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Energy use and Economic Analysis for Achieving Target Yield through Site Specific Nutrient Management in Soybean (*Glycine max* L.)- Chickpea Cropping System (*Cicer arietinum* L.)

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ABSTRACT

Background: The measure of energy flow in crop production system provides a good indicator of the production of technological aspects of crop production systems in agriculture. Sustainable agricultural management technologies should be studied in terms of increased productivity, profitability, energy saving and efficiency of agricultural inputs usage by using efficiency indices and sustainable indicators.

Methods: A field experiment was conducted at Agriculture Research Station, Janawada, Bidar during *kharif* and *rabi* seasons for two consecutive years (2014-15 and 2015-16) to know the energy use for achieving target yield. The experiement was laid out in randomized block design with three replications. The treatments *viz*., the two genotypes of soybean (JS335 and DSB 21) and chickpea (JG 11 and GBM 2) were tested for target yield of 2.0 t ha^{-1}, 2.5 t ha^{-1}, 3.0 t ha^{-1}, 3.5 t ha^{-1}, farmers practice and RDF were tested in medium black soils in randomized block design with three replications. The soil testing was carried out to determine the quantity of major nutrient for different target yields.

Result: The experimental results revealed that the significantly higher energy efficiency (5.28 MJ ha^{-1}), net energy (1,71,039.00 MJ ha^{-1}), energy productivity (0.40 kg MJ^{-1}), energy intensity (1,71,039.00 MJ ha^{-1}) in physical terms (13.29 MJ kg^{-1}) and economic terms (3.68 MJ Rs.$^{-1}$), crop profitability (723.53 Rs.ha^{-1} day^{-1}), system profitability (417.05 Rs.ha^{-1} day^{-1}) and relative economic efficiency (2.75) and soybean equivalent yield (5683 kg ha^{-1}) were noticed in JS 335/JG 11 + target yield 3.0 t ha^{-1} compared to rest of the treatments. Thus, it could be concluded that various efficiency indices also used as alternative indices for achieving target yield in cropping system.

Key words: Cropping system, Energy efficiency indices, System profitability, Target yield.

INTRODUCTION

Soybean and chickpea are important *kharif* and *rabi* crops and the production are limited by nutrients and scarcity of moisture. Timely nutrient management practices play an important role in the successful cultivation of these crops. Existing fertilizer recommendation for soybean-chickpea system often consists of fixed rates and timing of N, P and K for vast areas of production. Such recommendations are constant over the years over large areas. But crop growth and crop need for supplemental nutrients are strongly influenced by crop growing conditions, crop and soil management and climate which can vary greatly among field, season and year. The SSNM (site specific nutrient management) approach does not significantly aim to either reduce or increase fertilizer use. Instead, it aims to apply nutrients at optimal rates and times in order to achieve high yield and high efficiency of nutrient use by the crop, leading to high cash value of the harvest per unit of fertilizer invested (Shankar and Umesh, 2008). Considering the fertilizer cost and availability, this limited resource needs to be saved for sustainable crop production through improving the nutrient use efficiency by site specific application.

Sustainable agricultural management technologies should be studied in terms of increased productivity, profitability, energy saving and efficiency of agricultural inputs usage by using efficiency indices and sustainable indicators. Comparison of different cropping systems with reference to land use and yield advantages is possible through various efficiency indices. The various cropping and farming systems practiced in an area have to be properly evaluated to decide their suitability and relative advantages. The comparisons can be made with reference to many factors *viz.,* yield, monetary, water use efficiency, nutrient use efficiency, total dry matter production *etc*. Agricultural productivity is closely linked with the energy inputs. The measure of energy flow in crop production system provides a good indicator of the production of technological aspects

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of crop production systems in agriculture. Direct energy inputs to crop production system are derived from power sources like human, draught animals, engines, tractors, power tillers and electric motors *etc*., whereas indirect energy inputs are in the form of seeds, organic manures, fertilizers, pesticides and growth regulators *etc*.

Energy input-output relationships in cropping systems vary with the crops knitted in a sequence, type of soils, nature of tillage, operations, nature and amount of organic manures, chemical fertilizers, plant protection measures, yield level and biomass production (Devasenapathy *et al*., 2008). The energy input referred to the both renewable and non-renewable energy. Renewable energy constituted manual, animal/bullock, seed, manure *etc*., whereas non-renewable energy encompassed chemical fertilizers (NPK), tractor, diesel, electricity, lubricants, machinery and agro chemicals *etc*. Total physical output referred to both the grain and byproduct yield.

Generally, the production of a system depends not only on the efficiency of individual component crop of the system but also on how well these crops compliment with each other in time and space. Therefore, the overall productivity of soybean-chickpea system depended partly on the efficiency of soybean and chickpea. Since two crops are included in cropping systems, it becomes very difficult to compare the economic produce of one crop with the other. Hence, soybean equivalent yield, input energy, output energy, energy efficiency, specific energy, net energy, energy productivity, energy intensity in physical terms and in economic terms, crop profitability, system profitability and relative economic efficiency suggested for such studies was made use. The study on refining the nutrient application through SSNM was conducted to study the response on soybean-chickpea genotypes to inorganic fertilizers based on energy indices.

