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Integrated Nutrient Management on Economics and Energy Utilization in Vegetable Pea Production

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Abstract

The productivity, input use efficiency, cost-benefit ratio and energy use pattern of vegetable pea (*Pisum sativum* L.) production were significantly influenced by the use of integrated nutrient management technology (INM). The on-farm experimental data on three most popular varieties of pea (Azad P1, Azad P3 and Arkel) under different sets of nutrient management treatments with conventional flood irrigation and sprinkler irrigation for five years were collected from Indian Institute of Vegetable Research, Varanasi. Nutrient management with optimum dose of NPK along with sulphur (from organic source *i.e.* pressmud @ 2 t ha^{-1}) and seed treatments with *Rhizobium* inoculums coupled with sprinkler irrigation on 28 and 49 days after sowing were found to be a promising agro – technique to enhance seed yield (9.7 -13.5 q ha^{-1}), agronomic/ chemical nutrient use efficiency (0.22/170) and economic return (C: B=1:3.2). The peer conventional farmers' practice comprising of N, P and K application @ 30, 60 and 80 kg ha^{-1} respectively followed by flood irrigation just before flowering stage was found to produce 6-9 q ha^{-1} seed yield with nutrient use efficiency of 0.07/92 and cost-benefit ratio 1:1.96. The output – input energy ratio analysis of vegetable pea cultivation was found to range from 5.5 to 7.2 as compared to 4.2 reported for wheat production in Uttar Pradesh, India. This paper suggested that adoption of developed integrated nutrient management module for vegetable pea cultivation could reap higher economic return and save energy as compared to wheat cultivation in *transect 4* of the Gangetic Plain region.

1. Introduction

The decreasing factor productivity of crops in the grain-bowl of the Indo-Gangetic plains (IGP) needs an urgent attention. In recent years crop diversification from rice-wheat cropping system to high value crops including vegetables particularly in *transect 4* of IGP is getting momentum (Biswas et al., 2006). The nutrient use efficiency of applied fertilizer needs to be enhanced to sustain productivity and have better economic return. Pea is very sensitive to the soil moisture content particularly at seed germination, flowering and the pod filling stages. The use of sprinkler irrigation system has been proved superior over flood irrigation in increasing yield and water use efficiency in pea (De et al., 2007). In the present investigation an attempt was made to quantify productivity, input use efficiency, economic return and energy balance analysis of vegetable pea production under developed nutrient management module and compared it with the conventional wheat production system.

2. Materials and Methods

The IGP region can be subdivided into five broad transects based on physiographic, bioclimatic and social factors (Gupta and Seth, 2007). The low recovery of applied inorganic fertilizer, decrease in nutrient use efficiency, utilization efficiency of inputs and factor productivity in the intensive agricultural production system are of serious concern. In this paper we evaluated the effect of a developed integrated nutrient management module with recommended dose of $N_{30}P_{60}K_{80}$ and sulphur (from organic source i.e., press mud @ 2 t ha^{-1}) coupled with seed treatment by *Rhizobium* and soil application of PSM @ 5 kg ha^{-1} plus sprinkler irrigation at 28 and 49 days after sowing on seed yield, fertilizer use efficiency and economic return in pea (*Pisum sativum* L.) cultivation.

On farm experimental data were generated during rabi season in 2002 to 2006 at the Indian Institute of Vegetable Research farm (82.52^0 longitudes and 25.10^0 N latitude), Varanasi, with three prominent varieties of pea (Azad P1, Azad P3 and Arkel) under different treatments. The soil of the experimental site was sandy loam, Indo-Gangetic alluvium of Inceptisol origin (*Typic Ustochrept*) with neutral pH (7.6-7.8), low EC (0.41 dSm^{-1}), low organic carbon (0.38 – 0.41 %) and low to medium available N (270 – 310 kg ha^{-1}), available P (18 – 23 kg ha^{-1}), available K_2O (180 – 210 kg ha^{-1}) and S (10 – 14 kg ha^{-1}). Seeds of these varieties were sown during first week of November every year. The treatments were conventional, sprinkler and no irrigation to create difference levels of soil moisture in the rhizosphere of cultivated crop. The experiment was conducted in a split-plot design with three replications. The crop was planted in a flat bed system with row spacing of 20 cm keeping 10 cm distance between two plants. The entire recommended dose of N, P and K (@ 30, 60 and 80 kg ha^{-1}) fertilizers were applied at the time of field preparation just before sowing. The crop was irrigated through sprinkler and flood system at active growth stage and at pod initiation stage. The yield and yield attributes were recorded at physiological maturity stage.

