Indian Journal of Agronomy **63** (2): 211–215 (June 2018)

Research Paper

Evaluation of productive, profitable and energy-efficient alternate cropping system options for *pikka* tobacco (*Nicotiana tabacum*) on Alfisols of Odisha

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Received : December 2016; Revised accepted : February 2018

ABSTRACT

A field experiment was conducted during 2014–15 and 2015–16 at Berhampur, Odisha, to evaluate alternative cropping system to *pikka* tobacco (*Nicotiana tabacum* L.). The maximum tobacco cured leaf (1.64 t/ha) and net return of ₹66,462/ha were obtained in sole crop of tobacco which was significantly higher with 19.7% and 34.1% over maize (*Zea mays* L.) (green cob)– mungbean [*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 source of energy added was through fertilizer ranged from 29.6% in finger millet [*Eleusine coracana* (L.) Gaertn.]–horse gram [*Macrotyloma uniflorum* (Lam.) Verdc.] to 46.2% in cotton–mungbean cropping system, and human labour ranged from 12.7% in groundnut (*Arachis hypogaea* L.)–mung bean cropping system to 23.7% in tobacco. The highest energy output was obtained from maize (green cob)–mungbean (1,79,530 MJ/ha), followed by cotton–mungbean (1,65,360 MJ/ha), maize (green cob)–horse gram (1,62,730 MJ/ha). Energy productivity was the 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 .

Key words : Alternative cropping systems, Economics, Energy input, Energy productivity, Productivity, Specific energy, Tobacco

Tobacco, a high-value cash crop of Odisha, provides livelihood security, employment during its production, processing marketing and export. India has ratified the WHO-Framework convention on tobacco control (FCTC), (CTRI, 2011) and has proposed to reduce the area under tobacco cultivation, particularly the non-exportable types of tobacco to reduce the area to 0.20 million ha by the end of XII plan particularly the non-exportable type. Many anti-tobacco campaigns are creating awareness about ill-effects of tobacco use and encouraging moral responsibility of farmers towards society which warrants alternate options of cropping for tobacco. In India, tobacco is grown in an area of 0.45 m ha, out of which *pikka* tobacco is grown in 2,000 ha in Odisha. It is grown during late rainy season in August as rainfed monocrop on Alfisols of Odisha, where monsoon rain is received during June–September and length of growing season may accommodate 2 short-duration crops. Kasturi Krishna *et al*., (2007) found that none of the monocrops was profitable as flue-cured Virginia tobacco (FCV) in Vertisols of Andhra Pradesh rather 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 productive, profitable and energy-efficient cropping system to *pikka* tobacco utilizing monsoon and residual soil moisture requiring less input energy.

MATERIALS AND METHODS

The field experiment was conducted at the Orissa University of Agriculture and Technology, Berhampur (19°18’ N, 84° 54’ E and 34 m above mean sea-level) in the East and South Eastern Coastal plain zone of Odisha during rainy and winter seasons of 2014–15 and 2015–16. The soil of the experimental site was loamy sand class Aeric Haplustalfs, Order Alfisols, with *p*H 5.5, low in organic carbon (0.45%), low in available N, P and S (186.3, 3.4 and 18.1 kg/ha), medium in K (164.4 kg/ha), low in boron (0.204 ppm) and exchangeable calcium 1.5 c.mol

