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Resource recycling and their management under integrated farming system for lowlands of Bihar

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ABSTRACT

A field experiment was conducted at main farm of ICAR Research Complex for Eastern Region, Patna during 2007–10 to study resource recycling from different IFS models and to identify a suitable combination of components for maximum returns and employment generation under lowland situation of Bihar. Different combination of crop, animals, fishes and birds were examined in form of seven integrated farming systems (IFS) models. Among different IFS models crop + fish + duck + goat emerged as the best integrated farming system in terms of productivity, sustainability index (0.80%), net return (₹ 1 59 485/year) and employment generation (752 man-days/year) apart from addition of appreciable quantity of N, P_2O_5 and K_2O into the system in form of recycled animal and plant wastes. Crop + fish +duck + goat and crop + fish + cattle integration recorded nearly equal amount of rice- grain-equivalent yield. (21.20 and 21.18 tonnes/ha, respectively) but in terms of economics crop + fish +duck + goat supersedes by ₹ 30 870. The waste material/by products of crops and animals were recycled and used as inputs for other components of integrated farming system. Crop + fish + cattle model added higher quantity of N P and K overall other models.

Keywords: Integrated farming system, IFS models, Nutrient recycling, Productivity

In Bihar crop productivity trends have been below the Indian average for most cereal crops, and far below their potential yield, even after Bihar's fertile land and water resources. About 85% of the farmers are small and marginal but sharing only 50% of the land. The average size of the holding is 0.83 ha, with that of small and marginal farmers range from 0.32 to 0.5 ha (Barua 2001). With the average size of land holdings shrinking as a result of increasing fragmentation, many marginal farms are becoming economically non-viable and oriented towards subsistence. Due to failure of monsoon, the farmers are forced to judicious mix up of agricultural enterprises like dairy, poultry, pigeon, fishery, sericulture, apiculture etc., suited to their agro-climatic and socio-economic condition and largely dependent on the farm size. To overcome the problems of small resource poor farmers, diverse and risk prone environments has led to the development of a more holistic, resource based, client oriented and interacting approach, popularly known as integrated farming system. Integrated farming system is a reliable way of obtaining high productivity with substantial nutrient economy in combination with maximum compatibility and replenishment of organic matter by way of effective recycling of organic residues/wastes etc. obtained through integration of various land- based enterprises (Gill *et al.* 2010).

There is a huge population of cattle in Bihar and also in the eastern India. As a tradition every households possess 1–2 cows/buffaloes or 3–4 goats. The waste material (dung) of these animals are generally used as fuel by making dung-cakes and a very few quantity goes for FYM or compost production. If these materials are recycled within the farm a sizeable amount of money spent on chemical fertilizers can be saved. Likewise, the plant debris, viz leaves, roots, stem, weeds of vegetables and other crops could be converted into vermicompost and recycled to the crops in a system mode. These farmers can go for a suitable crop along with horticulture, animals, fisheries and other components that would minimize risks and provide additional income and employment from the same piece of land per unit time, apart from improving soil fertility over a period of time. Integrating different components with crop will increase the profitability through recycling of wastes of one component into another. Therefore, the present investigation on resource recycling from different IFS models was envisaged to identify a suitable combination of components for maximum returns and

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employment generation.

MATERIALS AND METHODS

Field studies were carried out at main farm of ICAR Research Complex for Eastern Region, Patna during 2007–10. Seven treatments (farming systems) involving field crops, vegetables, poultry, cattle, goat, mushroom farming, fishery and duckery were taken for evaluation in different combinations to recycle the residues and by products of one component over the others. Each system was allocated an area of 0.8 ha (2 acre). These systems were: (i) crop alone, (ii) crop+fish+poultry, (iii) crop+fish+duck, (iv) crop+fish+goat, (v) crop+fish+ duck+goat, (vi) crop+fish+cattle, and (vii) crop+fish+mushroom. The soil of the experimental block was clay loam in texture, having *p*H 6.6, electrical conductivity 0.44 ds/m, organic carbon 0.59 (kg/m^3), available N 186.0 kg/ha, available P 6.1 kg/ha and exchangeable K 211.0 kg/ha. The size of the experimental block was 4.0 acre. In a 2 acre (0.8 ha) farm, 0.1 ha was assigned for growing fodder crops to feed cattle (3 cows+3 calves) and goat (20 female goat + 1 buck), 0.02 ha allocated for goat shed, 0.02 ha for cattle shed, 0.02 ha for mushroom shed, 0.02 ha for FYM and vermi-pits and 0.12 ha allotted to two fish ponds. The cropping area of each system varied depending upon the area occupied by different components/enterprises, which vary from 0.54 to 0.66 in different farming systems.