The crops were grown under different set of nutrient management module which were represented as treatments viz., T_0- control, T_1 (N_{30}, P_{60}, K_{80} kg ha^{-1}), T_2 (T_1 + S_{40} kg ha^{-1}), T_3 (T_1 + pressmud @ 2 t ha^{-1}+ *Rhizobium* seed treatment + soil application of PSM @ 5 kg ha^{-1} at the time of sowing), T_4 conventional farmers' technique - poor farmer technique (external application of only nitrogen @ 30 kg ha^{-1}), and T_5- rich farmers' technique (external application of only nitrogen and phosphorus@ 30 and 60 kg ha^{-1}) applied at the time of sowing. The full amount of FYM, NPK and pressmud were applied at the time of field preparation. The field experiment was executed in a split plot design with three replications. The size of each replicated plot was 15 m^2. The crop was planted on 4th November in 2002, 2nd November in 2003, 6th November in 2004, 4th November in 2005 and 6th November in 2006 and recommended agronomic practices and plant protection measures were followed.

The water holding capacity of the experimental soil was measured by standards Keen's box technique. The average soil moisture content at sowing was 28.4 % leading to a uniform good germination of the crop. The first sprinkler irrigation was given at 28 days after sowing and soil moisture content shoots up from 12.5 % to 33 %. The second sprinkler irrigation was given at 49 DAS when soil moisture level decreased to 14.9 % from 33 %, and after irrigation the moisture level rose to 32.6 %, which gradually decreased to around 15 % during physiological maturity. Under flood irrigation system the soil moisture level shoots up from initial 12.5 % (at 28 DAS) to 43 % immediately after irrigation. A high level of soil moisture content, 35 %, 28 % and 24 % at 36, 43 and 49 DAS respectively were recorded during active growth to flowering and pod setting stage. The available soil moisture was found to be higher in sprinkler irrigation from 49 DAS to physiological maturity (70 DAS) stage, thereafter, soil moisture content was at par under both the system. In no irrigation system the soil moisture content gradually decreased from 12.5 % to 9.6 % at physiological maturity stage (Figure 1). The grain samples of pea were analyzed for nitrogen, phosphorus sulphur content by standard method (Jackson, 1967). The on farm primary data was analyzed for total uptake, agronomic use efficiency, chemical use efficiency, nutrient recovery fraction, utilization use efficiency and percentage return to fertilizer in term of yield following the method of Santos et al. 2003, and Baligar et al., 2001. The derivations of different productivity and use efficiency components were follows:

$$\text{Fertilizer use efficiency (FUE) on chemical components} = \frac{\text{Uptake of concerned chemicals (kg)}}{\text{application of concerned fertilizer (kg)}} \times 100$$

$$\text{Fertilizer Use Efficiency (FUE) on Agronomical components} = \frac{\text{Increase in yield (kg)}}{\text{Application of applied fertilizer (kg)}}$$

$$\text{Fertilizer Use Efficiency (FUE) on Economical components} = \frac{\text{Return in ₹ (yield)}}{\text{₹ invested as concerned inputs (cost of cultivation)}} \times 100$$

$$\text{Utilization efficiency} = \frac{\text{Increase in grain yield (kg)}}{\text{Increase uptake of nutrient (kg)}}$$

$$\text{Recovery fraction} = \frac{\text{Increase uptake of nutrient}}{\text{Increase applied dose of nutrient}} \times 100$$

$$\text{Percentage return to fertilizer} = \frac{\text{Increase return – (fertilizers + application cost)}}{\text{(fertilizers + application cost)}}$$

$$\text{Interaction impact on grain yield (\%)} = \frac{\text{Yield response to treated plot - yield response to untreated plot}}{\text{Yield response to untreated plot}} \times 100$$

$$\text{Interaction impact on economic Nutrient Use Efficiency, NUE (\%)} = \text{(NUE with treated plot -NUE of control plot)} \times 100$$

The input-output energy ratio analysis for vegetable pea production and comparative study with wheat crop was worked out following the method of Canakci et al. 2005 and Singh et al., 2007.