MATERIALS AND METHODS

The experiment was conduct at Agricultural Research Station, Janawada, Bidar as part of Ph.D. research work to study the influence of site specific nutrient management on soybean-chickpea in north eastern transitional zone of Karnataka during *kharif* and *rabi* seasons of 2014 and 2015. Survey was conducted in surrounding villages of experimental site with 25 farmers growing chickpea for their nutrient management. Based on their nutrient management practices, average quantity of fertilizers for farmer's practice treatment was worked out. The amount of fertilizer for SSNM treatments was calculated by using the formulae (IPNI web site).

FA = Nutrient uptake by crop per tonne grain yield × T

Where,
T = Targeted yield (t ha^{-1}).

The composite soil samples from each treatment at 0-15 cm depth was collected and analyzed before the initiation of experiment during *kharif* and *rabi* seasons of 2014 and 2015. The nutrient statuses of soils are mentioned in the Table 1. Nutrient removal by soybean and chickpea crop per tonne seed yield were 75, 16.4, 39.0 and 46.3, 8.4, 49.6 NPK kg ha^{-1} respectively (IPNI website) (Doberman *et al*., 2004). The nutrient ratings for soil available nutrient status are as below.

Nutrient rating	Quantity to be applied
Medium	Exactly removal quantity
Low	30% more
High	30% less

The available soil nutrient status of the soil before sowing of soybean during *rabi* 2014 and 2015 were low in nitrogen, medium in phosphorous and high in potash. The calculated fertilizer doses for different target yield of soybean are given in the Table 1. 50% of nitrogen through urea and entire quantity of phosphorus through DAP (Diammonium phosphate) and potassium through MOP (Murate of potash) were supplied at the time of sowing as a basal dose to each plot and remaining 50 per cent of nitrogen was applied at 30 days after sowing. The soil samples were analyzed by adopting standard procedures (Nitrogen - Subbaiah and Assija method (1956), Phosphorus - Olsen *et al.* (1954), Potassium - Jackson (1973).The soil was medium deep black, neutral in reaction.

The energy indices *viz*., were work out based on formula given by Devasenapathy *et al*., (2008). Input energy will be calculated for various inputs and management practices during crop cultivation and the output energy will be calculated from economic and byproduct yields (Table 2, 3 and 4).

Energy efficiency (MJ ha^{-1}) is cultural energy utilized through inputs and energy produced as products are calculated and expressed as Mega Joules. Energy efficiency

Table 1: The calculated fertilizer dose for different targeted yield for Soybean and Chickpea during *rabi* 2014 and 2015.

Treatment	Soybean			Chickpea		
	N	P	K	N	P	K
	-----kg ha^{-1}----					
Target yield of 2.00 t ha^{-1}	195	33	55	120	17	69
Target yield of 2.50 t ha^{-1}	244	41	68	150	21	87
Target yield of 3.00 t ha^{-1}	293	49	82	181	25	104
Target yield of 3.50 t ha^{-1}	341	57	96	211	29	122
RDF	40	80	25	25	50	0
Farmer's practice	18	46	0	9	23	0

Table 2: Energy equivalent for different inputs and outputs in crop production.

Particular	Units	Equivalent energy	Remarks
A. Inputs			
1. Human labour			
Adult man	Man-hour	1.96	
Women	Woman-hour	1.57	
2. Animals	Bullock-pair/day	64.56	
3. Diesel	Litre	56.13	Includes cost of lubricants
4. Petrol	Litre	48.23	Includes cost of lubricants
5. Electricity	KWh	11.93	
6. Machinery			
Electric motors	Kg	64.80	
Farm machinery including self propelled machines	kg	62.70	
7. Chemical fertilizers			
Nitrogen	kg	60.60	
Phosphates (P_2O_5)	kg	11.10	
Potash (K_2O)	kg	6.70	
8. Farm yard manure (FYM)	Kg	0.30	Dry matter
9. Chemicals (Superior)	Kg	120	Require dilution at the time of application
10. Seed	All output of crop production system		
B. Output			
1. Main product			
Rice	kg	14.70	Dry matter
Wheat	kg	15.70	Dry matter
Maize	kg	15.10	Dry matter
Soybean	kg	14.70	Dry matter
Chickpea	kg	14.70	Dry matter
Pigeonpea	kg	14.07	
Vegetable cowpea	kg	3.91	
Mustard	kg	22.72	
2. By product Stem/haulm	kg	12.50	Dry matter

Devasenapathy *et al.* (2008).

Table 3: Soybean equivalent haulm yield, input energy and output energy as influenced by site specific nutrient management in soybean-chickpea cropping system.