Two cropping systems, viz rice (*Oryza sativa* L.) – wheat (*Triticum aestivum* L. emend Fiori. & Paol.) – mungbean and rice – maize (*Zea mays* L.)– mungbean were taken each in 0.4 ha under system mode. Crops were raised with 50% of organic manures from different sources in combination with 50% of chemical fertilizers. Poultry and duckery recycled silts were used once in a year ie in the rice crop whereas; other organic sources were used in all the crops in the sequence. In the treatment crop alone, rice–wheat, and rice– maize were taken each in 0.4 ha with chemical fertilizers as per farmers' practices. Summer maize – napier grass (*Pennisetum purpureum* Schum.) – berseem (*Trifolium alexandrinum*) fodder system was followed in 0.1 ha of land.

Hundred numbers of poultry birds, 35 ducks sheltered over two fish ponds and cattle unit (three cows) maintained in cattle shed were linked to supplement the feed requirement of polycultured fingerlings (300 numbers) reared in each pond to assess the feasibility of rearing fishes by using different manure as feed. Vermi-pits and FYM pits were also linked with cattle and crops. To sustain the productivity of soil, inorganic fertilizers combined with organic wastes obtained from various components of IFS recycled poultry, duckery and cowdung as FYM, composted residues (veg. residues + cereal residues) and vermicompost each @ 10 tonnes/ha were applied to the crops.

Under goatry component, 20 female goats + 1 buck (Black Bengal) were reared for meat purpose and goat droppings were used as goat manure to the crops. In one year, 60 kids were reared and sold at the age of 9–10 months @ ₹ 100/kg live weight). Under poultry component, one-day old broiler chicks of Ross breed were reared in batches.100 broiler chicks/batch (total 9 batches/year) were maintained. Each batch was maintained for 40 days and broilers attained an average weight of 1.5 kg during the period and were sold @ ₹ 60/kg live weight. Twentyfive per cent of poultry droppings/litters were used in pond as feed for fishes and 75% of droppings were used in the crops as manure.

Under fishery component, mixed fish farming was practised. Fresh water fish, rohu (*Labeo rohita*) as column feeder (30%), catla (*Catla catla*) and silver carp (*Hypophthalmicthys molitrix*) as surface feeder (30%), mrigal (*Cirrhinus mrigala*) and common carp (*Cyprinus carpio* var. *communis*) as bottom feeder (40%) were raised in both the ponds. At the end of first year, the grown up fishes were harvested thrice at 20 days interval. Water in the ponds were drained and dried and selted silts (5 tonnes) were removed and applied as organic source to the first crop in the sequence. In duckery (Khakhi Campbell), 30 female and 5 male ducks were integrated with the pond. Droppings of ducks were fed to fishes and no extra feed was provided to the fishes. Number of eggs laid/annum were recorded.

Year-round mushroom production was also included in the system in an area of 0.02 ha by making a small hut with available local materials. From March–September, paddy straw mushroom (*Volvariella* spp) and milky mushroom (*Calocybe indica*) whereas, from October to February, Oyster mushroom (*Pleurotus* spp) were raised by making bamboo racks in the shed. Proper humidity (75–80%) was maintained in the hut during the crop season by sprinkling water over the walls of hut and over the bags. Proper agronomic management to all crops and health and hygiene were maintained to animals and birds.

Concentrate feed for animals and poultry were purchased from market and expenditures on these items were included in the cost of production. Observations were made on productivity in terms of rice grain equivalent, economics and employment for different farming systems. Economics were calculated on prevailing market price of different commodities, viz rice grain @ ₹ 12/kg, poultry @ ₹ 60/kg, duck egg @ ₹ 3/egg (or say ₹ 30/kg), goat meat @ ₹ 150/kg, milk @ ₹ 20/lit. and fish @ ₹ 70/kg.