3. Results and Discussion

The number of pod $plant^{-1}$, ten pod weight, pod length, the number of grain pod^{-1}, grain yield (18.9 q ha^{-1}) and vegetable pea yield (98.5 q ha^{-1}) were significantly greater in Azad P-1 followed by Azad P-3 and Arkel. Fresh root weight (1463.8 mg plant^{-1}) was significantly higher in Azad P-1 followed by Azad P-3 (1387.9 mg plant^{-1}) and Arkel (1012.9 mg plant^{-1}). There was no significant difference in nodule number among the varieties (Table 1). The nodule weight was significantly higher in Azad P-1 (246.7 mg plant^{-1}) over Arkel (194.3 mg plant^{-1}) and Azad P-3 (164.2 mg plant^{-1}).

The application of pressmud significantly increased the yield and yield attributes like number of pod per plant, ten pod weight, pod length and total yield, as evidenced in the treatment. The number of grain per pod significantly increased when treated with balanced dose of N, P, K and S compared to all tested treatments. The ratios of N, P, K and S significantly influenced growth parameter (Table 2). The amount of N, P and K added through chemical fertilizer coupled with the supply of S was found effective for better plant health and higher yield. Press-mud contains available S in the range of 7.8-11.2 %. Besides, supplying additional amount of nutrient N, P, K and S, it helped in improving soil physical properties and thereby increased water and nutrient holding capacity of the soil. It was also observed that the supply of nutrients through combination of inorganic and organic sources was more effective in enhancing yield and its attributing characters. Significant improvement in the yield attributes was due to better uptake of nutrients when treated with recommended dose of N, P and K with organic combinations. The balanced application of N, P, K and S significantly influenced the yield attributes of pea. The maximum nodule number and nodule weight was recorded when the crop was treated with pressmud plus *Rhizobium* and PSM inoculums. Superiority of dual inoculation with N fixing and P solubilizing microorganism compared to single inoculation of *Rhizobium* is also reported (Aulakh and Malhi, 2005). The favourable effect of *Rhizobium* and PSM in release of nutrients and subsequent uptake by the crop and their positive role on higher nodulation and growth attributes of pea has earlier been reported. The experimental results indicated the effect of N: S balance fertilization for higher yield and nodulation of pea crop. The application of sprinkler irrigation at 28 and 49 days after sowing (DAS) significantly increased the vegetable pod yield as well as yield attributes like number of pod/plant, 10 pod weight, and grain yield to the tune of 25 % to 50 % compared to flood irrigation once at 28 days after sowing or no irrigation during the entire crop growth period. The soil moisture level increased from initial 12.5 % (at 28 DAS) to 43 % immediately after flood irrigation and then gradually decreased to 35 %, 28 % and 24 % at 36, 43 and 49 DAS respectively during active growth to flowering and pod setting stage. The available soil moisture was higher under sprinkler irrigation from 49 DAS to physiological maturity (70 DAS) stage. In no irrigation system the soil moisture content uniformly decreased from 12.5 % (at 28 DAS) to 9.6 % at physiological maturity stage. The soil moisture depletion pattern over time in no irrigation plot for the experimental soil followed power function with

Table 1: Variation in yield and yield attributes of pea

Traits	Arkel	Azad P-1	Azad P-3	LSD (p=0.05)
Fresh weight plant^{-1} (g)	24.9^{a}	23.1^{b}	24.2^{ab}	1.47
Fresh root weight plant^{-1} (mg)	1012.9^{c}	1468.8^{a}	1387.9^{b}	49.5
Nodule no. plant^{-1}	46.3^{a}	50.8^{a}	45.6^{a}	6.1^{NS}
Nodule no. plant^{-1}	46.3^{a}	50.8^{a}	45.6^{a}	6.1^{NS}
No. of pod plant^{-1}	9.7^{ab}	10.1^{a}	8.35^{b}	1.58
Ten pod weight (g)	44.0^{a}	56.0^{a}	47.21^{a}	3.55^{NS}
Pod length (cm)	8.7^{b}	9.3^{a}	8.99^{ab}	0.35
No. of grains pod^{-1}	5^{c}	7.3^{a}	6.21^{b}	0.6
Vegetable pea yield (q ha^{-1})	75.4^{c}	98.5^{a}	86.2^{b}	6.3
Grain yield (q ha^{-1})	13.4^{c}	18.9^{a}	15.6^{b}	1.3