Treatment	Soybean equivalent haulm yield (kg ha^{-1})			Input energy (x10^3 MJ ha^{-1})			Output energy(x10^3 MJ ha^{-1})		
	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled
T_1	10055	10036	10046	38.20	38.20	38.20	188.73	196.32	192.52
T_2	9970	9900	9935	39.59	39.59	39.59	193.45	199.52	196.49
T_3	10265	10129	10197	39.96	39.96	39.96	208.69	213.30	211.00
T_4	9913	9983	9948	43.00	43.00	43.00	194.61	203.12	198.87
T_5	9495	9610	9553	45.58	45.58	45.58	167.57	174.87	171.22
T_6	9264	9381	9322	38.69	38.69	38.69	176.78	184.52	180.65
T_7	9614	9730	9672	38.20	38.20	38.20	180.89	189.77	185.33
T_8	9685	10001	9843	39.49	39.49	39.49	185.95	199.50	192.73
T_9	10009	9880	9945	40.25	40.25	40.25	202.38	206.91	204.65
T_{10}	9629	9565	9597	43.00	43.00	43.00	189.47	194.67	192.07
T_{11}	8947	9321	9134	38.69	38.69	38.69	172.91	183.08	178.00
S.Em.±	267	237	195	-	-	-	-	-	-
C.D. at 5%	789	699	576	-	-	-	-	-	-

T_1: JS 335/JG 11 + Target yield 2.0 t ha^{-1}
T_2: JS 335/JG 11 + Target yield 2.5 t ha^{-1}
T_3: JS 335/JG 11 + Target yield 3.0 t ha^{-1}
T_4: JS 335/JG 11 + Target yield 3.5 t ha^{-1}
T_5: JS 335/JG 11 + Farmer's practice
T_6: JS 335/JG 11 + RDF
T_7: DSB 21/GBM 2 + Target yield 2.0 t ha^{-1}
T_8: DSB 21/GBM 2 + Target yield 2.5 t ha^{-1}
T_9: DSB 21/GBM 2 + Target yield 3.0 t ha^{-1}
T_{10}: DSB 21/GBM 2 + Target yield 3.5 t ha^{-1}
T_{11}: DSB 21/GBM 2 + RDF

Table 4: Price of inputs and outputs (as per the prevailing market prices) during 2014-15 and 2015-16.

Particulars		Unit	Price (Rs.)
A. Input			
I	Soybean seed	kg	57
	Chickpea seed	Kg	45
II	Fertilizer		
	Urea	kg	5.69
	DAP	kg	24.47
	MOP	Kg	17.93
III	Labour		
	Men	Day	342
	Women	Day	342
	Bullock pair	Day	550
IV	Plant protection chemicals		
	Lambda-cyhalothrin	liter	560
	Profenophos	liter	350
	Quinolphos	liter	325
	Carbandizim	kg	1000
V	Herbicides		
	Pendimethalin 38.7CS	liter	650
	Pendimethalin 30 EC	liter	340
	Oxyflourfen 23.7 EC	liter	1600
	Imazethapyr 10 SL	liter	1600
	Quizalofop p ethyl 5 EC	liter	1550
	Fenoxyprop p ethyl	liter	1650
B. Output			
I	Soybean seed	q	3650 (2014) and 3725 (2015)
	Chickpea seed	q	3150 (2014) and 3250 (2015)
II	Haulm (soybean and chickpea)	t	500 (2014 and 2015)

($MJ\ ha^{-1}$) was worked out by taking in account in the input and output energy for each treatment.

Energy efficiency (EE) = Energy output / Energy input

Specific energy ($MJ\ kg^{-1}$) of the treatment can be calculated in terms of energy required to produce a kg of main product and expressed as $MJ\ kg^{-1}$.

Specific energy (SE) =

Energy input ($MJ\ ha^{-1}$) / Grain yield ($kg\ ha^{-1}$).

Net energy ($MJ\ ha^{-1}$) can be calculated by deducting the energy input from the energy output of particular treatment or practice.

Net energy (NE) =

Energy output ($MJ\ ha^{-1}$) - Energy input ($MJ\ ha^{-1}$)

Energy productivity ($kg\ MJ^{-1}$) describes the quantity of physical output obtained for every unit of input and expressed as $kg\ MJ^{-1}$.

$$\text{Energy productivity (EP)} = \frac{\text{Output (grain+byproduct) (kg ha}^{-1}\text{)}}{\text{Energy input (MJ ha}^{-1}\text{)}}$$

Energy intensity is the ratio between energy output and total physical output or cultivation expenses and expressed as $MJ\ ha^{-1}$ in physical terms or $MJ\ Rs^{-1}$ in economic terms.

In physical terms ($MJ\ ha^{-1}$) =

Energy output ($MJ\ ha^{-1}$) / Output (grain + byproduct) ($kg\ ha^{-1}$).

In economic terms ($MJ\ Rs^{-1}$) =

Energy output ($MJ\ ha^{-1}$)/ cost of cultivation ($Rs\ ha^{-1}$)

Crop profitability ($Rs\ ha^{-1} day^{-1}$) =

CP = Net return ha^{-1} /No. of days field occupied

System profitability ($Rs\ ha^{-1}\ day^{-1}$) =

SP = Net return $ha^{-1}\ year^{-1}$/ 365

Relative economic efficiency (%)

It is a comparative measure of economic gains over the existing system. The following method is proposed for calculating the REE. It is expressed as percentage.

