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Effect of bio-intensive complimentary cropping systems on crop yield, productivity, profitability and resource use efficiencies

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Abstract

A field experiment was conducted at Project Directorate for Cropping Systems Research, Modipuram for three years on sandy loam soil and laid out in randomized block design involving 10 cropping systems in three replications. Among various cropping systems maize (*Zea mays*L.)(cob) + vegetable cowpea (*Vigna sinensis* L.) on broad beds (BB) + sesbania (*Sesbania sesban*) in furrows – lentil (*Lens esculenta* L.) on BB + mustard (*Brassica juncea* L.) in furrows -green gram (*Vigna radiata* L.) for grain + residue on beds produced the highest rice equivalent yield (24.67 t/.ha/year) with productivity of 67.60 kg grain/ha/day and profitability of Rs. 547 /ha/day. Water use productivity of 591.3 kg grain/ha cm of water and nutrient use productivity of 61.7 kg grain/kg nutrient was also found to be highest in this system. On the other hand the water use productivity (78.4 kg grain/ha cm of water) was found to be lowest in rice (*Oryza sativa* L.)- wheat (*Triticum aestivum* L.) and nutrient use productivity (22.6 kg grain/kg) with sorghum (*Sorghum bicolor* L.) (grain) + cowpea (*Vigna sinensis* L.) (V)-oat (*Avena sativa* L.) (f)-pearlmillet (*Pennisetum typhoides* L.) (f)- cluster bean (*Cyamopsis tetragonoloba* L.)(V) system. Bio-intensive system, was also found to be remarkably better which resulted rice equivalent yield (22.83 t/ha/year) with productivity (62.55 kg grain/ha/day) and profitability (Rs. 514 /ha/day). The input energy was found to be in the range of 45218 to 100231 MJ/ha with highest in maize (*Zea mays* L.) +cowpea (*Vigna sinensis* L.) (f) – maize (*Vigna sinensis* L.) + black gram (*Vigna mungo* L.)– wheat+methi (*Trigonellafoenum-graecum*)(6:1)-green gram (*Vigna radiata* L.). The energy ratio was found to be highest (18.5) with sorghum +cluster bean (*Cyamopsis tetragonoloba* L.) (f)-maize (*Zea mays* L.) (Cobs)+black gram (*Vigna mungo* L.)(1:1)– methi (*Trigonellafoenum-graecum*)–cowpea (*Vigna sinensis* L.) (V+R) and (17.30) followed by sorghum (*Sorghum bicolor* L.) (grain) +cowpea (*Vigna sinensis* L.) (V)-oat (f)-pearlmillet (*Pennisetum typhoides* L.) (f)+cluster bean (*Cyamopsis tetragonoloba* L.) (V).

Key words: *Complimentary Cropping systems, Energy consumption, Nutrient use productivity, Rice equivalent yield*

Introduction

Improvement in productivity with input use efficiencies, reduction in cost of cultivation and creating gainful employment are considered very crucial in present day scenario of Indian agriculture. A concept of complementary intensive intercropping system was conceived to deal such issues (Gangwar, 1983). Further, due to continued fragmentation of land holdings, the average holding size of marginal farms reduced to 0.38 ha (2010-11). Therefore, the strategy needed to produce more output from less resource, especially to ensure high income by small and marginal farmers. Using various land configurations offers scope for growing more than two crops in association at the same time in the same piece of land. Moreover, we have to consider the soil health and also changing climate scenarios and to think of climate smart systems with enhanced biological productivity aims for more biomass productions both above and below ground (*Rizosphere)* from root biomass. Keeping these issues in mind the concept of "Bio-intensive complimentary cropping systems" was conceived by the senior author during 2008. Latter further refined considering emerging scenarios' in agriculture in developing countries. The concept of "Bio-intensive complimentary cropping system" was defined as growing of morphologically and physiologically different two or more than two crops in association under different land configurations which complements each other and subsequent crops on one hand and saves the resources on the other. Under such systems, not only the higher productivity and total

biomass yield both above & below ground along with enhanced microbial activity could be achieved but a lot of resources could also be saved. As understood, the microbes play a very important role in such systems for improving the yield of crops, by improving soil health, more judicious use of water, nutrients, radiant energy may result in resource saving too. To study all these aspects the present study was undertaken.

