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Effect of moisture and nutrient management on yield, energy budgeting and economics of green gram under limited moisture conditions

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Abstract
An experiment was conducted at Research farm, ICAR- Indian Agricultural Research Institute, New Delhi during 2010-12. The treatment comprised of four land configurations (Flatbed, flatbed with mulch, ridge-furrow, and broadbed-furrow) and three fertility levels (Control, 15 kg N+30 kg P_2O_5/ha and 15kg N+30 kg P_2O_5+PSM/ha) with factorial Randomized block design in green gram crop. The boradbed furrow method of land configuration recorded the highest grain and stover yield whereas among the fertility levels treatment applied with15kg N+30 kg P_2O_5+PSM/ha recorded the highest grain and stover yield. The maximum gross return, net return, net B:C ratio, value: cost ratio and return ₹/ha/day was found with broadbed-furrow closely followed by ridge-furrow whereas flatbed with mulch had minimum gross returns and net return and B:C ratio. Application of 15kg N+30 kg P_2O_5+PSM/ha brought improvement over 15 kg N + 30 kg P_2O_5/ha but both were significant over control in terms of gross return, net return, net B:C ratio, value: cost ratio and return ₹/ha/day. Broadbed-furrow recorded the highest energy output, energy efficiency, energy productivity, and energy intensity while minimum in flatbed with mulch. A dose of 15 kg N+30 kg P_2O_5+PSM/ha proved maximum net energy, energy efficiency, energy productivity, and energy intensity and minimum with control but energy output in the flatbed.

Keywords: Net return, return (₹)/ha/day, energy productivity, energy efficiency and greengram

Introduction
Green gram (*Vigna radiata)* is an important crop of limited water availability areas. At present, it is cultivated in 3.44 million hectares with a total production of 1.4 million tonnes having a productivity level of 406 kg/ha (Agropedia, 2011) [1].

Soil moisture is the principal factor governing the crop production under dryland ecosystem. To conserve soil moisture, the mulches play an important role. Mulches prevent soil from blowing and being washed away as it reduces evaporation, increases infiltration, keeps down weeds, improves soil structure, and eventually increase crop yields. Studies on mulching carried out in India under rainfed agriculture have concentrated on the measurement of crop responses rather than on how the crop responses are influenced. Again the ridge-furrow and broadbed-furrow system of planting help in soil moisture conservation, soil aeration, and synergistic effect on the availability of nitrogen and phosphorus. Thus, conservation of moisture is most important for boosting agriculture productivity and enhancing the recovery of applied nutrients.

Dryland areas are not only thirsty but also hungry. Nitrogen and phosphorus are the major nutrients that play an important role in crop production. The nitrogen recognized as kingpin to the fertilization program for higher yield. Nitrogen is an important constituent of chloroplast which plays an important role in photosynthesis. Phosphorus increases the root biomass including nodules in pulses which in turn improves moisture utilization under dryland conditions. Nitrogen and phosphorus are involved in a wide range of plant processes from permitting cell division to the development of plants.

The use of bio-inoculant is gaining importance day by day due to the acute energy crisis and the high cost of chemical fertilizers. There is a good scope of using biofertilizers to take advantage of nutrient saving, maintaining soil health in an eco-friendly manner. The PSB produces growth-promoting substances, besides enhancing P availability that influences plant growth. VAM has an important role in the efficient use of P-fertilizers and improves N_2-fixation. Thus both nutrients balance the above ground and underground development of plants. Since only part of the fertilizer applied to the soil is utilized by the crop remaining may be utilized by succeeding crop but the amount of nutrient left by succeeding crop need to be quantified.

The energy in agriculture is important in terms of crop production and agro-processing for value addition (Karimini *et al*., 2008) [8]. The relation between agriculture and energy is very close. Agriculture itself is an energy user and energy supplier in the form of bio-energy. At present, productivity and profitability of agriculture depend on energy consumption (Alam *et al*., 2005 and Esengun *et al*., 2007) [6, 7].