REE = DNR-ENR/ ENR

Where,

DNR- Net income obtained under improved/diversified system.

ENR- Net return obtained under existing system.

The experiment was laid out in randomized block design with the eleven treatment and three replications. The post popular cultivars of soybean and chickpea were JS 335, DSB 21 and JG 11, GBM 2 respectively used for the study. The data was analyzed statistically for test of significance following the procedure described by Gomez and Gomez (1984). The results have been discussed at the probability level of five per cent. The level of significance used in 'F' and 't' test were p=0.05. Critical difference values were calculated whenever the 'F' test was significant.

RESULTS AND DISCUSSION

Energy indices

Significantly higher energy efficiency, net energy, energy productivity, energy intensity in physical terms and economic terms, crop profitability, system profitability and relative economic efficiency were noticed in JS 335/JG 11 + target yield 3.0 t ha^{-1} (5.28 $MJ\ ha^{-1}$, 1,71,039.00 $MJ\ ha^{-1}$, 0.40 $kg\ MJ^{-1}$, 13.29 $MJ\ kg^{-1}$ and 3.68 MJ $Rs.^{-1}$, 723.53 $Rs.ha^{-1}\ day^{-1}$, 417.05 $Rs.ha^{-1}\ day^{-1}$ and 2.75, respectively) compared to JS 335/JG 11 + farmer's practice (3.76 $MJ\ ha^{-1}$, 1,25,638.83 $MJ\ ha^{-1}$, 0.29 $kg\ MJ^{-1}$, 13.09 $MJ\ kg^{-1}$ and 3.20 MJ $Rs.^{-1}$, 397.21 Rs. $ha^{-1}\ day^{-1}$, 228.90 Rs. $ha^{-1}\ day^{-1}$ and 0.00, respectively) Table 5 ,6, 7 and Fig 1, 2, 3). The treatments which produce higher energy efficiency, net energy, energy productivity, energy intensity, crop profitability, system profitability and relative economic efficiency are economically beneficial, advisable and recommended for large scale adoption.

Specific energy follows opposite trend as that of energy efficiency, significantly lower specific energy was recorded in JS 335/JG 11 + target yield 3.0 t ha^{-1} (7.05 $MJ\ kg^{-1}$) over JS 335/JG 11 + farmer's practice (13.01 $MJ\ kg^{-1}$), but it was on par with JS 335/JG 11 + target yield 3.0 t ha^{-1}(7.39 MJ kg^{-1}). Minimum energy required to produce a kg of seed was noticed in JS 335/JG 11 + target yield 3.0 t ha^{-1} than JS

335/JG 11 + farmer's practice. Thus, it may be concluded that site-specific nutrient management approach may break the yield barrier of soybean and chickpea by enhancing yield through judicious exploitation of available nutrients by plants. Nutrients applied to soybean crop have definite carry over beneficial effects on enhancing yield of succeeding chickpea crop. This indicates for a cautious and balanced use of nutrients for enhancing systems productivity and profitability without endangering soil and human health. The results can be correlated with findings of Mandal *et al*. (2002), Billore *et al*. (2009), Kirankumar *et al*. (2013), Mauriya *et al*. (2013), Walia *et al*. (2014) and Jain *et al*. (2015).

Table 5: Energy efficiency (EE), specific energy (SE) and net energy (NE) as influenced by site specific nutrient management in soybean-chickpea cropping system.

Treatment	Energy efficiency (MJ ha^{-1})			Specific energy (MJ kg^{-1})			Net energy (×10^3 MJ ha^{-1})		
	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled
T_1: JS 335/JG 11 + Target yield 2.0 t ha^{-1}	4.94	5.14	5.04	8.93	7.95	8.44	150.52	158.12	154.32
T_2: JS 335/JG 11 + Target yield 2.5 t ha^{-1}	4.89	5.04	4.96	8.48	7.76	8.12	153.86	159.93	156.90
T_3: JS 335/JG 11 + Target yield 3.0 t ha^{-1}	5.22	5.34	5.28	7.32	6.78	7.05	168.73	173.35	171.04
T_4: JS 335/JG 11 + Target yield 3.5 t ha^{-1}	4.53	4.72	4.63	9.02	8.08	8.55	151.61	160.13	155.87
T_5: JS 335/JG 11 + Farmer's practice	3.68	3.84	3.76	13.73	12.28	13.01	121.99	129.29	125.64
T_6: JS 335/JG 11 + RDF	4.57	4.77	4.67	9.40	8.54	8.97	138.09	145.83	141.96
T_7: DSB 21/GBM 2 + Target yield 2.0 t ha^{-1}	4.73	4.97	4.85	9.26	8.26	8.76	142.69	151.57	147.13
T_8: DSB 21/GBM 2 + Target yield 2.5 t ha^{-1}	4.71	5.05	4.88	8.95	7.79	8.37	146.46	160.01	153.24
T_9: DSB 21/GBM 2 + Target yield 3.0 t ha^{-1}	5.03	5.14	5.08	7.67	7.11	7.39	162.13	166.67	164.40
T_{10}: DSB 21/GBM 2 + Target yield 3.5 tha^{-1}	4.41	4.53	4.47	9.18	8.43	8.81	146.47	151.67	149.07
T_{11}: DSB 21/GBM 2 + RDF	4.47	4.73	4.60	9.32	8.56	8.94	134.22	144.39	139.31
S.Em.±	0.13	0.13	0.10	0.34	0.35	0.23	5.50	5.20	4.11
C.D. at 5%	0.39	0.38	0.29	1.01	1.02	0.70	16.24	15.34	12.12