Materials and methods

A field study was conducted during 2010 to 2013 at Project Directorate for Farming Systems Research (now IIFSR), Modipuram, Meerut involving ten bio-intensive complementary cropping systems along with land configurations, in-situ green manuring, residue incorporation, zero/minimum tillage and inter cropping. The soil of the experimental plot was sandy loam containing initial level of 125.4 kg/ha available nitrogen, 24.5 kg/haP_2O_5 and 126.2 kg/haK_2O. The treatments were laid out in RBD replicated three times. In control treatment (T_0), the crop of rice (*Oryza sativa* L.)-(Saket4) and wheat (*Triticum aestivum* L.) (PBW 343) were grown using conventional package of practices. Under treatment T_1, after harvest of hybrid rice (*Oryz asativa* L.)(PRH10)-wheat (*Triticum aestivum* L.) was grown in furrows while lentil (*Lens esculenta* L.) (Pant lentil4) grown on ridges using FIRB system. In treatment T_2, the broad bed and furrow system (BBF) was adopted. On broad beds (105 cm width), maize (*Zea mays* L.) hybrid (Ankur56) for cobs was sown at the spacing of 70x20 cm and a row of vegetable cowpea (*Vigna sinensis* L.) (Gomti) was grown in between two rows of maize while *sesbania* (*Sesbania sesban*) was grown in furrows (30 cm wide) and was incorporated after 32 days after sowing during *kharif*. Three pickings of vegetable cowpea (*Vigna sinensis* L.) were taken and foliage harvested alongwith maize green straw for feeding to cattle. In *rabi,* mustard (*Brassica junceaL.*) (Pusa bold) was grown in furrows, while three rows of lentil (*Lens esculenta* L.) (Pusa lentil 4) were grown at 30 cm in rows on beds using minimum tillage. In summer, 3 rows of greengram (*Vigna radiata* L.) (SML 668) at 30x10 cm were sown on beds with zero till machine for grain + residue incorporation and the furrows were used for light irrigations. In sequence T_3, maize (*Zea mays* L.)Ankur 56 for (grain) + blackgram (*Vignamungo* L.)(Pant urad 35) for grain in *kharif* while in *rabi*, furrow irrigated raised beds were used for growing vegetable pea (*Pisum sativum* L.) (Arkel)-green gram (*Vigna radiata* L.)(SML 668) in summer for grain and green residue incorporation.

In T_4, between two rows of maize for cobs;one row of sesbania(*Sesbania sesban*) was grown in *kharif* and incorporated after 32 days after sowing. In *rabi*,toria (*Brassica napus*) (Type 9)was sown and gobhisarson(*Brassica napus*) hybrid(Hyola-401) was transplanted between the two rows of toria in the month of December. In summer, green gram (*Vigna radiata* L.) (SML 668) was sown for grain. After harvesting of pods, the residue was incorporated. In treatment T_5, sorghum(*Sorghum bicolor* L.)(Kanpuri) + cluster bean (*Cyamopsis tetragonoloba* L.) (Gayatri 71) for fodder was grown in *kharif* and maize (cob) + black gram was sown in August. After its harvest in last week of November methi (*Trigonellafoenum-graecum*) (Kasuri) was sown first week of December. While in summer, vegetable cowpea (Gomti) was grown and foliage incorporated in the soil. In T_6, pigeonpea (*Cajanuscajan* L.) (UPAS 120) + blackgram (*Vigna mungo* L.) (Pant urd 35) was sown in June (*kharif*) followed by wheat (PBW 226) sown in last week of December and cowpea fodder using zero till approach in summer. In T_7, pigeonpea (Cajanus cajan L.) was sown in *kharif*, late sown wheat (*Triticumaestivum* L.) + methi (*Trigonellafoenum-graecum*)in *rabi* and cowpea fodder raised using zero till in summer.In treatment T_8,maize (*Zea mays* L.) + cowpea (*Vigna sinensis* L.) for fodder was grown in *kharif* and after its harvest, maize (cob) + black gram was sown in the month of August. In summer, vegetable cowpea was taken and foliage incorporated in the soil. In treatment T_9, sorghum (*Sorghum bicolor* L.)(CSH 16) + vegetable cowpea during *kharif*, oat (Kent) during *rabi* and pearl