Energy is a crucial input to agriculture production. Continuously rising prices, an increasing proportion of commercial energy in the total energy input to agriculture, and the growing scarcity of commercial energy sources, such as fossil fuels, have necessitated the more efficient use of these sources for different crops (Singh *et al*., 1999) [9]. Crop productivity can be expressed as the ratio of output to input from a unit of land either in energy or in monetary terms. Agro-ecosystem productivity evaluation using energy budgeting is important and interesting. Energy is one of the most important indicators of crop performance. The net energy of a cropping system can be quantified for the sound planning of sustainable cropping systems. Yield and economic parameters increased linearly as the level of fertility increased, while the reverse trend is observed with energy use efficiency, energy productivity, and energy intensiveness.

The share of agriculture in national energy consumption has been rising consistently over the last three decades. Presently, it accounts for nearly a quarter of the country's electric consumption. The yield of different crops can be increased by up to 30% by using the optimal level of energy input. However, it needs energy budgeting and meticulous planning. The energy agriculture relationship is becoming more and more important with the intensification of the cropping systems in resource-scarce situations. The energy is invested in various forms such as mechanical (farm machines, human labor, and animal draft), mineral fertilizer, pesticides, herbicides, electrical, etc. Sufficient availability of the right energy and its efficient use are prerequisites for improved agricultural production.

Energy parameters such as net energy return, energy ratio, and energy productivity are meaningful indicators for assessing or comparing the efficiency of the production system. However, energy consumption and output differ widely among crops, production systems, and management intensity. Indeed, studies on energy use are strongly influenced by experimental plot data, upon which the computations are based, system boundaries, and methodologies. However, in developing countries, the primary objectives of mechanizing crop production are to reduce human drudgery and to raise the output of the farm by either increasing the crop yield or increasing the area under cultivation. This can only be done by supplementing the traditional energy input i.e. human labor with substantial investments in farm machinery, fertilizers, soil and water conservation practices, weed management practices, etc. These inputs and methods represent various energies that need to be evaluated to ascertain their effectiveness and to know how to conserve them. Energy budgeting, therefore, is necessary for efficient management of scarce resources for improved agricultural production. It would identify production practices that are economical and effective. The information on energy use in different cropping systems is not available in the area of study. Therefore, to identify energy-efficient cropping systems and for satisfactory energy output and net return.

Material& Methods

The experiment was conducted during 2010-11 and 2011-12 at research farm Indian Agricultural Research Institute, New Delhi, situated at a latitude of 28°38′N, longitude of 77°11′E and altitude of 228.6 m above the mean sea level. The mean annual rainfall of Delhi is 650 mm and more than 80% generally occurs during the southwest monsoon season with mean annual evaporation of 850 mm. The rainfall was good during the first year as compared to the second year. Thus, the establishment of crops, their growth, and productivity were better in 2010-11. The soils of the experimental field had 145.5 kg/ha alkaline permanganate oxidizable, 11.8 kg available P kg/ha, 212 kg 1N ammonium acetate exchangeable K, 0.33% organic carbon with 7.6 pH of the soil (1:2.5::soil: water). The moisture at 1/3 and 15 atmospheric tensions were 16.61 and 7.63%, respectively with bulk density 1.5 (g/cm^3) of 0-30 cm soil depth.

The experiment laid out in factorial Randomized block design in *the Kharif* season. The treatment comprised of four land configuration (Flatbed, flatbed with mulch, ridge-furrow and broadbed-furrow) and three preceding fertility level to green gram (Control, 15 kg N+30 kg P_2O_5/ha and 15kg N+30 kg P_2O_5 +PSM (PSB + VAM)/ha) replicated thrice. In green gram, spacing 30cm row to row and 10 cm plant to plant. Pusa Vishal was a variety of green gram. The crop was grown as per the recommended package of practices without any irrigation. Economics of different treatment was worked out by taking into account the cost of inputs and income obtained from the output (grain and stover yield). The gross and net returns as well as a benefit: cost ratio was worked out as followed for each treatment.