Table 2: Effect of IPNM modules on yield and yield attributes of vegetable pea

Treatment	T_0	T_1	T_2	T_3	T_4	T_5	$LSD_{0.05}$
No. of pod plant^{-1}	7.6^{c}	9.1^{bc}	9.6^{c}	10.9^{ab}	8.8^{bc}	9$_{bc}$	2.58
Ten pod weight (g)	33.3^{c}	46.3^{b}	43.5^{b}	57.6^{a}	37.9b^{c}	39.6^{bc}	8.73
Pod length (cm)	8.2^{e}	8.8^{cd}	9.1^{cd}	9.7^{ab}	8.8^{cde}	8.4^{de}	0.58
No. of grain pod^{-1}	5.1^{d}	5.9^{bcd}	6.4^{bc}	6.7^{b}	5.6^{cd}	5.6^{cd}	0.98
Fresh wt plant^{-1} (g)	21.4^{c}	26.2^{a}	24.7^{a}	25.9^{a}	21.8^{bc}	21.9^{bc}	2.4
Fresh root weight plant^{-1} (mg)	872.2^{d}	1443.3^{ab}	1211^{bc}	1433.4^{c}	1290^{bc}	1178.9^{c}	80.9
Nodule no. plant^{-1}	38.6^{c}	51.4^{ab}	42.7^{bc}	52.3^{ab}	42.9^{bc}	45.6^{abc}	9.97
Nodule weight plant^{-1}(mg)	132.8^{d}	198.3^{bc}	260.1^{a}	221.7^{ab}	169.4^{c}	190^{bc}	36.8
Grain yield (q ha^{-1})	10.2^{d}	16.4^{b}	18.1^{b}	22.2^{a}	12.4^{c}	13.7^{c}	2.2
Fresh pod yield (q ha^{-1})	41.8^{d}	65.3^{b}	73.6^{b}	88.7^{a}	49.6^{cd}	54.7^{c}	8.2

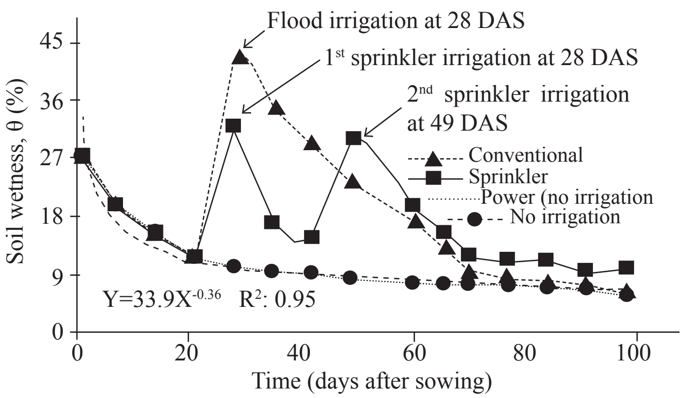

Figure 1: Soil moisture regime under conventional, sprinkler and no irrigation system (with trend line equation)

high correlation value (R^2=0.95). The soil moisture regime in the root zone of the crop might have impact on the yield and nodule properties of pea crop.

A critical evaluation of data indicated that application of recommended dose of NPK along with pressmud @ 2t ha^{-1} (13.2 q ha^{-1}) resulted in maximum grain yield which was at par to recommended dose of inorganic fertilizer NPK with S @ 40 kg ha^{-1} (12.6 q ha^{-1}). Application of organic sources of sulphur in combination with recommended dose of NPK was significantly superior in increasing yield (60 %) compared to other treatment combinations. Organic and inorganic combination of nutrient supply may be synergistic as organic source improve soil physical and biological environment which in turn increase the availability of nutrients from inorganic source. The increased N, P and S content in soil and their uptake by grains as evidenced in the present experiment (table 3) can be attributed to release of both macro (N, P and S) and micro (Fe, Mo and Cu) nutrients from organic manure and their availability to plant uptake. Further microbial activity brings about the transformation of insoluble inorganic nutrients to available forms which are easily taken up by the plant.