Soybean cultivars- JS 335 and DSB 21.

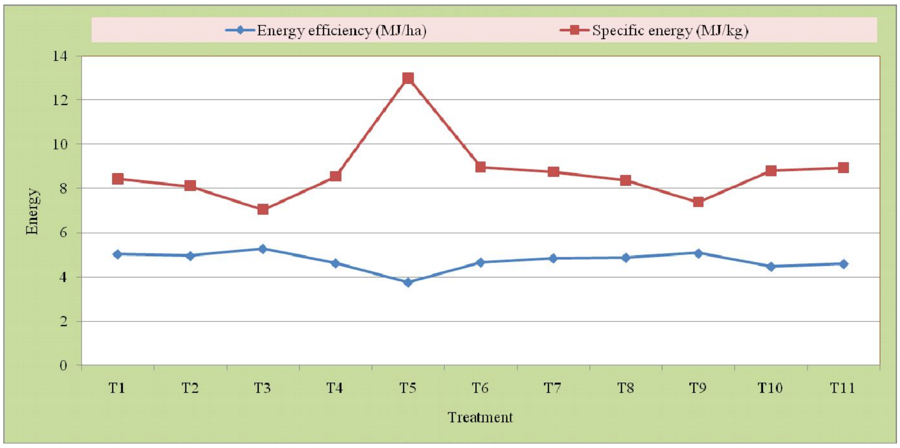
Chickpea cultivars- JG 11 and GBM 2.

Table 6: Energy productivity (EP), energy intensity (EI) in physical terms and energy intensity (EI) in economic terms as influenced by site specific nutrient management in soybean-chickpea cropping system.

Treatment	Energy productivity (kg MJ^{-1})			Energy intensity (Physical) (MJ kg^{-1})			Energy intensity (Economic) (MJ Rs^{-1})		
	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled
T_1: JS 335/JG 11 + Target yield 2.0 t ha^{-1}	0.36	0.37	0.37	13.16	13.21	13.19	3.53	3.63	3.58
T_2: JS 335/JG 11 + Target yield 2.5 t ha^{-1}	0.36	0.37	0.37	13.20	13.25	13.23	3.64	3.71	3.68
T_3: JS 335/JG 11 + Target yield 3.0 t ha^{-1}	0.39	0.40	0.40	13.26	13.31	13.29	3.66	3.79	3.72
T_4: JS 335/JG 11 + Target yield 3.5 t ha^{-1}	0.34	0.36	0.35	13.22	13.27	13.24	3.25	3.38	3.32
T_5: JS 335/JG 11 + Farmer's practice	0.28	0.29	0.29	13.07	13.11	13.09	3.17	3.24	3.20
T_6: JS 335/JG 11 + RDF	0.35	0.36	0.35	13.18	13.22	13.20	3.24	3.37	3.31
T_7: DSB 21/GBM 2 + Target yield 2.0 t ha^{-1}	0.36	0.38	0.37	13.16	13.21	13.19	3.50	3.66	3.58
T_8: DSB 21/GBM 2 + Target yield 2.5 t ha^{-1}	0.36	0.38	0.37	13.19	13.24	13.21	3.40	3.63	3.51
T_9: DSB 21/GBM 2 + Target yield 3.0 t ha^{-1}	0.38	0.39	0.38	13.26	13.30	13.28	3.61	3.75	3.68
T_{10}: DSB 21/GBM 2 + Target yield 3.5 tha^{-1}	0.33	0.34	0.34	13.22	13.27	13.24	3.53	3.60	3.56
T_{11}: DSB 21/GBM 2 + RDF	0.34	0.36	0.35	13.20	13.22	13.21	3.17	3.35	3.26
S.Em.±	0.01	0.01	0.01	0.01	0.01	0.01	0.09	0.09	0.07
C.D. at 5%	0.02	0.02	0.02	0.03	0.04	0.02	0.28	0.27	0.21

Table 7: Relative economic efficiency, crop profitability and system profitability as influenced by site specific nutrient management in soybean-chickpea cropping system.