millet for fodder + vegetable cluster bean (Gayatri 71) were included in the study. The details of packages used in different systems are described in (Table.1)

The prevailing rates of different crops were used to calculate the rice equivalent yield (REY). The system productivity and profitability was calculated by dividing REY and net returns by 365. The irrigation system productivity was calculated by dividing the crop equivalent yield by the total amount of irrigation water was used to grow the crop(Katyal and Gangwar2011). Similarly, nutrient use productivity was calculated by dividing the rice equivalent yield by the total quantity of nutrients used in the cropping system. The energy production and specific energy under different cropping systems were calculated using the procedures as described by (Gopalan*et al.* 1978).

Results and Discussion

Equivalent yield, system productivity and profitability

Raising of maize for cobs + vegetable cowpea in 1:1 ratio on broad beds (BB) and sesbania in furrows during *kharif* and mustard in furrows and 3 rows of lentil on broad beds in *rabi* while 3 rows of green gram on beds in summer was found to be highest yielder of 24.67 t/ha/year as rice equivalent with productivity of 67.60 kg grain/ha/day and profitability of Rs. 547/ha/day (Table 1). Bio-intensive system of raising maize + cowpea (for fodder) during *kharif*- maize (cobs) + black gram as late (August) - wheat + methi in 6:1 ratio during *rabi* and green gram in summer was also found to be remarkably better which resulted in 22.83 t/ha/year rice equivalent yield with productivity of 62.55 kg grain/ha/day and profitability Rs. 514/ha/day (Table 2). This system provided to be second best in the order of merit. The complimentary effects in the system reflected due to broad bed and furrow (BBF) system of land configuration, the furrows served as drainage channels during heavy rains in *kharif* which were utilized for *in-situ* green manuring with 35 t/ha green foliage incorporated after 35 days of sowing and then mustard was timely sown in these furrows and a bonus yield of lentil intercropped with mustard could be harvested. Besides the yield advantage, around 40% of irrigation water could be saved as applied only in furrows. In summer, harvest of green gram pods for grain while incorporation of its green foliage of about 8 t/ha in the soil further helped the system favourably (Table 3).

Water use productivity and nutrient use productivity

Water use productivity591.3kg grain/ha cm of water and nutrient use productivity61.7 kg grain/kg) nutrient (Table 2) was found to be highestinmaize (C) +vegetable cowpea (BB)+Sesbania (F)-lentil(BB)+mustard(F)-green gram (G+R) system indicating efficient utilization both to applied nutrient and water. Water use productivity 78.4 kg grain/ha cm of water was found to be lowest in rice-wheat and nutrient use productivity 22.6 kg grain/kg was found to be lowest with sorghum (G) + cowpea (V) -oat (f)-pearl millet(f) + cluster bean (V) system (Table 4).

Energy consumption and output

The input energy required for production was found to be in the range of 45218 to 100231 MJ/ha with highest in maize+cowpea (f)-maize+blackgram–wheat+methi (6:1)-green gram (G+R) and lowest in maize (G) +black gram (1:1)-vegetable pea (FIRB) +mustard (F)-green gram (G+R). However, the specific energy 2.08 MJ/kg (i.e energy required to produce one kg of grain) was found to be lowest in maize(C)+vegetable cowpea (BB)+*Sesbania*-lentil(BB)+mustard(F)-greengram(G+R) and highest with sorghum (G) + cowpea (V) -oat (f)-pearl millet(f)+ cluster bean (V).The energy ratio was found to be highest(18.5)with sorghum+cluster bean (f)-maize(C)+black gram (1:1)-methi-cowpea (V+R) and 17.30 followed by sorghum(G)+cowpea (V)-oat (f)-pearl millet(f)+ cluster bean (V) (Table 4).

