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Agronomic and Energy – Efficiency Evaluation of Alternative Cropping System for Pikka Tobacco (*Nicotiana tabacum* L.) in Odisha

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Abstract A field experiment was conducted during 2014-15 and 2015-16 to evaluate alternative cropping system to pikka tobacco (*Nicotiana tabacum* L.). The maximum tobacco cured leaf (1.64 t/ha) and net return of Rs 66,462/ha was obtained in sole crop of tobacco which was significantly different with 19.7% and 34.1% higher over maize (*Zea mays* L.) (green cob)-mung bean [*Vigna radiata* (L.) Wilczek] cropping system. The highest total energy input (23,700 MJ/ha) was reported for cotton (*Gossypium hirsutum* L.)–Sesame (*Sesamum indicum* L.) Major portion of energy was added through fertilizer (29– 46%), human labor (12.7– 23.7%). Highest energy out put was obtained from maize (green cob) – mung bean (1,79,530 MJ/ha) followed by cotton – mung bean (1,65,360 MJ/ha), maize (green cob) – horse gram [*Macrotylomauni florum (*Lam) Verdc.] (1,62,730 MJ/ha). Energy productivity was highest in tobacco (0.13 kg/MJ) followed by maize (green cob)– mung bean (0.08 kg/MJ). The maize (green cob) – mung bean cropping system having highest energy use efficiency (10.1) and energy output efficiency (1300 MJ/ha/day) and lowest specific energy is the next best option to pikka tobacco on Alfisols of Odisha.

Keywords Tobacco, Alternative cropping system, Economics, Energy input, Energy productivity.

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Introduction

Pikka tobacco is grown during late *kharif* in the month of August as rain fed monocrop on alfisols of Odisha, where monsoon rain is received during June to September and length of growing season may accommodate two short duration crops. Tobacco (*Nicotiana tabacum* L.) is a high value cash crop of Odisha. India has ratified the WHO-Framework convention on tobacco control (FCTC), [1]. Farmers are to be advised for alternate profitable crops to pikka tobacco. None of the monocrop was profitable as FCV tobacco in vertisols of Andhra Pradesh [2] rater cropping systems were more remunerative. The production of cropping system with high yield target cannot be achieved without energy input to the system. Moreover inclusion of some crops into the system may reduce the energy production as they are poor converter of energy. So the present experiment was conducted to find out alternative profitable and efficient energy converter cropping system to pikka tobacco.

Materials and Methods

The field experiment was conducted at center for pulses Research, Orissa University of Agriculture and Technology, Berhampur ($19^0 18´$north latitude, 84^0

54´east longitude and 34 m above MSL.)in the East and South Eastern Coastal plain zone of Orissa, during rainy and winter season of 2014-15 and 2015-16. The soil of the experimental site was loamy sand class Aeric Haplustalfs, order Alfisols with pH 5.5, organic carbon 0.45%, low in available N, P and S (186.3, 3.4 and 18.1 kg/ha) respectively, medium in K (164.4 kg/ ha), low in boron (0.204 ppm)and exchangeable calcium 1.5 c. mol (p^+) kg^{-1}. Lime requirement (LR) of soil was 2.6 t/ha. The experiment was conducted with thirteen cropping systems, viz. maize (green cob)–mung bean, maize (green cob) – horse gram, maize (green cob) – sesame, finger millet [*Eleusine coracana* (L.) Gaertn] -mung bean, finger millet - horse gram, finger millet – sesame, groundnut (*Arachis hypogaea* L.)-mung bean, groundnut – horse gram, ground nut–sesame, tobacco, cotton- mung bean, cotton – horse gram, cotton – sesame, replicated three times in randomized block design. Maize P3501, finger millet Bhairabi, groundnut Smruti, cotton Banni tobacco Gajapati in *kharif* and mung bean PDM54, horse gram Urmi, sesame Nirmala during *rabi* season were grown with recommended agronomic practices and plant protection practices . There was 1031.4 and 897 mm rainfall, in 83 and 72 rainy days with temperature range of 16.4^{0}C to 35.8^{0}C and 15.94^{0}C to 36.4^{0}C during cropping seasons of 2014-15 and 2015-16 respectively. The yield of *kharif* and *rabi* crops were converted into tobacco cured leaf equivalent yield by multiplying yield with prevailing price of produce and divided by price of tobacco cured leaf in different years. The net return and benefit : cost ratio of cropping systems has been calculated. The prevailing market price of maize, finger millet, groundnut, mung bean, horse gram, sesame, tobacco and cotton Rs 13,100, 15,500, 34,000, 50,000, 20,000, 30,000, 65,000 and 37,000 per ton respectively.