Treatment	Relative economic efficiency			Crop profitability ($Rs.ha^{-1}day^{-1}$)			System profitability ($Rs.ha^{-1}day^{-1}$)		
	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled
T_1: JS 335/JG 11 + Target yield 2.0 t ha^{-1}	1.27	1.35	1.31	494.83	611.38	553.10	287.41	350.08	318.74
T_2: JS 335/JG 11 + Target yield 2.5 t ha^{-1}	1.77	1.81	1.79	547.91	655.77	601.84	318.24	375.49	346.87
T_3: JS 335/JG 11 + Target yield 3.0 t ha^{-1}	2.80	2.71	2.75	671.01	776.06	723.53	389.74	444.37	417.05
T_4: JS 335/JG 11 + Target yield 3.5 t ha^{-1}	2.01	2.01	2.01	545.71	662.46	604.08	316.96	379.32	348.14
T_5: JS 335/JG 11 + Farmer's practice	0.00	0.00	0.00	353.61	440.81	397.21	205.38	252.41	228.90
T_6: JS 335/JG 11 + RDF	0.90	1.09	0.99	457.08	553.70	505.39	265.48	317.05	291.27
T_7: DSB 21/GBM 2 + Target yield 2.0 t ha^{-1}	0.97	1.16	1.07	467.67	578.35	523.01	271.63	331.16	301.40
T_8: DSB 21/GBM 2 + Target yield 2.5 t ha^{-1}	1.37	1.68	1.53	501.72	640.14	570.93	291.41	366.54	328.98
T_9: DSB 21/GBM 2 + Target yield 3.0 t ha^{-1}	2.49	2.43	2.46	634.65	736.21	685.43	368.62	421.56	395.09
T_{10}: DSB 21/GBM 2 + Target yield 3.5 tha^{-1}	1.83	1.73	1.78	527.00	623.22	575.11	306.09	356.86	331.48
T_{11}: DSB 21/GBM 2 + RDF	1.00	1.00	1.00	458.15	545.39	501.77	266.10	312.29	289.20
S.Em.±	0.32	0.22	0.22	28.67	33.35	23.47	16.65	19.09	13.52
C.D. at 5%	0.95	0.66	0.66	84.58	98.38	69.25	49.13	56.33	39.90



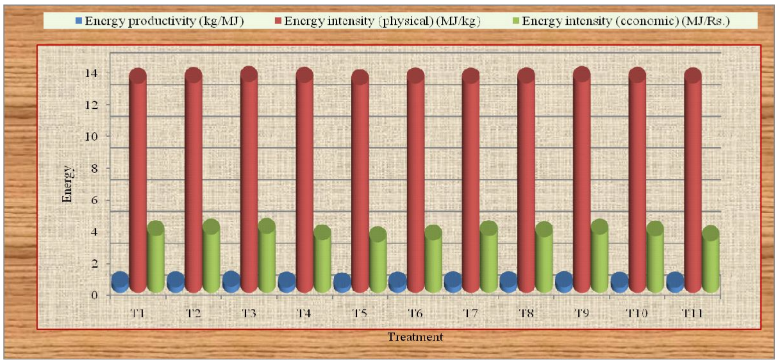
T_1 : JS 335/JG 11 + Target yield 2.0 t ha^{-1}
T_2 : JS 335/JG 11 + Target yield 2.5 t ha^{-1}
T_3 : JS 335/JG 11 + Target yield 3.0 t ha^{-1}
T_4 : JS 335/JG 11 + Target yield 3.5 t ha^{-1}
T_5 : JS 335/JG 11 + Farmer's practice
T_6 : JS 335/JG 11 + RDF
T_7 : DSB 21/GBM 2 + Target yield 2.0 t ha^{-1}
T_8 : DSB 21/GBM 2 + Target yield 2.5 t ha^{-1}
T_9 : DSB 21/GBM 2 + Target yield 3.0 t ha^{-1}
T_{10} : DSB 21/GBM 2 + Target yield 3.5 t ha^{-1}
T_{11} : DSB 21/GBM 2 + RDF

Fig 1: Energy efficiency and specific energy as influenced by site specific nutrient management in soybean-chickpea cropping system.

These indices suggest that the target yield based on SSNM equation not only optimizes the soybean-chickpea system yield to the desired level but maintains the better soil health which is a prime factor for sustainable crop production and for large scale adaptation. The above findings suggest that SSNM technology may be the appropriate approach for optimum nutrient supply which improves the soil properties especially the soil health and productivity in a long run in comparison to other nutrient management technologies. The results indicated that the maximum potential yield of genotypes for both soybean and chickpea was achieved upto target yield of 3.0 t ha^{-1}.