The present study conclusively revealed that under small and marginal farming situations the bio-intensive complementary cropping systems may result in highly significant increase in productivity and profitability on one hand and save the resources upto 50% on the other. However, deserves further investigations under both inorganic and organic situations at various locations.

Table1. Details of package of practices used for different crops

Tret.	Kharif	Pre rabi	Rabi	Summer
		Crop, Variety, Duration and Fertilizer dose (kg/ha) used		
T0	Rice, Saket 4, 115 (120:60:40:25)	-	Wheat, PBW 343, 150 (120:60:40)	-
T1	Hybrid rice,PRH 10, 115 (150:60:40:25)	-	Lentil, Pusa lentil 4, 135 Wheat, PBW 343, 150 (120:60:40)	Cowpea, Gomti, 75 (20:50)
T2	Maize (Cob) , Ankur-56, 100 (120:60:40) Vegetable cowpea, Gomti, 100 Sesbania, Local, 35	-	Lentil, Pusa lentil 4, 135 Mustard, Pusa bold, 135, (20:60:30)	Green gram, SML 668, 75 (20:50)
T3	Maize (Grain), Ankur-56, 120 (120:60:40) Black gram, Pant Urd 35, 75	-	Vegetable pea, Arkel, 70 Mustard, Pusa Bold, 135, (20:60:30)	Green gram, SML 668, 75 (20:50)
T4	Maize(Cob) , Ankur-56, 100 (120:60:40) Sesbania, Local, 35	Toria, T 9, 90, (60:60:40) GobhiSarson, Hyola-401(Hybrid), 140	-	Green gram, SML 668, 75 (20:50)
T5	Sorghum (f), Kanpuri, 60, (80:40) Cluster bean, local, 60	Maize(Cob), Ankur-56, 100 (120:60:40) Black gram, Pant Urd, 35, 75	Methi, Kasuri, 135, (25:25:50)	Cowpea, Gomti, 75 (20:50)
T6	Pigeonpea, UPAS 120, 120, (20:80:40) Black gram, Pant Urd 35, 75	-	Wheat, PBW 226, 135, (120:60:40) Mustard, Pusa Bold, 135	Cowpea (f), Local, 75, (20:50)
T7	Pigeonpea, UPAS 120, 120, (20:80:40)	-	Wheat, PBW 226, 135, (120:60:40) Methi, Kasuri, 135	Cowpea (f), Local, 75, (20:50)
T8	Maize (f), local, 65, (60:40) Cowpea (f), local, 65	Maize (Cob), Ankur-56, 100 (120:60:40) Black gram, Pant Urd 35, 75	Wheat, PBW 226, 135, (120:60:40) Methi, Kasuri, 135	Green gram, SML 668, 75 (20:50)
T9	Sorghum(Grain), CSH 16, (100:50:40) vegetable cowpea, Gomti, 100	-	Oat (f), Kent, 120, (90:40)	Pearl millet (f), local, 60, (100:40:30) vegetable cluster bean, Gayatri 71, 90 (60:40:30)

Table 2.Crops yield (t/ha.) as influenced by cropping systems grown in varying management configurations