Energy values for various input and output used in the experiment are given [3] in (Table 1). The total energy input for a given cropping system was calculated by adding the energy requirement for human labor, diesel, herbicides, Farm Yard Manure (FYM) seed and fertilizer used in that sequence. The energy output was calculated by accumulating the main product and by product produced from different cropping systems. Subtracting input energy from output energy derived the net return of energy. The output: input ratio was worked out by dividing total energy generated from main product and by product by the total energy used for raising the crop in the unit area. The energy input and output were computed as Mega Joule (MJ) by using different formulae. The energy efficiency (EE) and specific energy (SE) were worked out as per Dazhong and Pimental [4].

SE=Energy output (MJ/ha)/Energy input (MJ/ha).
SE=Total System input (MJ/ha)/Tobacco cured leaf equivalent yield (t/ha)

Energy output efficiency (MJ/ha/day) and energy productivity were calculated by :

Energy output efficiency = Energy output (MJ/ha)/ Duration of the system (days)
Energy productivity = Tobacco cured leaf equivalent yield (kg/ha)/Energy input (MJ/ha)

The plant samples at harvest were collected and dried separately for stem, leaf, leaf midrib and roots and N, P and K content were determined through standard prodcedure. Soil samples were collected from 0-22.5 cm depth at pre sowing and post harvest after two cycles and used to determine pH, organic carbon, available N, P and K contents following standard procedures.

Results and Discussion

Energy input in cropping systems

Energy input for different cropping system was computed for two years (Table 2). Total energy input in different cropping systems under study was in the range from 12,520 to 23, 700 MJ/ha. Fertilizer accounted for a major share of energy input (29.6–46.2%) followed by human labor (12.7-23.7%), seed (0.002-21.4%), Diesel (12.6-19.7%), FYM (10.9–18.8%), pesticides and herbicides (1.9–5.2%) machinery (1.4 - 4.5%), fungicide (1.0-3.4%). The highest energy input was required for fertilizer for different cropping system has been observed by [5]. The highest energy input was recorded in cotton-sesame (23700 MJ/ ha) followed by cotton-mung bean (21,940 MJ/ha) and cotton-horse gram (20,910 MJ/ha). Tobacco crop required the lowest energy input of (12,520 MJ/ha) because it is a monocrop. The highest energy inputs

Table 1. Equivalents for direct and indirect sources of energy.

Particulars	Units	Equivalent energy (MJ)	Remarks
Inputs			
Human labor			
(a) Adult man	Mon-hour	1.96	
(b) Woman	Woman hour	1.57	
Diesel	Liter	56.31	
Machinery			Distribute the weight of the machinery equally over the total life span of the machinery (in hours). Find the use of machinery (hours) for the particular operation in a crop.
(a) Electric motor	kg	64.80	
(b) Prime movers other than electric motors (including self-propelled machines)	kg	64.80	
Chemical fertilizers			
(i) N	kg	60.60	
(ii) P_2O_5	kg	11.1	
(iii) K_2O	kg	6.7	
Farm yard manure	kg (dry mass)	0.3	
Chemicals			
(i) Superior chemicals	kg	120	Chemical requiring dilution at the time of application. Chemical not requiring dilution at the time of application (gypsum)
(ii) Inferior chemicals	kg	10,0	
Seed			
(a) Output of crop production system and not processed	kg		Same as that of output of crop production system
(b) Output of crop production system and is processed before using it for seed (groundnut, cotton)	kg		Add 1.0 and 0.5 MJ/kg for groundnut and other seeds respectively to the equivalent energy of the product of crop
Output	Units	Main product (MJ/kg)	By-product (dry mass) (MJ/kg)
Maize	kg	14.7	18.0
Finger-millet	kg	14.7	12.5
Ground nut (pods)	kg	25.0	12.5
Tobacco	kg	0.8	18.0
Cotton	kg	25.0	18.0
Mung bean	kg	14.7	12.5
Horse gram	kg	14.7	12.5
Sesame	kg	25.0	18.0

required for cotton based cropping system was due to use of high value inputs like fertilizers, human labor, FYM, diesel and pesticides. Thereafter total energy requirement were in decreasing order for groundnut, maize and finger millet based cropping system.