The IFS models were evaluated based on sustainability index (S I) as described by Vittal *et al* (2002). The S I for any IFS model can be computed as: S I = (NR–SD) / (MNR) where, NR stands for net returns obtained under any model, SD stands for standard deviation of net returns of all models and MNR stands for maximum net returns attained under any model. A suitable and viable IFS model could be identified for their existence based on net return, sustainability index, employment generation and improvement in soil fertility attained over a period of time.

RESULTS AND DISCUSSION

Productivity and sustainability index

Integrated farming system provides an opportunity to increase yield and economics per unit area per unit time by virtue of intensification of crops and applied enterprises. To compare the productivity of different systems, yield of each component, (viz crop/fish/duck/poultry/goat/cattle/ mushroom) was converted into rice-grain-equivalent yield. The contribution of crops towards the system productivity ranged from 57.1 to 81.1%, while fish ranged from 8.5 to11.8%; for goat 26.6 to 28.7%; for poultry 24.2%; for duck 7.4 to 10.1%; for cattle 34.4% and for mushroom 7.2% (Table 1). Results on different combinations for three years revealed that integration of crop + fish + duck + goat resulted in highest system productivity in terms of rice-grain equivalent yield. Crop + fish + duck + goat and crop + fish + cattle model recorded 130% more productivity over cropping alone. Similarly crop + fish + goat model gave 113% higher productivity than growing crops alone. Besides inorganic fertilizer application of recycled pond silt, poultry manure, duck manure, goat manure and cowdung as FYM, composted residues (cereal residues) and vermicompost under different IFS module provide congenial situation to increase the yield. Kumar *et al.* (2011) also opined that an integrated farming system is much better over existing cropping system. Among different cropping sequences, under IFS compared, rice–maize mungbean recorded higher average mean yields of 13.25, 12.86, 13.11, 12.94 and 13.07 tonnes when applied with recycled fish pond silt + poultry manure, duck manure, goat manure, cattle manure and vermicompost, respectively than rice–wheat–mungbean cropping sequence (Fig 1). However, rice–maize–mungbean sequence registered higher average productivity of 13.25 tonnes with recycled pond silt

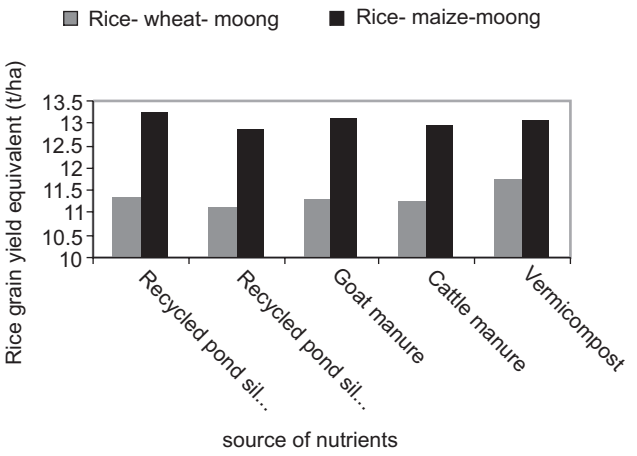

Fig. 1 Productivity (RGEY) of different cropping sequences (mean yield of 2007–10)

+ poultry manure (50 + 50%), followed by vermicompost in combination with 50% inorganic fertilizers. An average of 35.2 tonnes of grasses and legume mixture (maize–napier–berseem) was also obtained from 0.1 ha/year, and was utilized as feed for animals.

Crop + fish + duck + goat and crop + fish + cattle integration recorded nearly equal amount of rice grain equivalent yield, ie 21.20 and 21.18 tonnes/ha respectively (Table 2). but in terms of economics crop + fish +duck + goat supersedes (₹ 159485/year). Crops applied with enriched pond silts having higher nutrients and integration of high value components like fish/poultry/duck/goat/cattle might have contributed for better crop productivity. Similar results of high productivity was also reported by Jayanthi *et al* (2003) by integrating crop + fish + goat in lowland farming in Tamilnadu.

