rs. ha^{-1}	Rs. Re^{-1}
T1	Maize – Sunflower (Check)	43065	74636	31571	0.73	26893	29704	2811	0.10	34382	0.49
T2	Pear millet + Soybean (3:2) - Potato	20460	25595	5135	0.25	58053	66225	8172	0.14	13307	0.17
T3	Maize - Groundnut	43065	79524	36459	0.85	35150	40561	5411	0.15	41870	0.54
T4	Pear millet + Soybean (3:2) – Sunflower + Groundnut (2:3)	20460	23775	3315	0.16	33168	45224	12056	0.36	15371	0.29
T5	Maize + Soybean (2:3) – Potato	47390	67355	19965	0.42	58053	64325	6272	0.11	26237	0.25
T6	Bt cotton + Soybean (1:3) – Sesame + Groundnut	56250	102595	46345	0.82	27886	36017	8131	0.29	54476	0.65
T7	Maize (Flat) + Soybean (RB) – Castor (F)+ Green gram (RB) (2:3)	49390	69101	19711	0.40	27793	50447	22654	0.82	42365	0.55
T8	Bt cotton + Greengram (1:3) - Pearl millet	53350	102206	48676	0.91	17005	20034	3029	0.18	51705	0.73
T9	Soybean - Potato	27560	33774	6214	0.23	58053	71800	13747	0.24	19961	0.23
T10	Bt cotton + Green gram (1:2) –Sesame	51370	94795	43425	0.85	15995	17800	1805	0.11	45230	0.67
T11	Pearl millet – Groundnut	16140	18849	2709	0.17	35150	42678	7528	0.21	10237	0.20
T12	Bt Cotton+ Green gram (1:2) –Maize for green cobs	51370	90506	39136	0.76	30930	70614	39684	1.28	78820	0.96

Table 3: Efficiency of crops under the bio-intensive complementary cropping systems

	Treatment	Total duration of the system (days)	Production efficiency (kg ha^{-1}day^{-1})	Land use efficiency (%)	Economic efficiency (Rs ha^{-1}day^{-1})	Total water use of the system (mm)	Water productivity (kg ha^{-1}mm^{-1})	Employment generation (Man days)
T1	Maize – Sunflower (Check)	234	32.67	64	146.93	989.5	10.92	87
T2	Pear millet + Soybean (3:2) - Potato	214	31.43	59	62.18	863.6	11.21	127
T3	Maize - Groundnut	222	39.63	61	188.60	989.5	12.57	102
T4	Pear millet + Soybean (3:2) – Sunflower + Groundnut (2:3)	226	22.37	62	68.01	963.6	7.22	136
T5	Maize + Soybean (2:3) – Potato	222	43.45	61	118.18	939.5	14.84	121
T6	Bt cotton + Soybean (1:3) – Sesame + Groundnut	284	35.76	78	191.82	853.2	18.46	151
T7	Maize (Flat) + Soybean (RB) – Castor (F)+ Green gram (RB) (2:3)	309	28.34	85	137.10	939.5	13.47	130
T8	Bt cotton + Greengram (1:3) - Pearl millet	290	30.83	79	178.29	972.3	16.26	118
T9	Soybean - Potato	194	39.87	53	102.89	879.5	11.90	108
T10	Bt cotton + Green gram (1:2) –Sesame	284	29.05	78	159.26	853.8	15.00	119
T11	Pearl millet – Groundnut	214	21.07	59	47.84	913.6	6.94	102
T12	Bt Cotton+ Green gram (1:2) –Maize for green cobs	260	45.40	71	303.15	853.8	21.46	114

Conclusion

It can be inferred that alternate systems gave better results in terms of productivity and in water use efficiency in comparison to prevailing maize-sunflower system in Southern Telangana Zone. Cotton + green gram (1:2)–maize for green cobs system recorded highest MEY (11803 kg ha^{-1}) with Rs 78,820 ha^{-1} net returns followed by *Bt* cotton + soybean (1:3) – sesame + groundnut (T6) system (10155 kg ha^{-1}) along with higher PUE, MSE, LUE and water productivity.

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