Energy output of different cropping system

The energy output was computed from main product and by - product of different cropping system and it ranged from 13,000 to 179,530 MJ/ha (Table 3). The mean of two years revealed that the highest total energy output was obtained from maize (green cob)-mung bean.

(1,79,530 MJ/ha) followed by cotton- mung bean (1, 65, 360 MJ/ha), maize (green cob)-horse gram (1, 62, 730 MJ/ha) and maize (green cob) - sesame (1, 57, 300 MJ/ha) are at par. Higher energy output was due to higher productivity of maize and mung bean [6]. The lowest energy output was obtained from tobacco (13,000 MJ/ha) because the tobacco leaves have very low energy value and it is a monocrop. Maize (green cob)- mung bean cropping system is an efficient convertors of energy resulted higher output.

Table 2. Energy values (× 10^3 MJ/ha) in various inputs in different cropping system.

Cropping system	Human labor	Diesel	Seed	Machine	Fungicide	Pesticide /herbicide	FYM	Fertilizer	Total input
Maize (green cob) – mung bean	3.09 (17.4)	2.56 (14.4)	0.85 (4.8)	0.43 (2.4)	0.48 (2.7)	0.60 (3.4)	2.40 (13.5)	7.35 (41.4)	17.76
Maize (green cob) – horse gram	3.05 (18.2)	2.56 (15.3)	0.85 (5.1)	0.24 (1.4)	0.36 (2.2)	0.60 (3.6)	2.40 (14.3)	6.68 (39.9)	16.74 .
Maize (green cob) – sesame	3.60 (18.4)	3.15 (16.2)	0.47 (2.4)	0.49 (2.5)	0.48 (2.5)	0.69 (3.5)	3.00 (15.4)	7.65 (39.2)	19.52
Finger millet – mung bean	2.51 (17.7)	2.56 (18.0)	0.77 (5.4)	0.44 (3.1)	0.48 (3.4)	0.48 (3.4)	2.40 (16.9)	4.57 (32.2)	14.21
Finger millet-horse gram	2.47 (18.7)	2.56 (19.4)	0.77 (5.9)	0.24 (1.8)	0.36 (2.7)	0.48 (3.6)	2.40 (18.2)	3.90 (29.6)	13.19
Finger millet-sesame	3.02 (18.9)	3.15 (19.7)	0.40 (2.5)	0.49 (3.1)	0.48 (3.0)	0.57 (3.6)	3.0 (18.8)	4.87 (30.5)	15.98
Groundnut– mung bean	2.46 (12.7)	2.76 (14.2)	3.94 (20.3)	0.57 (2.9)	0.48 (2.5)	0.57 (2.9)	2.40 (12.4)	6.21 (32.1)	19.39
Groundnut – horse gram	2.42 (13.2)	2.76 (15.0)	3.94 (21.4)	0.37 (2.0)	0.36 (2.0)	0.57 (3.1)	2.40 (13.1)	5.54 (30.2)	18.36
Groundnut - sesame	2.97 (14.0)	3.35 (15.8)	3.56 (16.8)	0.62 (2.9)	0.48 (2.3)	0.66 (3.1)	3.00 (14.2)	6.51 (30.08)	21.15
Tobacco	2.96 (23.7)	1.58 (12.6)	0.0004 (0.002)	0.56 (4.5)	0.12 (1.0)	0.24 (1.9)	1.50 (12.0)	5.56 (44.4)	12.52
Cotton – mung bean	3.51 (16.0)	2.76 (12.6)	0.75 (3.4)	0.94 (4.3)	0.36 (1.6)	1.08 (4.9)	2.40 (10.9)	10.13 (46.2)	21.94
Cotton – horse gram	3.47 (16.6)	2.76 (13.2)	0.75 (3.6)	0.75 (3.6)	0.24 (1.1)	1.08 (5.2)	2.40 (11.5)	9.46 (45.2)	20.91
Cotton - sesame	4.02 (17.0)	3.35 (14.1)	0.38 (1.6)	1.00 (4.2)	0.36 (1.5)	1.17 (4.9)	3.00 (12.5)	10.43 (44.0)	23.70