Treatment/crops grown				Actual yield (t/ha)														Ave. of 3 years REY (t/ha)
				I st Year(2010-11)				REY (t/ha)	II nd Year (2011-12)				REY (t/ha)	III rd Year (2012-13)				REY (t/ha)	
Kharif	Pre *rabi*	*Rabi*	Summer	*Kharif*	Pre *rabi*	*Rabi*	Summer		*Kharf*	Pre *rabi*	*Rabi*	Summer		*Kharf*	Pre *rabi*	*Ravi*	Summer		
T0-Rice	-	Wheat	-	5.11		4.16		9.96	5.00		6.28		13.26	5.11		5.17		11.26	11.49
T1-Hybrid rice	-	L (B)+W (FIRB)	Cowpea (V+R)	6.33		0.72+ 2.98	0.79	13.74	6.11		0.16+ 3.16	1.92	15.10	6.28		0.18+5.05	0.76	13.89	14.24
T2-Maize(C) +Veg. Cowpea (BB) +Ses. (F)	-	L(BB)+Mu (F)	Green gram (MT) (G+R)	8.61+ 0.60		1.35+ 1.84	1.59	21.86	10.22+0.92		1.47+ 2.02	1.25	24.60	10.94+1.08		1.33+2.00	1.66	27.56	24.67
T3-Ma (G)+Black gram (1:1)	-	Veg. pea (FIRB)+Mu (F)	Green gram (G+R)	2.72+ 0.37		1.03+ 1.86	1.43	21.57	2.50+0.51	-	0.58+2.05	1.11	15.37	2.33+ 0.45	-	0.83+0.94	1.60	15.11	17.35
T4-Ma (C) +Sesbenia.	Toria+Gobhisarson(TPT)		Green gram (ZT) (G+R)	8.72	1.17+ 1.05		1.63	16.62	10.44	0.80+ 0.67		1.08	16.12	11.67	1.39		1.54	20.30	17.68
T5-Sorgum+C. bean (f)	Maize(C) + B. gram (1:1)	Methi	Cowpea (V+R)	38.33	7.72 + 0.37	0.75	0.77	11.49	37.38	10.44+ 0.42	2.33	1.94	17.84	23.94	12.67+0.44	2.28	0.74	23.94	17.76
T6-P. pea+B. gram (1:1)	-	W+Mu (6:1) (ZT)	Cowpea (f) (ZT)	1.96+ 0.37		4.38+ 0.86	25.00	18.30	1.40+ 0.43		5.38+ 0.08	25.00	16.32	15.38		4.61+0.08	23.34	15.38	16.67
T7-Pigeonpea	-	W+Methi (6:1)(ZT)	Cowpea (f) (ZT)	1.78		4.21+ 0.42	28.00	15.76	1.79		5.11+ 0.06	21.94	15.49	1.80		4.53+0.07	26.27	14.84	15.36
T8-Ma+Cowpea (f)	Maize(C) + B. gram	W+Methi (6:1)	Green gram(G + R)	25.83	7.83 + 1.04	4.05+ 0.39	1.36	20.87	22.33	6.39+ 0.46	5.83+ 0.05	1.00	24.24	27.66	11.72+0.36	4.50+0.2	1.33	23.38	22.83
T9-So(G) + Veg. Cowpea CD (P=0.05)	-	Oat (f)	Pearl millet(f) + veg. C. bean	1.17 + 1.40		31.66	31.6+ 0. 25	6.55	2.35+ 0.88		51.67	46.38+ 0.33	11.15	2.50+ 2.17		52.78	47.40	15.47	11.06 5.13

L: lentil, V:vegetable, R: Residue, C: Cobs, Mu: Mustard, F:Furrow, BB: Broad Bad, Ma: Maize, G: Grain, Ses: Sesbania, ZT: Zero Till, So: Sorghum, C. bean: Cluster bean, W:Wheat, f: fodder

Table 3.Effect of bio-intensive complementary cropping systems on higher productivity and profitability under different systems as alternative to rice-wheat (pooled of 3 years)