The present paper highlights and compares the effect of INM modules and farmers practice on yield, nutrient use efficiency and economics of pea cultivation. The agronomic nutrient use efficiency for N and P under INM module comprising of N: P: K @ 30:60:80 kg ha^{-1} plus pressmud @ 2 t ha^{-1} were 3 and 3.2 times greater than those under conventional farmers' practice while chemical nutrient use efficiency for N and P increased by 90% and 100% respectively over conventional farmers practice. The per cent return to fertilizer, interaction impact on grain yield and interaction impact on economically nutrient use efficiency were 6.7%, 100% and 140% respectively under the said INM module in comparison to 2.4%, 29% and 20% respectively under the conventional farmers' practice. With the use of developed INM module, 60% increase in average pea yield with significantly higher benefit (120%) per rupee invested was realized.

3.1. Nutrient use efficiency versus grain yield

Among the various nutrient management modules studied, maximum agronomic use efficiency and chemical use efficiency of nitrogen and phosphorus were found in INM module where Pressmud @ 2t ha^{-1} was applied along with recommended dose of NPK (Table 3). The reduced losses of nitrogen and phosphorus and higher availability of nutrients resulting from integrated use of organic and inorganic sources of nutrients lead to improvement in grain yield and consequently higher nutrients use efficiency (Singh and Agarwal 2005). A linear trend line equation with high degree of correlation (R^2=0.97) was observed between nutrient use efficiency and yield (t ha^{-1}), which indicated a direct proportional yield rise (slope = 0.41) with increase in FUE (Figure 2).

3.2. Apparent recovery of nutrients

Apparent recovery of nitrogen and phosphorus increased from

Table 3: Effect of inorganic and organic alone and combination on yield and content, uptake and use efficiency of nutrient in pea

Treatment		Nutrient content in grain (%) / Nutrient uptake by grain (kg ha^{-1})^a			Agronomic nutrient use efficiency / Chemical nutrient use efficiency (%)^b			Utilization use efficiency of nutrient / Nutrient recovery fraction (%)^c		
		N	P	S	N	P	S	N	P	S
Control		3.2/21.1	0.47/3.1	0.20/1.3	NA	NA	NA	NA	NA	NA
$N_{30}P_{60}K_{80}$ kg ha^{-1}		3.4/27.8	0.55/4.5	0.29/2.4	0.07/92	0.003/7.5	NA	0.23/22	1.14/3	1.4/NA
$N_{30}P_{60}K_{80}$ kg ha^{-1} + S_{40} kg ha^{-1}		3.8/47.9	0.60/7.6	0.37/4.7	0.20/159	0.10/13	0.15/12	0.22/20	1.33/10	1.7/15
Pressmud @2 t ha^{-1} + $N_{30}P_{60}K_{80}$ kg ha^{-1}		3.8/50.2	0.61/8.2	0.35/4.7	0.22/170	0.11/15	NA	0.22/22	1.9/11	2.0/NA
Conventional Farmers' technique	PF	3.4/12.4	0.50/3.5	0.10/NA	0.013/82	0.006/5.5	NA	0.13/1.3	0.1/0.7	0.7/NA
	RF	3.5/33.9	0.56/5.4	NA	0.05/113	00/8.0	NA	0.23/1.0	0.24/5.0	NA

NA= not applicable; ^{a}Numerator unit %, Denominator unit kg ha^{-1}; ^{b}Numerator unit less, Denominator unit %; ^{c}Numerator unit less, Denominator unit %; N: Nitrogen; P: Phosphorus; S: Sulphur; PF: Poor Farmer; RF: Rich Farmer

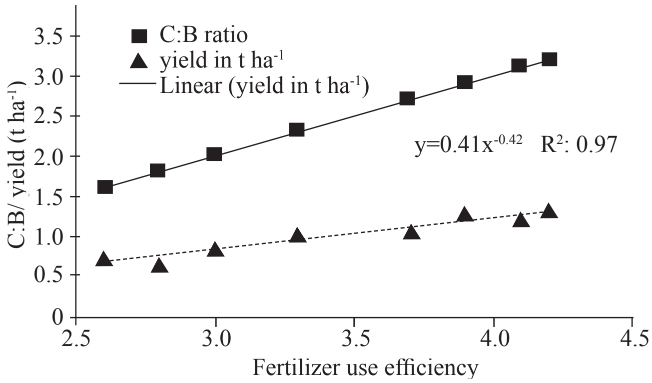

Figure 2: Interrelationship of fertilizer use efficiency, cost: benefit ratio and yield (with trend line equation) in pea