Specific energy, energy-output efficiency and energy productivity

Two year pool data (Table 3) showed that cotton-sesame had significantly higher specific energy 27.5 MJ/kg over other cropping system followed by finger millet-seasame (26.3 MJ/kg), cotton- horse gram (24.7 MJ/kg) and cotton-mung bean (23.1 MJ/kg) which indicate that these cropping system required higher inputs to deliver a unit of produce. Sole crop of tobacco had the least specific energy (7.6 MJ/kg) preceded by maize (green cob) – mung bean (12.8 MJ/ha). Groundnut -mung bean (14.1 MJ/kg). These crops consumed less input to deliver a unit of produce [7]. Maize based cropping system had higher energy output efficiency (1,000-1,300 MJ/ha/day). Sole tobacco had least energy output efficiency (100 MJ/ha/day) as compared to other cropping system. Sole crop of tobacco had the maximum energy productivity (8.13 kg/MJ)which implied that lowest energy input (12.52 × 10^3 MJ/ha) was required for production. Among different cropping system maize (green cob) - mung bean had the next maximum energy productivity (0.08 kg/MJ) because of proportionately higher production of tobacco cured leaf equivalent yield (1.39 t/ha) with low energy input.

System productivity and economics

Sole crop of tobacco recorded the highest tobacco cured leaf equivalent yield (TCLEY) (1.64 t/ha) which was significantly superior to all other cropping systems (Table 3) and 168% more than finger millet - sesame system. Maize (green cob) - mung bean produced TCLEY (1.39 t/ha) was the next best cropping system and at par with groundnut – mung bean (1.37 t/ha). This was due to higher productivity of maize and market price of mung bean. Pulse mung bean that supplied the additional nitrogen was reflected in yield [8]. Economics of the systems revealed that highest net return of Rs 66, 462 / ha and B:C ratio of 2.7 was observed in tobacco which was significantly different from others and was followed by maize (green cob) – mung bean with net return Rs 49,563/ha B:C

Table 3. Tobacco cured leaf equivalent yield (t/ha), and energy pattern of different cropping system.

Cropping system	Tobacco cured leaf equivalent yield (t/ha)	Net return (Rs/ha)	Benefit : Cost	Duration (days)	Energy input (×10³ MJ /ha)	Energy output (×10³ MJ/ha)	Energy efficiency	Specific energy (MJ/kg)	Energy output efficiency (×10³ MJ /ha/day)	Energy productivity (kg/MJ)
Maize (green cob)-mung bean	1.39	49563	2.2	142	17.76	179.53	10.1	12.8	1.3	0.08
Maizet (green cob)-horse gram	1.01	36855	2.3	160	16.74	162.73	9.7	16.6	1.0	0.06
Maize (green cob)-sesame	1.00	32584	2.0	147	19.52	157.30	8.1	19.6	1.1	0.05
Finger millet-mung bean	0.99	30909	2.0	174	14.21	81.21	5.7	14.3	0.5	0.07
Finger millet-horse gram	0.73	27122	2.4	192	13.19	75.48	5.7	18.2	0.4	0.05
Finger millet-sesame	0.61	15451	1.6	179	15.98	63.56	4.0	26.3	0.4	0.04
Groundnut–mung bean	1.37	46144	2.1	172	19.39	110.06	5.7	41.1	0.6	0.07
Groundnut–horse gram	0.99	33212	2.1	190	18.36	95.51	5.2	18.6	0.5	0.05
Groundnut-sesame	1.02	31266	1.9	177	21.15	91.13	4.3	20.7	0.5	0.05
Tobacco	1.64	66462	2.7	165	12.52	13.00	1.0	7.6	0.1	0.13
Cotton–mung bean	0.95	31820	2.1	230	21.94	165.36	7.5	23.1	0.7	0.04
Cotton – horse gram	0.85	25069	1.8	248	20.91	90.74	4.3	24.7	0.4	0.04
Cotton – sesame	0.86	26046	1.9	235	23.70	86.94	3.7	27.5	0.4	0.04
SEm ±	0.05	881	0.06	7.9		4.35	0.27	0.8	0.039	0.003
CD (p =0.05)	0.14	2654	0.2	22.9		12.6	0.81	2.3	0.12	0.01

ratio 2.2 and groundnut - mung bean Rs 2.2 are similar. Maize based cropping sequences had higher system productivity, net return and B:C ratio [9].

It was concluded that tobacco is most profitable however maize (green cob) -mung bean is next best alternative cropping system in Alfisols of odisha considering net return, B : C ratio, energy output efficiency, energy use efficiency and energy productivity followed by groundnut based cropping system.

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