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(p^+)/kg. Lime requirement (LR) of soil was calculated as 2.6 t/ha. The experiment was conducted with 13 cropping systems, viz. maize (green cob)–mung bean, maize (green cob)–horse gram, maize (green cob)–sesame, finger millet–mungbean, finger millet–horse gram, finger millet–sesame, groundnut–mungbean, groundnut–horse gram, groundnut–sesame, tobacco, cotton–mungbean, cotton–horse gram, cotton–sesame, replicated 3 times in randomized block design. Maize hybrid 'P3501', finger millet variety 'Bhairabi', groundnut variety 'Smruti', cotton hybrid 'Bunny', tobacco variety 'Gajapati' were grown in the rainy season and mung bean variety 'PDM 54', horse gram variety 'Urmi', sesame variety 'Nirmala' during the winter season were grown with recommended agronomic practices and plant-protection practices. There was 1,031.4 and 897 mm rainfall, in 83 and 72 rainy days with temperature range of 16.4°C to 35.8°C and 15.94°C to 36.4°C during cropping seasons of 2014–15 and 2015–16 respectively. The yield of rainy (*kharif*) and winter (*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 were calculated. The prevailing market price of maize, finger millet, groundnut, mungbean, horse gram, sesame, tobacco and cotton were taken as ₹13.10, 15.50 , 34.00, 50.00, 20.00, 30.00, 65.00 and 37.00/kg respectively.

Energy values used for calculating input and output as Mega Joule (MJ) by using different formulae as per Singh and Mittal, (1992). Output : input ratio was worked out by dividing total energy generated from main product and byproduct by the total energy used for raising the crop in the unit area .The energy efficiency (EE) and specific energy (SE) were worked out as per Dazhong and Pimental (1984).

$$\text{EE} = \frac{\text{Energy output (MJ/ha)}}{\text{Energy input (MJ/ha)}}$$

$$\text{SE} = \frac{\text{Total system input (MJ/ha)}}{\text{Tobacco cured leaf equivalent yield (t/ha)}}$$

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

$$\text{Energy output efficiency} = \frac{\text{Energy output (MJ/ha)}}{\text{Duration of the system (days)}}$$

$$\text{Energy productivity} = \frac{\text{Tobacco cured leaf-equivalent yield (kg /ha)}}{\text{Energy input (MJ/ha)}}$$

Soil samples were collected from 0–22.5 cm depth at pre-sowing and post-harvest after two cycles and used to determine *p*H, organic carbon, available N, P and K contents following standard methods. Statistical analysis of the data was carried out using standard analysis of variance (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Productivity and profitability

Sole crop of tobacco recorded the highest tobacco cured leaf-equivalent yield (TCLEY) (1.64 t/ha) which was significantly superior to all the other cropping systems (Table 1). The TCLEY given by maize (green cob)–mungbean (1.39 t/ha) was the next best cropping system and at par with groundnut–mungbean (1.37 t/ha). This was owing to higher productivity of maize and market price of mungbean. The biological nitrogen-fixing ability of leguminous mungbean that not only supplied the additional nitrogen but also helped the plant to provide more macro and micro-nutrients through the improvements in biological properties of the soil which was reflected in yield (Choudhary and Kumar, 2014). Economics of the systems revealed that the highest net returns of ₹66,462/ha and benefit: cost ratio of 2.7 were observed in tobacco which was significantly different from others and was followed by maize (green cob)–mungbean with net return ₹49,563/ha and benefit: cost ratio of 2.2, which was at par with groundnut–mungbean. Kasturi Krishna *et al.* (2010) also found that maize-based cropping sequences had higher system productivity, net returns and B:C ratio .

Land-use and production efficiency

Land-use efficiency was the highest in cotton-based cropping system (63.0–67.9%). Cotton–horse gram showed the highest land-use efficiency (67.9%) because the system occupied the land for a longer period (Table 3). Similarly, production efficiency was the highest in maize-based cropping system (29.4–35.3 kg/ha/day). Maize (green cob)–mungbean cropping system exhibited the highest production efficiency of 35.3 kg/ha/day because higher quantity of produce from maize in a short period (Table 2).

