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Energy studies of sweet corn-potato cropping sequence under integrated nutrient management

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Abstract
The present investigation was conducted for kharif and rabi season on sweet corn-potato cropping system for two consecutive years (2014-15 and 2015-16) in a clayey in texture soil at the Post Graduate Institute Research Farm, M.P.K.V., Rahuri (Maharashtra) India. To evaluate the energy studies of sweet corn-potato cropping sequence under integrated nutrient management. The results revealed that significant enhancement in the energy output (457541, 468162 and 462852 MJ ha^{-1}), energy balance (385966, 396152 and 391059 MJ ha^{-1}), energy balance per unit input (5.39, 5.50 and 5.45 MJ ha^{-1}) and energy use efficiency (6.39, 6.50 and 6.45 MJ ha^{-1}) of the sweet corn-potato cropping system with the application of treatment T$_7$-125% RDN + 25% N through vermicompost during the period of study. Thus, use of organic sources vermicompost significantly improved the Energy output, energy balance per unit input and energy use efficiency of the sweet corn-potato cropping system.

Keywords: Sweet corn-potato cropping system, energy output, energy balance, energy balance per unit input, energy output per unit input ratio

Introduction
Maize has high genetic yield potential than other cereal crops. Hence it is called as 'miracle crop' and also as 'queen of cereals'. The *sweet corn-potato* cropping sequence has the highest nutrient requirement; however, it is most attractive system in terms of economics returns and energy efficiency (Vyas *et al*., 2012) [4]. In India, after the green revolution, intensive agriculture involving exhaustive high yielding varieties has lead to heavy withdrawal of nutrients from the soil. The imbalanced use of chemical fertilizers by farmers has deteriorated soil health. The organic sources of nutrients helps in improving and maintaining soil health for enhancing and sustaining agricultural production (Meena *et al*., 2011) [6]. In India, agriculture not only provides food for all, but also employment to 70% of the population, which generates 40% of the national income and consumes about 10% of the commercial forms of energy. Energy is a critical aspect of a national development process it is also expended in agricultural operations. Crop cultivation requires application of both animal and inanimate forms of energy at different stages. Nutrients are provided through organic manure, chemical fertilizer or both. Seed, manures, labour and draft animal can be termed as integrated nutrient management (INM), a combined application of organic and inorganic sources of nutrients, maintains storage of plant nutrients in soil and improves nutrients-use efficiency that is essential for sustainable crop production. Organic matter acts as a source and a sink for plant nutrients as well as provides energy substrate for soil micro--organisms. Thus, it enhances activities of soil flora and fauna as well as intrinsic soil properties, soil nutrient capital, water-holding capacity and soil structure in turn makes soil less susceptible to leaching and erosion. Therefore, INM practices are essential to maintain/enhance the soil quality and sustainability of an agro-ecosystem (Zeidan, 2007) [8]. Kharif maize often face terminal drought resulted crop failure or very less productivity. It may be overcome by growing the maize for sweet corn instead of green cob. Besides farmyard manure (FYM), now-a-days vermicompost is gaining attention of both the researchers and the farmers due to its immense production potential using farm. Nutrients are one of the most important inputs, required by the plants for their growth and yield. The organic manures is considered as the promising renewable source of energy, nutrient rich source and can be served as a substitute to cut down the cost of fertilizer input and to increase the productivity in addition to maintain soil productivity, improve the eco-system

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and ultimately resulting in improved soil-plant-health in a sustainable agricultural eco-system. Keeping this in view, the present investigation was taken up to study the effect of integrated nutrient management on sweet corn – potato cropping system and its energy balance since limited information is available pertaining to this.