Gross returns (₹/ha) = Economic yield × market price of produce

Net returns (₹/ha) = Gross returns-cost of cultivation

$$\text{Benefit: cost ratio} = \frac{\text{Net return (₹/ha)}}{\text{Cost of cultivation (₹/ha)}} \times 100$$

$$\text{Value cost ratio} = \frac{\text{Gross return (₹/ha)}}{\text{Cost of cultivation (₹/ha)}}$$

$$\text{Per day return (₹/ha)} = \frac{\text{Net return (₹/ha)}}{\text{Cropping period (days)}}$$

Total energy input and output of crop and cropping system were estimated by using the energy equivalent as suggested by Singh *et al.* (1997) **[10]**. The energy input through land preparation, seedbed preparation, seed sowing, fertilizer and pesticide application, intercultural operations, harvesting, carrying, thrashing, and drying expressed as human labor, seed, fertilizer, pesticide, and fuel use for land preparation and machinery operation were calculated. The energy input from non-commercial sources was ignored because this energy was coming from natural sources. 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 the total energy generated from the main product and by-product by the total energy used for raising the crop in the unit area. The energy efficiency, energy production, and energy intensity were computed as Megajoule (MJ) by the following formula:

$$\text{Energy efficiency} = \frac{\text{Energy out (MJ/ha)}}{\text{Energy input (MJ/ha)}}$$

$$\text{Energy productivity (kg/MJ)} = \frac{\text{Output (grain+by product) (kg/ha)}}{\text{Energy input (MJ/ha)}}$$

$$\text{Energy intensity (MJ/₹)} = \frac{\text{Energy output (MJ/ha)}}{\text{Cost of cultivation}}$$

Net Energy ($MJha^{-1}$) = Energy out (MJ/ha) - Energy input (MJ/ha)

Result and discussion

Yield

The grain and stover yield of greengram responded significantly to land configuration and fertility levels. The result pointed out that broadbed-furrow and ridge-furrow were produced significantly more grain and stover yield over flatbed with mulch and without mulch (Table 1). The broadbed-furrow increased grain yield 45.1 and 35.1%, stover yield 38.3% and 21.7% and ridge- furrow increased grain yield 35.4% and 28.4%, stover yield 30.4 and 16.7% over flatbed in first and second year, respectively. The fertility levels applied with 15 kg N +30 kg P2O5+PSM and 15 kg N+30 kg P2O5/ha were at par with each other significantly superior over control. The 15 kg N+30 kg P_2O_5+PSM/ha improved grain yield 54.7% and 59.4%, stover yield 46.5% and 48.6% and 15 kg N+30 kg P_2O_5/ha grain yield 45.3% and 50.0%, stover yield 41.4% and 45.8% over control in first and second year, respectively. This increased grain yield and stover yield under broadbed-furrow and fertility levels may be attributed to increase in growth parameters, physiological parameters and yield attributing character which leading to highest yield. These results are in conformity with the results of Tayo, (1985) and Jat and Ahlawat, (2001) [11&12].

Energy Budgeting

The significant energy input, energy output and net energy was observed among the various treatments of land configurations and fertility levels (Table 2). It was observed that highest energy input was required in land configuration flatbed with mulch (66.9 x10^3 MJ ha^{-1}) whereas the energy input for both the fertility levels applied with nutrients showed approximately same energy input value (20.3 x10^3 MJ ha^{-1}) during both the year of experimentation. The energy input value was highest in flatbed with mulch was due to application of 5 tha^{-1} mulch. In case of energy output it was observed that among the different land configurations broadbed-furrow recorded the highest value (76.7 and 65.9 x10^3 MJ ha^{-1}) which was closely followed by ridge-furrow. Among fertility levels treatment applied with 15 kg N +30 kg P2O5+PSM recorded highest energy output of 74.5 and 67.8 x10^3 MJ ha^{-1} in both the year of experimentation. The net energy was found highest with broadbed-furrow > ridge-furrow > flatbed while it went negative in flatbed with mulch. With the increasing fertility level, net energy was gone up. The less energy needed to grow the crop on a flatbed and the highest biomass production resulted in the highest net energy in broadbed-furrow. In flatbed with mulch, net energy was gone on the negative side because 5 t ha^{-1} mulch which multiplied with 12.5 MJ kg^{-1} is around 66x10^3 $MJkg^{-1}$.