Energy input

Energy input for different cropping systems was computed for 2 years (Table 2). Total energy input in different cropping systems under study was in the range from 12,520–23,700 MJ/ha. Fertilizer accounted for a major share of energy input (29.6–46.2%), followed by human labour (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 required for different cropping systems from fertilizer has been observed by Negi *et al.* (2016). The highest energy input was recorded in cotton–

Table 1. Equivalent yield, economics and energy efficiency of different cropping systems

Cropping system	Tobacco cured leaf-equivalent yield (t/ha)	Net returns (₹/ha)	Benefit : cost	Duration (days)	Energy input (× 10^3 MJ/ha)	Energy output (× 10^3 MJ/ha)	Energy efficiency	Specific energy (MJ/kg)	Energy output efficiency (×10^3 MJ/ ha/day)	Energy productivity (kg/MJ)
Maize (green cob)–mungbean	1.39	49,563	2.2	142	17.76	179.53	10.1	12.8	1.3	0.08
Maize (green cob)-horse gram	1.01	36,855	2.3	160	16.74	162.73	9.7	16.6	1.0	0.06
Maize (green cob)–sesame	1.00	32,584	2.0	147	19.52	157.30	8.1	19.6	1.1	0.05
Finger millet–mungbean	0.99	30,909	2.0	174	14.21	81.21	5.7	14.3	0.5	0.07
Finger millet–horse gram	0.73	27,122	2.4	192	13.19	75.48	5.7	18.2	0.4	0.05
Finger millet–sesame	0.61	15,451	1.6	179	15.98	63.56	4.0	26.3	0.4	0.04
Groundnut–mungbean	1.37	46,144	2.1	172	19.39	110.06	5.7	14.1	0.6	0.07
Groundnut–horse gram	0.99	33,212	2.1	190	18.36	95.51	5.2	18.6	0.5	0.05
Groundnut–sesame	1.02	31,266	1.9	177	21.15	91.13	4.3	20.7	0.5	0.05
Tobacco	1.64	66,462	2.7	165	12.52	13.00	1.0	7.6	0.1	0.13
Cotton–mungbean	0.95	31,820	2.1	230	21.94	165.36	7.5	23.1	0.7	0.04
Cotton–horse gram	0.85	25,069	1.8	248	20.91	90.74	4.3	24.7	0.4	0.04
Cotton–sesame	0.86	26,046	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	2,654	0.2	22.9		12.6	0.81	2.3	0.12	0.01

Table 2. Input energy (× 10^3 MJ/ha) of different cropping systems

Cropping system	Human labour	Diesel	Seed	Machine	Fungicide	Pesticide/herbicide	FYM	Fertilizer	Total input
Maize (green cob)–mungbean	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 (100)
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 (100)
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 (100)
Finger millet–mungbean	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 (100)
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 (100)
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 (100)
Groundnut–mungbean	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 (100)
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 (100)
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 (30.8)	21.15 (100)
Tobacco	2.96 (23.7)	1.58 (12.6)	0.0003 (0.002)	0.56 (4.5)	0.12 (1.0)	0.24 (1.9)	1.50 (12.0)	5.56 (44.4)	12.52 (100)
Cotton–mungbean	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 (100)
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 (100)
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 (100)

Figures in parentheses are per cent share to total input energy sesame (23,700 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 required for cotton-based cropping system was due to use of high-value inputs like fertilizers, human labour, FYM, diesel and pesticides. Thereafter total energy requirement were in decreasing order for groundnut, maize and finger millet based cropping systems. In groundnut-based cropping system, more energy input was required for groundnut seed because of higher seed rate. Seed-bed preparation, weeding, harvesting were found to be most energy-intensive operations in groundnut. The results confirm the findings of Ashoka *et al.* (2010).

Energy output

The energy output was computed from main product and by-product of different cropping systems and it ranged from 13,000 to 1,79,530 MJ/ha (Table 1). Mean of 2 years revealed that the highest total energy output was obtained from maize (green cob)–mungbean system (179,530 MJ/ha), followed by cotton–mungbean (165,360 MJ/ha), maize (green cob)–horse gram (162,730 MJ/ha) and maize (green cob)–sesame (157,300 MJ/ha). Higher energy output was owing to higher productivity of maize and mungbean (Walia *et al.*, 2014).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)-mungbean cropping system is an efficient convertor of energy which resulted in higher output.