Material and methods
A field experiment was conducted from 2014 to 2015 at the Post Graduate Institute Research Farm, of Mahatma Phule Krishi Vidyapeeth, Rahuri is lies between 190 48'N and 190 57'N Latitude and 740 32'E and 740 19'E longitude. The altitude varies from 495 to 569 meters above mean sea level. This tract is lying on the Eastern side of Western Ghat and falls under rain shadow area. Climatologically, it falls in semi arid tropics with an annual rainfall varying from 307 to 619 mm. The average annual precipitation is 520 mm. Out of the total annual rainfall, about 80 per cent rains are received from South – West monsoon (June to September), while rest receives from North – East monsoon. The number of rainy days varies from 15-45 in a year. The mean annual maximum and minimum temperature ranges from 33 0C to 43 0C and 3 0C to 18 0C, respectively. The mean relative humidity during morning and evening hours is 59 and 35 per cent, respectively. The mean pan evaporation ranges from 5.3 to 12.1 mm and the sunshine hours ranges from 7 to 9 day^{-1}. The soil of experimental site was sandy loam with bulk density of 1.39 Mg m-3. In soil organic carbon was 0.51 with 241.35 kg ha-1 available N, 22.85 kg ha-1 available P, 365.75 kg ha-1 available K in first year, respectively. The pH was 8.20 with EC of 0.33 dSm respectively. The experiment included two crops per year, namely, *kharif* sweet corn (July-November), winter potato (November- March).The field trial was conducted on the same field and on same layout without changing randomization during both the years. The experiment was laid out in Randomized Block Design, during *kharif* season the main plot treatments comprised of the gross recommended dose of fertilizers and three levels of FYM and vermicompost to sweet corn, replicated thrice and during *rabi* season each sub plot treatment was divided into two sub plot treatments with two levels of the gross recommended dose of fertilizers to potato. Thus, during *rabi* season there were fourteen treatments comprised of seven main plot treatment of FYM and vermicompost and two sub plot treatments comprised of two levels of fertilizer to potato replicated thrice in split plot design. The recommended dose of NPK in sweet corn was applied through urea, single super phosphate and muriate of potash, respectively. The nitrogen was applied into three split (1/3 each as basal, tasseling and grain formation stage). The full dose of P and K was applied as basal. The treatment consisted T_1 – 100% GRDF, T_2 - 75% RDN + 25% N through FYM, T_3 - 75% RDN + 25% N through VC, T_4 – 100% RDN + 25% N through FYM T_5 - 100% RDN + 25% N through VC, T_6 – 125% RDN + 25% N through FYM and T_7 – 125% RDN + 25% N through VC for *kharif* sweet corn as a main plot treatment, whereas for *rabi* potato two sub plot treatment levels of GRDF viz., F1 - 75% GRDF and F2 - 100% GRDF replicated two times in split plot design resulting in seven treatment combinations replicated thrice during *kharif* season and fourteen treatment combinations during rabi season in RBD-split plot design replicated thrice. The experiment was conducted on same site without changing the randomization of the treatments for successive years. The required quantity of different manures viz. vermicompost and FYM as per the treatments was applied in field ten days

before sowing of both the crops. The available N, P and K content were 1.02, 0.50 and 0.80% in vermicompost, 0.50, 0.20, and 0.44% in FYM. In doing so the respective contribution of P and K from vermicompost and FYM was also considered. The fertilizers used were urea for N, single superphosphate for P, and muriate of potash for K. The seed of of sweet corn var. Suger-75 was dibbled on the ridge sides at a spacing of 20 cm at 4 cm depth and required plant population (83,000 plant ha-1) was maintained by thinning of plants after one week of germination. Similarly, potato var. K. Jyoti seed tubers of 25–30 cm size were sown 5 cm deep on the south side of the ridges at a spacing of 20 cm between tubers in rainy and winter seasons respectively. The energy input, energy output, energy balance per unit inputs and energy input output ratio (MJ ha^{-1}) of the system were worked out. The energy input was worked out by using the item wise energy values for each treatment and expressed as MJha^{-1}. The energy output from sweet corn and potato of respective crop was worked out by multiplying yields (calorific value of harvested biomass of sweet corn and potato) with their energy values for respective crop i.e., sweet corn and potato and expressed as MJ ha^{-1}. The energy balance was worked out by deducting the energy input from the energy output for each treatment and expressed as MJ ha^{-1}. Energy balance per unit input (MJ ha^{-1}) was calculated as - energy balance dividing energy input The energy output per unit input ratio (MJ ha^{-1}) was estimated by dividing energy output values with input values. Energy use efficiency (MJ ha^{-1} worked out as energy balance divided by energy input.

Results and discussion
Productivity: Yield
The data on biomass yield of sweet corn and potato at harvest as influenced by different treatments are presented in Table 1. The treatment T_7 -125% RDN + 25% N through VC proved its superiority in recording higher green cob (275.55, 281.55 q ha^{-1}) and green fodder yield (542.83, 554.19q ha^{-1}) [1] respectively than other fertilizer levels. The higher yield observed with the application of vermicompost in comparison to FYM may be explained on the basis of higher nutrient content, faster decomposition and released nutrients in vermicompost besides enhancing the microbial population and higher root biomass (Kannan *et al.,* 2005) [5]. Similarly, the treatment T_1-100% GRDF recorded significantly maximum in terms of tuber yield (280.21, 286.96 q ha^{-1}) and haulm yield (12.31, 13.52 q ha^{-1}) than rest of other treatments. The superiority of FYM was attributed to its slow decomposition (Singh *et al.*, 1996) [7], which caused immobilization of nitrogen and low availability of nitrogen for the sweet corn crop found to be reversed during the succeeding potato crop.