Table1 Productivity in terms of rice grain equivalent yield (tonnes/ha) of different models (mean value of 2007–10)

Farming system	Component productivity (RGEY)							RGEY of system (tonnes/ha)
	Crop	Poultry	Fish	Duck	Goat	Cattle	Mushroom	
Cropping alone	9.23 (100)							9.23
Crop + fish + poultry	12.30 (66.1)	4.50 (24.2)	1.81 (9.7)					18.61
Crop + fish + duck	12.00 (78.1)		1.81 (11.8)	1.56 (10.1)				15.37
Crop + fish + goat	12.20 (62.1)		1.81 (9.2)		5.63 (28.7)			19.64
Crop + fish + duck + goat	12.20 (57.5)		1.81 (8.5)	1.56 (7.4)	5.63 (26.6)			21.20
Crop + fish + cattle	12.09 (57.1)		1.81 (8.5)			7.28 (34.4)		21.18
Crop + fish + mushroom	12.42 (81.1)		1.81 (11.8)				1.10 (7.2)	15.33

Figures in parentheses indicate per cent contribution to the total system productivity

While considering the individual animal component, average productivity of 5.63 tonnes was obtained with 20 + 1 goat unit. The goat unit also produced 2.3 tonnes of goat manure, which was used in crops within the system. While, assessing the feasibility of rearing fish by using poultry and duck droppings as feed, the fishes fed with poultry droppings resulted in higher average fish yield of 170 kg/0.06 ha over duck fed droppings (140kg/0.06 ha) during the experimental period (Table 4). A higher level of fish productivity through recycling of poultry manure was reported by Singh *et al* (2004) owing to better plankton development as well as direct feed to fishes.

Income and economics

Net income, production cost and benefit:cost ratio has been studied as individual component wise (Table 2) as well as system wise (Table 3) both. While considering the individual animal component, highest average net return of ₹ 42 746/year was obtained with one (20 + 1) goat unit (Table 2). Poultry (broilers) rearing is economical only when proper care had been taken, otherwise, it is a risky enterprise due to frequent occurrence and breakout of severe pest and diseases leading to 50–100% mortality of the birds, which will result in high degree of economic losses. So, proper hygienic conditions should be maintained and birds should be properly vaccinated (Solaiappan *et al* 2007). Higher net returns and B:C ratio was obtained with application of different droppings/recycled manures used in the crops in combination with 50% inorganic fertilizers over crop raised alone on chemical fertilizers (Table 2) as in case where only crops were taken. The rice grain equivalent yield of crop + fish + cattle model was equal to that of crop + fish + duck + goat model and higher overall other models but when economics of different models were considered then it ranks IV in respect of net returns and sustainability index. This might be due to the fact that cattle rearing incurred higher expenditures (₹ 66 820/year) out of total average system expenditure. (₹ 125 625). This higher expenditure on rearing cattle was because of purchasing concentrates mixtures from the market. Further, if concentrates were prepared at farmers' level with materials produced in the system, expenditure can be lessened by 50% and crop + fish + cattle system can be made more profitable. Kumar *et. al.* (2011) also reported increase in net income through integrated farming system due to use of recycled products within the system. The highest average net returns of ₹ 159 485/year was obtained from an area of 1.0 ha with an average annual expenditure of ₹ 94 915/year by integrating crop + fish + duck + goat combination in the system followed by crop + fish + goat (₹ 1 51 479/year) and crop + fish + poultry (₹ 139 460/year) combinations. Sustainability index was also found higher in both the combinations (80 and 75.1%) respectively (Table 3). Crop + fish + duck + goat model emerged as highest profitable enterprise for irrigated lowlands with an average net return of ₹ 471/day during the period of experimentation. This was due to the fact that system as a whole provided opportunity to make use of byproduct or waste materials, of one component as input on another. Hence, there is possibility for reduction in the cost of production of different enterprises and finally production cost of the system. Results on these combinations for three years revealed that integration of crop +fish +duck + goat also showed higher average sustainability index (80%). All other combinations tested here also resulted in higher av. net returns/year, while their sustainability index varied from 51.5–75.1% over cropping alone. Cropping alone has resulted in lower sustainability index value of 19.3% only. Sustainability Index itself clarifies the benefits from different combinations/unit area. Higher the sustainability index, higher will be the net returns (Vittal *et al* 2002).