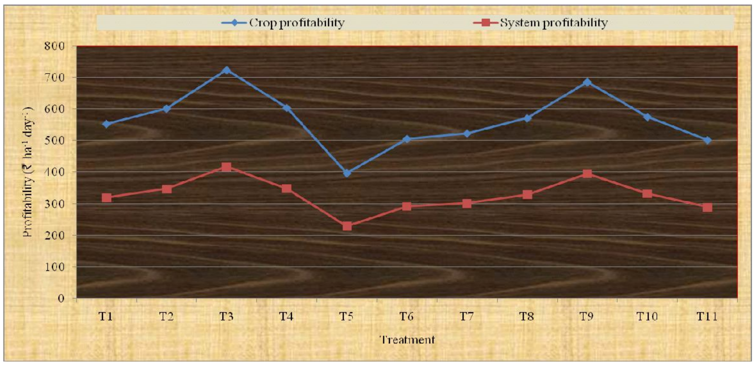
Soybean equivalent yield and system profitability

Among the different target yield levels (Table 8 and Fig 4), the pooled data indicated that significantly higher soybean equivalent yield, gross return, net return and BC ratio were obtained in JS 335/JG 11 with target yield of 3.0 t ha^{-1} (5683 kg ha^{-1}, Rs.2,09,623 ha^{-1}, Rs. 1,52,224 ha^{-1} and 3.65 respectively) compared to rest of the target yield levels but it was found to be on par with that of DSB 21/GBM 2 with target yield of 3.0 t ha^{-1} (5465 kg ha^{-1}, Rs. 2,01,612 ha^{-1}, Rs.1,44,208 ha^{-1} and 3.51 respectively), while significantly lower soybean equivalent yield was registered in the target yield treatments of DSB 21/GBM 2 with target yield of



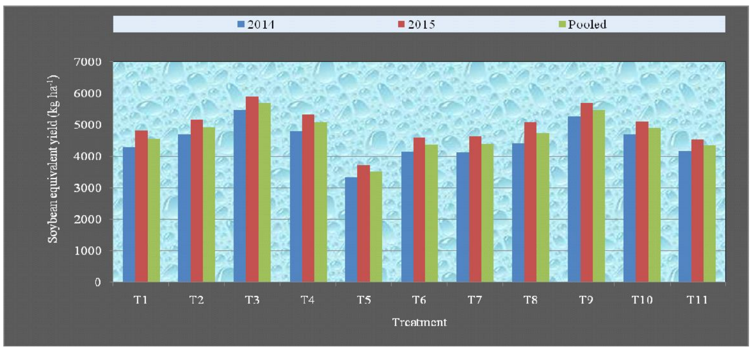
T_1: JS 335/JG 11 + Target yield 2.0 t ha^{-1}
T_2: JS 335/JG 11 + Target yield 2.5 t ha^{-1}
T_3: JS 335/JG 11 + Target yield 3.0 t ha^{-1}
T_4: JS 335/JG 11 + Target yield 3.5 t ha^{-1}
T_5: JS 335/JG 11 + Farmer's practice
T_6: JS 335/JG 11 + RDF
T_7: DSB 21/GBM 2 + Target yield 2.0 t ha^{-1}
T_8: DSB 21/GBM 2 + Target yield 2.5 t ha^{-1}
T_9: DSB 21/GBM 2 + Target yield 3.0 t ha^{-1}
T_{10}: DSB 21/GBM 2 + Target yield 3.5 t ha^{-1}
T_{11}: DSB 21/GBM 2 + RDF

Fig 2: Energy productivity, energy intensity (physical) and energy intensity (economic) as influenced by site specific nutrient management in soybean-chickpea cropping system.



T_1: JS 335/JG 11 + Target yield 2.0 t ha^{-1}
T_2: JS 335/JG 11 + Target yield 2.5 t ha^{-1}
T_3: JS 335/JG 11 + Target yield 3.0 t ha^{-1}
T_4: JS 335/JG 11 + Target yield 3.5 t ha^{-1}
T_5: JS 335/JG 11 + Farmer's practice
T_6: JS 335/JG 11 + RDF
T_7: DSB 21/GBM 2 + Target yield 2.0 t ha^{-1}
T_8: DSB 21/GBM 2 + Target yield 2.5 t ha^{-1}
T_9: DSB 21/GBM 2 + Target yield 3.0 t ha^{-1}
T_{10}: DSB 21/GBM 2 + Target yield 3.5 t ha^{-1}
T_{11}: DSB 21/GBM 2 + RDF

Fig 3: Crop profitability and system profitability as influenced by site specific nutrient management in soybean-chickpea cropping system.



T_1: JS 335/JG 11 + Target yield 2.0 t ha^{-1}
T_2: JS 335/JG 11 + Target yield 2.5 t ha^{-1}
T_3: JS 335/JG 11 + Target yield 3.0 t ha^{-1}
T_4: JS 335/JG 11 + Target yield 3.5 t ha^{-1}
T_5: JS 335/JG 11 + Farmer's practice
T_6: JS 335/JG 11 + RDF
T_7: DSB 21/GBM 2 + Target yield 2.0 t ha^{-1}
T_8: DSB 21/GBM 2 + Target yield 2.5 t ha^{-1}
T_9: DSB 21/GBM 2 + Target yield 3.0 t ha^{-1}
T_{10}: DSB 21/GBM 2 + Target yield 3.5 t ha^{-1}
T_{11}: DSB 21/GBM 2 + RDF

Fig 4: Soybean equivalent yield as influenced by site specific nutrient management in soybean-chickpea cropping system.