Energy studies of cropping sequence
The data pertaining to the total energy output, total energy input, total energy balance (MJ ha^{-1}) and total energy balance per unit input and total energy use efficiency of sweet corn-potato cropping sequence during first year, second year and pooled mean over years as influenced by different treatments are presented in Table 2.

Energy Study: Energy output
The different fertilizer levels to preceding sweet corn affected the total energy output significantly during both years and in pooled mean. The treatment T_7-125% RDN + 25% N through VC (457541, 468162 and 462852 MJ ha^{-1}) registered highest

total output energy than rest of other treatments and at par with treatment T_6-125% RDN + 25% N through FYM (456708, 465670 and 461189 MJ ha^{-1}) and again at par with treatment T_1-100% GRDF (452991, 464112 and 458552 MJ ha^{-1}) during first year, second year and in pooled mean over years, respectively. The lowest total output energy was observed in T_2-75% RDN + 25% N through FYM (429312, 442617 and 435965 MJ ha^{-1}) during both the years and when the data pooled over years. Mandal *et al.* (2002) [3] revealed that highest total bioenergy output of the crop production system was observed in soybean - wheat crop sequence.

Energy input
Numerically treatment T_6-125% RDN + 25% N through FYM exhibited highest values of total input energy (72475, 72910 and 72693 MJ ha^{-1}) than rest of other treatments and was followed by treatment T_1-100% GRDF (71875, 72310 and 72093 MJ ha^{-1}) during first year, second year and mean over years. The lowest energy input was observed in treatment T_3-75% RDN + 25% through VC (67975, 68410 and 68193 MJ ha^{-1}).

Energy balance
The various fertilizer levels to preceding sweet corn crop significantly influenced the total energy balance. The T_7-125% RDN + 25% N through VC recorded maximum total energy balance (385966, 396152 and 391059 MJ ha^{-1}) than rest of other treatments and T_6-125% RDN + 25% N through FYM (384233, 392760 and 388497 MJ ha^{-1}) and again at par with treatment T_1-100% GRDF (381116, 391802 and 386459 MJ ha^{-1}) during first year, second year and in pooled mean over years, respectively. The total energy balance was lowest in treatment T_2-75% RDN+25% N through FYM (360425, 373295 and 366860 MJ ha^{-1}). Similar results were also

reported by Joshi and Billore (2004) [2] that energy output, energy balance, energy balance per unit input and energy output per input ratio of cropping sequence were at higher magnitude due to conjunctive use of organic manures and biofertilizers.

Energy balance per unit input
The maximum energy balance per unit input was recorded in treatment T_7-125% RDN + 25% N through VC (5.39, 5.50 and 5.45) than rest of other treatments and at par with treatment T_3-75% RDN + 25% through VC (5.36, 5.51and 5.44) during the year 2014, 2015 and pooled mean. The lowest energy balance per unit input was observed in treatment T_4-100% RDN + 25% N through FYM (5.23, 5.37 and 5.30). Vyas and Khandwe (2012) [4] also showed that application of soybean residue + FYM 5 ton ha^{-1} + Zn 5 kg ha^{-1} recorded highest energy input and gross energy output ratio in soybean-wheat cropping system.

Energy use efficiency
The treatment T_7-125% RDN + 25% N through VC (6.39, 6.50 and 6.45) recorded significantly maximum energy use efficiency than rest of other treatments and at par with treatment T_3-75% RDN + 25% through VC (6.36, 6.51 and 6.44) during first year, second year and when the data pooled over years, respectively. The lowest energy use efficiency was observed in treatment T_4-100% RDN + 25% N through FYM (6.23, 6.37 and 6.30) during first year, second year and when the data pooled over years, respectively. The energy evaluation studies in respect of energy output, energy balance, energy balance per unit input and energy output per unit input ratio showed that these parameters were significantly increased with successive increase in yield level.