1.3 to 22 and 0.7 to 11 % respectively with the application of pressmud @ 2t ha^{-1} along with recommended dose of NPK, which implied to less nitrogen losses and more phosphorus solubilization through microbial activity stimulated by organic manure (*i.e.* pressmud) via release of organic acids and synchronization of nitrogen and phosphorus supply as per crop need (Rao and Shaktawat, 2002)

3.3. Economics

The INM module, application of pressmud @ 2t ha^{-1} along with recommended dose of NPK, yielded maximum net return with cost benefit ratio ranging from 1.6 to 3.2 (Fig 2). The increase in net return, cost benefit ratio and percentage return to fertilizer by application of pressmud @ 2t ha^{-1} along with recommended dose of NPK was attributed to the synergistic effect of organic sulphur and *Rhizobium* inoculums on grain yield which was corroborated with the earlier reports of Singh and Agarwal, 2005, Singh et al. (2007).

3.4. Energy use pattern

The energy use pattern and energy input-output analysis of pea crop grown under control and recommended INM package were calculated and compared with wheat crop. The operational input energy was found to be 17,420 MJ ha^{-1} for wheat cultivation at eastern Uttar Pradesh condition (Singh, 2007), which is 3 to 4 times higher compared to pea cultivation. The operational input energy was found to vary from 4,102 to 7474 MJ ha^{-1} for pea cultivation under Varanasi condition. The values of the output energy was calculated considering 1 kg of dry grain is equivalent to 14.7 MJ and straw as fuel as 12.5 MJ as per the recommendation of All India Coordinated Research Project on Energy Requirements in Agricultural sector, Punjab Agricultural University, India. As per the recommendation the output-input ratio turns out to be on the tall end in the present experimental condition and a maximum value of 7.2 and a minimum value of 5.5 were realized for cultivation of pea under control and recommended INM module respectively (Table 4), clearly indicating higher energy use efficiency in INM module. This is particularly relevant with recent increases in the international prices of energy, depletion of ground water level and mineral commodities to raise prices for essential food items such as wheat and rice. Any technology leading to higher energy use efficiency i.e., lower output-input energy ratio will lead to decline in food prices on different economies of the world, particularly so for developing countries like India.

The experimental results and energy value calculations in the

Table 4: Mean energy use pattern for pea and compared to wheat cultivation (Singh et al. 2007) in transect 4 of IGP

Particulars	Weighted mean values		
	Pea		Wheat
	Control	T3 (INM module)	
A. Operations (MJ ha^{-1})			
Field preparation	1580	1975	3485
Sowing	400	540	626
Bund making	230	0	669
Irrigation	450	2590	6003
Weeding	0	0	564
Fertilizer application	100	350	503
Harvesting	400	580	1305
Threshing	480	590	1360
Transportation	460	690	1420
Post harvest activity	0	120	1485
Total	4100	7435	17420
B. Source (MJ ha^{-1})			
Human	282.3	416	1049
Diesel	1070	1980	4431
Electricity	750	1568	4235
Seeds	1050	1050	1695
FYM	400	1050	1320
Fertilizers	550	1090	4196
Chemicals	0	0	343
Machinery	0	320	361
Total input energy	4102.3	7474	17630
C. Others			
Yield (kg ha^{-1}) seed / grain	970	1350	2550
Yield (kg ha^{-1}) straw/ other biomass	1222.2	1701	2930
Total output energy	29537	41108	74110
Energy ratio	7.2	5.5	4.2

present case requires further refinements, however, it focused some insight about the energy balance scenario of crop cultivation in *transect 4* of IGP.

4. Conclusion

The present paper highlights the positive effect of INM modules on yield attributes, yield, nutrient use efficiency and economics of pea cultivation as compared to farmers practice. The dual inoculation of N fixing and P solubilizing micro-organism compared to single inoculation of *Rhizobium* was found superior. Further, the application of sprinkler irrigation at 28 and 49 days after sowing (DAS) resulted significant increase in yield (50 %) compared to flood irrigation once at 28 days after sowing or no irrigation.

The agronomic nutrient use efficiency and per cent return to fertilizer for N and P was 3 and 3.2 times higher respectively under INM module compared to conventional farmers' practice. Moreover, adoption of INM module caused on an average 60 % increase in pea grain yield with 120% higher benefit per rupee invested.

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