Table 8: Soybean equivalent yield, cost of cultivation, gross returns, net returns and BC ratio as influenced by site specific nutrient management in soybean-chickpea cropping system.

Treatment	Soybean equivalent yield (kg ha^{-1})			Cost of cultivation ($Rs.ha^{-1}$)			Gross returns ($Rs.ha^{-1}$)			Net returns ($Rs.ha^{-1}$)			B:C ratio		
	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled
T_1	4288	4821	4555	51610	51810	51710	156513	179588	168051	104903	127778	116341	3.03	3.47	3.25
T_2	4682	5155	4918	54750	54950	54850	170907	192005	181456	116157	137055	126606	3.12	3.49	3.31
T_3	5467	5898	5683	57304	57494	57399	199557	219690	209623	142253	162196	152224	3.48	3.82	3.65
T_4	4810	5329	5069	59862	60062	59962	175553	198515	187034	115691	138453	127072	2.93	3.31	3.12
T_5	3325	3724	3524	46392	46592	46492	121357	138722	130040	74965	92130	83548	2.62	2.98	2.80
T_6	4148	4575	4362	54513	54713	54613	151413	170437	160925	96900	115724	106312	2.78	3.12	2.95
T_7	4130	4636	4383	51610	51810	51710	150756	172684	161720	99146	120874	110010	2.92	3.33	3.13
T_8	4414	5067	4740	54750	54950	54850	161115	188739	174927	106365	133789	120077	2.94	3.43	3.19
T_9	5256	5674	5465	57304	57504	57404	191851	211373	201612	134547	153869	144208	3.35	3.68	3.51
T_{10}	4701	5109	4905	59862	60062	59962	171587	190314	180950	111725	130252	120988	2.87	3.17	3.02
T_{11}	4155	4529	4342	54513	54713	54613	151640	168700	160170	97127	113987	105557	2.78	3.08	2.93
S.Em.±	166	187	133	-	-	-	-	-	-	6078	6970	4937	0.10	0.12	0.08
C.D. at 5%	491	552	394	-	-	-	-	-	-	17932	20562	14564	0.31	0.38	0.26

Price of soybean: Rs. 3650 q^{-1} (2014) and Rs. 3725 q^{-1} (2015). Price of chickpea: Rs.3150 q^{-1} (2014) and Rs.3225 q^{-1} (2015).

T_1 : JS 335/JG 11 + Target yield 2.0 t ha^{-1}
T_2 : JS 335/JG 11 + Target yield 2.5 t ha^{-1}
T_3 : JS 335/JG 11 + Target yield 3.0 t ha^{-1}
T_4 : JS 335/JG 11 + Target yield 3.5 t ha^{-1}
T_5 : JS 335/JG 11 + Farmer's practice
T_6 : JS 335/JG 11 + RDF
T_7 : DSB 21/GBM 2 + Target yield 2.0 t ha^{-1}
T_8 : DSB 21/GBM 2 + Target yield 2.5 t ha^{-1}
T_9 : DSB 21/GBM 2 + Target yield 3.0 t ha^{-1}
T_{10} :DSB 21/GBM 2 + Target yield 3.5 t ha^{-1}
T_{11} : DSB 21/GBM 2 + RDF

soybean/chickpea to 2.0 t ha^{-1} (4383 kg ha^{-1}, Rs. 1,61,720 ha^{-1}, Rs. 1,10,010 ha^{-1} and 3.13). Significantly lower soybean equivalent yield, gross return, net return and BC ratio were noticed in JS 335/JG 11 with farmer's practice (3524 kg ha^{-1}, Rs. 1, 30,040 ha^{-1}, Rs. 83,548 ha^{-1} and 2.80) among all the treatments. The cost of cultivation of soybean-chickpea cropping sequence was higher with JS 335/JG 11 + target yield 3.0 t ha^{-1} (Rs.57,399 ha^{-1}) over JS 335/JG 11 + farmer's practice (Rs.46,492 ha^{-1}). This may be due to higher cost of fertilizers resulted in increased cost of cultivation in soybean-chickpea cropping sequence. The higher gross returns observed in the above treatment was mainly attributed to significantly higher grain and straw yields obtained in the respective treatments. Significantly higher grain yield of preceding soybean coupled with higher market price for succeeding chickpea contribution for higher system net return. This might be due to higher grain, seed and straw yield of component crops (soybean-chickpea) due to different targeted yield levels. These results are in conformity with the findings of Mauriya *et al*. (2013), Honnalli and Chittapur (2014), Jain *et al*. (2015) and Shreeharshakumar and Gaddanakeri (2015).

CONCLUSION

The target yield based on SSNM equation not only optimizes the soybean- chickpea system yield to the desired level but maintains the better soil health which is a prime factor for sustainable crop production and for large scale adaptation by efficiently comparison with energy efficiency.

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