Table 1: Yield (q ha^{-1}) of sweet corn and potato during both years as influenced by different treatments

Treatment		Green cob yield (q ha^{-1})		Green fodder yield (q ha^{-1})		Tuber yield (q ha^{-1})		Haulm yield (q ha^{-1})	
		2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
Fertilizer levels to sweet corn									
T_1 :	100% GRDF	265.25	271.99	527.85	540.80	280.21	286.96	12.31	13.52
T_2 :	75% RDN + 25% N through FYM	249.75	256.25	509.49	520.66	260.35	272.35	10.46	10.54
T_3 :	75% RDN + 25% N through VC	255.35	262.09	518.36	531.26	255.71	266.72	10.31	10.46
T_4 :	100% RDN + 25% N through FYM	258.45	264.84	522.07	534.76	265.53	276.51	10.90	11.12
T_5 :	100% RDN + 25% N through VC	260.74	267.04	524.09	536.58	261.65	274.71	10.66	10.97
T_6 :	125% RDN + 25% N through FYM	271.94	277.49	538.44	546.82	275.36	282.11	11.17	12.26
T_7 :	125% RDN + 25% N through VC	275.55	281.55	542.83	554.19	271.55	278.95	11.06	11.17
	S. Em. ±	2.69	2.75	3.26	3.51	2.47	2.53	0.41	0.47
	C. D. at 5%	7.98	8.25	9.80	10.55	7.41	7.59	1.22	1.41
Fertilizer levels to potato									
F_1 :	75% GRDF					264.66	274.75	10.69	10.95
F_2 :	100% GRDF					270.21	279.60	10.98	11.64
	S. Em. ±					2.44	1.04	0.13	0.11
	C. D. at 5%					NS	NS	NS	NS
	Interaction					NS	NS	NS	NS
	General mean					267.44	277.18	10.83	11.29

Table 2: Energy output, energy input, energy balance, energy balance/ unit input and energy use efficiency of sweet corn- potato sequence as influenced by different treatments

Treatment	Total output energy (MJ ha⁻¹)			Total input energy (MJ ha⁻¹)			Energy balance (MJ ha⁻¹)			Energy balance per unit input			Energy use efficiency		
	2014-15	2015-16	Pooled mean	2014-15	2015-16	Pooled mean	2014-15	2015-16	Pooled mean	2014-15	2015-16	Pooled mean	2014-15	2015-16	Pooled mean
Fertilizer levels to sweet corn															
T₁ : 100% GRDF	452991	464112	458552	71875	72310	72093	381116	391802	386459	5.30	5.42	5.36	6.30	6.42	6.36
T₂ : 75% RDN + 25%N through FYM	429312	442617	435965	68887	69322	69105	360425	373295	366860	5.24	5.38	5.32	6.24	6.38	6.32
T₃ : 75% RDN + 25% N through VC	432101	445594	438848	67975	68410	68193	364126	377184	370655	5.36	5.51	5.44	6.36	6.51	6.44
T₄ : 100% RDN + 25%N through FYM	440126	453397	446762	70687	71122	70905	369439	382275	375857	5.23	5.37	5.30	6.23	6.37	6.30
T₅ : 100% RDN + 25% N through VC	439545	453873	446709	69787	70222	70005	369758	383651	376705	5.30	5.46	5.38	6.30	6.46	6.38
T₆ : 125% RDN + 25% N through FYM	456708	465670	461189	72475	72910	72693	384233	392760	388497	5.30	5.39	5.34	6.30	6.39	6.34
6T₇ : 125% RDN + 25% N through VC	457541	468162	462852	71575	72010	71793	385966	396152	391059	5.39	5.50	5.45	6.39	6.50	6.45
S. Em. ±	2217	1449	1690	-	-	-	1867	1942	1902	0.03	0.018	0.002	0.03	0.019	0.003
C. D. at 5%	6726	4397	4829	-	-	-	5602	5827	5712	0.08	0.05	0.006	0.08	0.057	0.006
Fertilizer levels to potato															
F₁ : 75% GRDF	442627	455000	448814	67739	68174	67957	374888	386826	380857	5.53	5.67	5.60	6.53	6.67	6.60
F₂ : 100% GRDF	445735	457716	451726	73193	73628	73411	372542	384088	378315	5.09	5.22	5.15	6.09	6.22	6.15
S. Em. ±	1119	1140	1186	-	-	-	1119	1129	1129	0.02	0.06	0.001	0.02	0.02	0.002
C. D. at 5%	3356	3421	3559	-	-	-	3358	3387	3387	0.06	0.19	0.003	0.06	0.06	0.006
Interaction	NS	NS	NS	-	-	-	NS	NS	NS	NS	NS	NS	NS	NS	NS
General mean	444181	456358	450270	70466	70901	70684	373715	385457	379586	5.31	5.45	5.38	6.30	6.44	6.37

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