Treatment	REY (t/ ha)	Productivity (kg/ha/day)	Net returns (Rs./ha)	Profitability (Rs./ha/day)
Rice-wheat	11.49	31.49	84406	231
Hybrid rice-lentil (B)+wheat (FIRB)-cowpea (V+R)	14.24	39.01	109909	301
Maize(C)+vegetable cowpea(BB)+sesbania (F)-lentil(BB)+mustard(F)-green gram (MT) (G+R)	24.67	67.60	199482	547
Maize (G)+black gram (1:1)-vegetable pea (FIRB)+mustard (F)-green gram (G+R)	17.35	47.53	102054	280
Maize (C)+sesbania -toria+gobhisarson(TPT)- green gram (ZT) (G+R)	17.68	48.43	121978	334
Sorghum+cluster bean (f)-maize(C)+black gram (1:1)-methi-cowpea (V+R)	17.75	48.64	131020	359
Pigeonpea+black gram (1:1)-wheat+mustard (6:1)(ZT)-cowpea (f) (ZT)	16.67	45.66	138806	380
Pigeonpea-wheat+methi (6:1)(ZT)-cowpea (f) (ZT)	15.36	42.09	129455	355
Maize+cowpea (f)- maize(C)+black gram- wheat+methi (6:1)-green gram(G+R)	22.83	62.55	187695	514
Sorghum(G) + vegetable cowpea -oat (f)-pearl millet(f)+vegetable cluster bean	11.06	30.29	53828	147
CD (P=0.05)	5.13	14.06	55425	152

Note: MT (Minimum tillage), ZT (Zero tillage)
L: lentil, V:vegetable, R: Residue, C: Cobs, Mu: Mustard, F:Furrow, BB: Broad Bad, Ma: Maize, G: Grain, Ses: Sesbania, ZT: Zero Till, So: Sorghum, C. bean: Cluster bean, W:Wheat, f: fodder

Table4.Irrigation water use productivity, nutrient use productivity, energy consumption and output underdifferent bio-intensive cropping systems(pooled of 3 years)

Treatment	IWUP (kg grain/ha cm of water)	NUP (kg grain/ kg nutrient)	Input energy (MJ/ha)	Output energy (MJ/ha)	Energy ratio	Specific energy (MJ/kg)
Rice-wheat	78.42	24.72	77321	330110	4.27	6.82
Hybrid rice-lentil (B)+wheat (FIRB)-cowpea (V+R)	84.59	24.34	67796	666636	9.84	4.77
Maize(Cob)+vegetable cowpea(BB)+sesbania (F)-lentil(BB)+mustard(F)-green gram (MT) (G+R)	591.25	61.68	51105	591159	11.58	2.08
Maize (G)+black gram (1:1)-vegetable pea (FIRB)+mustard (F)-green gram (G+R)	477.70	38.55	45218	345505	7.64	2.68
Maize (C)+sesbania-toria+gobhisarson(TPT) green gram (ZT) (G+R)	323.03	39.28	82577	521204	6.40	4.69
Sorghum+cluster bean (f)-maize(Cob)+black gram (1:1)-methi-cowpea (V+R)	237.09	32.28	62260	1151793	18.50	3.84
Pigeonpea+black gram (1:1)-wheat+mustard (6:1) (ZT)-cowpea (f) (ZT)	370.37	38.76	58883	554381	9.42	3.54
Pigeonpea-wheat+methi (6:1)(ZT)-cowpea (f) (ZT)	341.41	35.73	57110	547385	9.59	3.72
Maize+cowpea (f)-maize(Cob)+black gram-wheat+methi (6:1)-green gram(G+R)	331.53	32.16	100231	872642	8.71	4.41
Sorghum(G)+vegetable cowpea-oat (f)-pearl millet(f)+vegetable cluster bean	197.43	22.56	79370	1373324	17.30	8.12

Note: IWUE- Irrigation Water use productivity, NUE- Nutrient use productivity, MT- Minimum tillage, ZT- Zero tillage and TPT- Transplanting technology
L: lentil, V:vegetable, R: Residue, C: Cobs, Mu: Mustard, F:Furrow, BB: Broad Bad, Ma: Maize, G: Grain, Ses: Sesbania, ZT: Zero Till, So: Sorghum, C. bean: Cluster bean, W:Wheat, f: fodder

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