Specific energy, energy-output efficiency and energy productivity

Two-year pooled data (Table 1) showed that cotton–sesame had significantly highest specific energy (27.5 MJ/kg) over the other cropping systems, followed by finger millet–sesame (26.3 MJ/kg), cotton–horse gram (24.7 MJ/kg) and cotton–mungbean (23.1 MJ/kg), which indicate that these cropping systems 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)–mungbean (12.8 MJ/ha) and groundnut–mungbean (14.1 MJ/kg). These crops consumed less input to deliver a unit of produce (Nanda *et al*., 2008). Maize-based cropping system had higher energy-output efficiency (1,000–1,300 MJ/ha/day). Sole tobacco had the least energy-output efficiency (100 MJ/ha/day) as compared to the other cropping systems. Sole crop of tobacco had the maximum energy productivity (0.13 kg/MJ) which implied that lowest energy input (12.52×10^3 MJ/ha) was required for production. Among different cropping systems, maize (green cob)–mungbean showed 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.

Soil fertility status

After 2 years of cropping, the mean residual soil-fertility status showed decrease in *p*H, increase in organic carbon and decrease in N, P and K (Table 3). Cropping system with mungbean, and horse gram showed lower in *p*H than the other because the legumes absorb the base cations and release H^+ into soil resulting acidification and decrease in *p*H (Crews and People, 2004) and biological N fixed in the soil increased the organic carbon. Growing sesame as a winter crop resulted in depletion of available P due to higher demand of P by oilseed crop. Available P and K had decreased after tobacco which is mainly due to higher amount of K demand and removal along with P (Krishnamurthy and Chandra, 2002).

Table 3. Soil-fertility status after harvesting of the cropping systems

Treatment	Individual crop yield (t/ha)				Land-use efficiency	Production efficiency	*p*H	Organic carbon	Soil-available nutrients (kg/ha) after 2 cycles		
	2014–15		2015–16								
	K	R	K	R	(%)	(kg/ha/day)			N	P	K
Maize (green cob)–mungbean	4.49	0.64	4.31	0.59	38.9	35.32	6.36	0.37	168.5	3.14	155.0
Maize (green cob)–horse gram	4.44	0.34	4.32	0.31	43.8	29.41	5.30	0.36	168.1	3.16	153.2
Maize (green cob)–sesame	4.59	0.16	4.38	0.15	40.3	31.56	5.33	0.37	166.4	3.16	154.1
Finger millet–mungbean	2.14	0.62	2.02	0.58	47.7	15.40	5.43	0.38	169.2	3.26	152.5
Finger millet–horse gram	2.13	0.34	3.07	0.29	52.6	15.18	5.40	0.37	169.4	3.24	153.4
Finger millet–sesame	2.15	0.21	2.11	0.19	49.0	13.02	5.42	0.37	169.3	3.25	155.2
Groundnut–mungbean	1.68	0.64	1.67	0.61	47.1	13.37	5.41	0.36	170.5	3.31	153.1
Groundnut–horse gram	1.71	0.32	1.68	0.26	52.1	10.45	5.39	0.35	166.3	3.29	155.1
Groundnut–sesame	1.76	0.23	1.71	0.21	48.5	11.05	5.40	0.37	167.2	3.30	154.5
Tobacco	1.66	0	1.61	0	45.2	9.91	5.42	0.36	162.1	3.26	150.5
Cotton–mungbean	1.32	0.23	1.28	0.27	63.0	6.74	5.40	0.38	166.2	3.28	153.4
Cotton–horse gram	1.34	0.21	1.31	0.28	67.9	6.33	5.31	0.36	165.4	3.21	152.2
Cotton–sesame	1.35	0.17	1.33	0.19	64.4	6.47	5.38	0.37	166.0	3.22	153.1

It can be concluded that tobacco is most profitable crop on Alfisols of Odisha; however, maize (green cob)–mungbean and groundnut-based cropping systems were found to be the best alternative cropping systems considering production efficiency, net return, benefit: cost ratio, energy output efficiency, energy-use efficiency and energy productivity followed by groundnut-based cropping system .

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