Table 2 Productivity (tonnes) and economics (₹) of individual components under developed Integrated farming systems (0.8 ha), mean yield of three years (2007–10)

Component	RGEY (tonnes)	Production cost	Gross returns (₹/ha)	Net returns (₹/ha)	B: C ratio
Cropping alone	7.38	48 000	88 560	40 560	1.8
Crop + poultry manure	9.84	52 120	117 600	65 480	2.3
Crop + duck manure	9.60	52 004	115 200	63 196	2.2
Crop + goat manure	9.76	51 886	117 120	65 234	2.3
Crop + FYM	9.67	51 580	116 040	64 460	2.2
Crop + vermicompost	9.81	52 100	119 280	67 180	2.3
Poultry(100 no./batch)	4.5 (900)	24 600	54 000	29 400	2.2
Duckery (30 + 5)	1.56 (6225no.)	10 990	18 720	7 730	1.7
Goat (20 +1)	5.63 (450)	24 814	67 560	42 746	2.7
Cattle (3+3)	7.28 (4370 lit)	66 820	87 360	20 540	1.3
Mushroom	1.10 (160 kg)	5 620	13 200	7 580	2.3
Fish fed with poultry dropping (0. 06 ha)	0.99 (170 kg)	4 810	11 880	7 070	2.5
Fish fed with poultry dropping (0. 06 ha)	0.82 (140 kg)	4 810	9 840	5 030	2.0

Figures in parentheses denote actual yield

Table 3 Productivity (RGEY) kg/ha and economics of different farming systems (mean value of three years)

Farming system	RGEY (tonnes/ha)	Production cost (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	Net return/ day (₹)	Sustainability index (%)
Cropping alone	9.23	48 000	110 76m0	62 760	172	19.3
Crop + fish + poultry	18.61	83 945	223 405	139 460	382	67.4
Crop + fish + duck	15.36	70 219	184 520	114 301	313	51.5
Crop + fish + goat	19.63	83 925	235 404	151 479	415	75.1
Crop + fish + duck + goat	21.20	94 915	254 400	159 485	437	80.0
Crop + fish + cattle	21.18	125 625	254 240	128 615	352	60.6
Crop + fish + mushroom	16.56	70 799	198 671	127 872	350	60.2
Mean	17.40	82 490	208 791	126 301	346	59.2
SD ±	4.22	24 138	50 632	31 902	87	
CV (%)	24.2	29.2	24.2	25.3	25.1	

Employment generation

Integration of different components in an integrated farming system increases the employment generation on yearly basis (Table 4). The average employment generation increased to 752 man-days/ha/year by integrating crop + fish + duck +goat overall other farming systems and was followed by crop + fish + cattle (722 man-days/ha/year). An extra average employment of 96 man-days/year was generated from crop components due to inclusion of one more crop (moong) into the system over the traditional cropping system (rice–wheat). Keeping in view, the other enterprises like fish, poultry, duck and goatry an additional employment of 40, 60, 70 and 130 man-days respectively had been generated (Table 4). Combining of crops with other enterprises would increase labour requirement and thus provide scope to employ more family labours round-the-year without giving much relaxation during lean season as in traditional agriculture. Similar increase in employment was also confirmed by Ravisankar *et al.* (2007) with integration of crop + horticulture + goat + poultry into the system.

Nutrient recycling

Integration of different components in a system and recycling of by products and farm wastes has been practised in this study. Samples of raw animal and bird droppings, recycled products like FYM, goat manure, vermicompost and silted silt in the ponds were collected and analysed for their N, P, K contents. The quantity of nutrients received through poultry, duck, goatry, cattle as droppings and plant wastes in form of vermicompost have been presented in Table 5. The nutrient content of raw droppings and plant wastes increased manifolds after recycling into compost and vermicompost. Residue recycling revealed that integration of crop with fish and poultry resulted in higher fish productivity over duck dropping fed fishes which resulted in higher net returns of ₹ 7 090/year from 0.06 ha of pond. Poultry unit had produced 2 880 kg of raw droppings containing 80.6, 52.4, 24.7 kg N, P_2O_5, K_2O respectively. Out of this total raw droppings produced, 25% was fed to fish and from rest 75% poultry manure (2 160 kg) was prepared and applied to the crops. Conversion of raw droppings into poultry manure and pond manure nearly doubled the nutrients and an additional quantity of N:95.7 kg, P_2O_5:56 kg and K_2O: 38.4 kg/year were generated over raw droppings of poultry. While, in case of duck unit, 1 500 kg raw dropping were produced per year and total droppings were allowed to fed to fishes. Recycling of whole duck droppings through fish ponds,enhanced the nutrient content by 2–3 folds (46.0, 18.0, 33.5 kg of N, P_2O_5 and K_2O respectively). Due to recycling of different droppings an additional quantity of N:188kg, P_2O_5 :162.1 kg and K_2O : 118.1 kg were generated over raw droppings which were used within the system as input. Acharya and Mondal (2010)

Table 4 Employment generation (man-days*/year) by different integrated farming systems (mean value of three years)

Farming system	Crop	Poultry	Fish	Duckery	Goatry	Cattle	Total system employment generation
Cropping alone	416						416
Crop + fish + poultry	512	60	40				612
Crop + fish + duck	512		40	70			622
Crop + Fish + goat	512		40		130		682
Crop + fish + duck + goat	512		40	70	130		752
Crop + fish + cattle	512		40			170	722

*1 man-day = 8 hr/day

also reported similar benefits due to recycling of different animal droppings and plant wastes from their findings. By analyzing all waste materials obtained from animal and plants, it can be interpreted that cattle recycled droppings generated highest P_2O_5 and K_2O, while poultry generated highest N into the system (Table 5). The additional nutrients gained by recycling of waste/byproducts over raw wastes were also confirmed by Rangasamy and Jayanthi (1994) and Baishya *et al* (2004) in lowland situation. Recycling of organic manures obtained from different components added 506.2 kg N, 348.5 kg P_2O_5 and 341.7 kg K_2O into the system as a whole, which can minimize the dependency upon chemical fertilizer up to some extent and provide good soil health on long-term basis. Recycling of wastes obtained in the IFS having field crop + fish+ cattle generated 235.7 kg N, 192.7 kg P and 225.2 kg K, whereas crop + fish + poultry system added 192.5 kg N, 19.7 kg P and 77.8 kg K/year which was followed by crop + fish + duck + goat model by adding 110.4 kg N, 58.7 kg P and 68.1 kg K/year.

Results on integration of different components with crop in a system depending upon their suitability and preferences were found encouraging. Hence, it can be concluded that to enhance the productivity, economic returns, generating employment and maintaining soil health of farm and farm families crop + fish + duck + goat combinations can be adopted successfully in lowlands of Bihar instead of cultivating crop alone on same piece of land under irrigated condition. Recycling of organic residues in form of animal

Table 5 Nutrient recycling within integrated farming systems, (mean value of three years)

Nutrient	Raw poultry dropping		Poultry manure (75 %)		Pond manure (25 %)		Additional nutrient gained by recycling
	%	kg/2 880 kg	%	kg/2 160 kg	%	kg/5 000 kg	kg
N	2.80	80.6	3.72	80.3	1.92	96.0	95.7
P_20_5	1.82	52.4	2.68	57.9	50.5	50.5	56.0
K_20	0.86	24.7	1.23	26.6	36.5	36.5	38.4
	Raw duck droppings		Pond manure				Additional nutrient gained by recycling
	%	kg/1 500 kg	%	kg/5 000 kg			kg
N	1.80	27.0	0.92	46.0			19.0
P_20_5	0.65	9.7	0.36	18.0			8.2
K_20	1.02	15.3	0.62	33.5			18.2
	Raw goat droppings		Goat manure				Additional nutrient gained by recycling
	%	kg/2 300 kg	%	kg/1 840 kg			kg
N	1.48	34.0	2.62	48.2			14.2
P_20_5	0.93	21.4	1.60	29.4			8.0
K_20	0.66	15.2	1.08	19.9			4.2
	Raw cow dung		Farmyard manure				Additional nutrient gained by recycling
	%	kg/14 000 kg	%	kg/11 200kg			kg
N	1.18	165.2	1.96	219.5			54.3
P_20_5	0.72	100.8	1.62	181.4			80.6
K_20	1.12	156.8	1.88	210.5			53.7
	Plant waste		Vermicompost				A dditional nutrient gained by recycling
	%	kg/1 060 kg	%	kg/742 kg			kg
N	1.13	9.0	2.5	16.2			4.8
P_20_5	0.82	6.6	2.12	11.3			3.1
K_20	1.1	8.8	2.24	14.7			3.6

and plant wastes could be beneficial in improving the soil health and productivity over a longer period of time with lesser environmental hazards. Livelihood of small and marginal farmers could be upgraded by adopting IFS technologies on a larger scale.

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