Energy productivity (Table 3) was the highest in broadbed-furrow whereas lowest in flatbed with mulch. Broadbed-furrow and ridge-furrow, flatbed and flatbed with mulch were attained 17.60, 16.57, 12.60, and 0.87 in the first year and 15.09, 14.44, 12.16 and 0.83 kg/MJ in the second year. It was because of higher biomass production in broadbed-furrow whereas in flatbed with mulch, mulch application and low yield lead lowest energy productivity. The application of 15 kg N+30 kg P_2O_5 + PSM/ha turnout highest energy productivity while lowest in control. The 15 kg N+30 kg P_2O_5+PSM/ha and 15 kg N+30 kg P_2O_5/ha were measured 13.8 and 8.9% higher energy productivity in the first year and 16.1 and 13.0% in the second year over control. This was to increase biomass production with an increasing level of fertility. The maximum value of energy intensity recorded in broadbed-furrow whereas lowest with flatbed with mulch. With the application of 15 kg N+30 kg P_2O_5+PSM/ha found maximum value of energy intensity and lowest with control. It was observed that energy efficiency was highest in broadbed-furrow and lowest in flatbed with much (Table 3). Broadbed-furrow, ridge-furrow, flatbed, and flatbed with mulch were 4.03. 3.74. 2.75 and 0.19 in the first year and 3.38, 3.20, 2.50, and 0.18 in the second year, respectively. Fertility levels improved energy efficiency.

Economics

The cost of cultivation was maximum in flatbed with mulch whereas minimum in the flatbed (Table 4). The broadbed-furrow and ridge-furrow had the same cost of cultivation. The maximum gross (42.5 and 39.2 x 10^3 ₹/ha) and net returns (29.23 and 24.02 x 10^3 ₹/ha) calculated in broadbed-furrow followed by ridge-furrow. Similar findings reported by Singh and Rana 2006 [3]. The minimum gross returns (29.3 and 29.4 x 10^3 ₹/ha) in flatbed and net returns (16.51 and 14.59 x 10^3 ha^{-1}) were found in flatbed with mulch in the first and second year. Lowest gross (26.9 and 25.1 x 10^3 ₹ha^{-1}) and net returns (14.09 and 10.44 x ₹10^3ha^{-1}) were obtained when green gram was grown in control in both the years of study. These result corroborated by Ahlawat and Gangaiah, 2010[4]. These returns were increased with the application of nutrients. Highest gross return (41.3 and 40.0 x 10^3 ₹/ha) and net returns (27.49 and 24.37 x 10^3 ₹/ha) were achieved from green gram when fertilized with 15 kg N +30 kg P_2O_5 + PSM/ha in both the years. A dose of 15 kg N + 30 kg P_2O_5/ha was next to 15 kg N +30 kg P_2O_5 + PSM/ha in order of recording gross and net returns. The increase in the cost of cultivation in 2011 was due to an increase in labor wages (>33% of 2010). These result conformity with the result of Kantwa *et al*, 2005[2].

The highest benefit: cost ratio (2.20 and 1.57) was obtained in broadbed-furrow whereas lowest (1.11and 0.87) in flatbed with mulch in respective years. The maximum benefit: cost ratio was got with the application of 15 kg N +30 kg P_2O_5 + PSM/ha (2.02 and 1.56) followed by 15 kg N+30 kg P_2O_5/ha and minimum with control (1.11 and 0.71) in the first and second year. This might be because 15 kg N + 30 kg P_2 O_5 + PSM/ha slightly more yield and cost of cultivation also slightly more than 15 kg N+30 kg P_2O_5/ha resulted in higher net return and B:C ratio. Similar result was reported by Kumar and Rana, 2007 [3].

The return (₹/ha/day) was highest in broadbed-furrow (Table 5) while lowest in flatbed with mulch. The broadbed-furrow, ridge-furrow, flatbed, and flatbed with mulch were fetched 321.26, 288.74, 187.42, and 181.47 (₹/day/ha) in the first year and 240.17, 220.54, 152.79 and 145.92 (₹/day/ha) in the second year. The maximum benefit was got with the application of 15 kg N +30 kg P_2O_5+PSM/ha (302.09 and 243.68 ₹/day/ha) closely followed by 15 kg N+30 kg P_2O_5/ha (277.22 and221.51 ₹/day/ha) and minimum with control (154.87 and 104.37₹/day/ha). The maximum value:cost ratio (3.19 and 2.58) was found in broadbed-furrow whereas minimum (2.11 and 1.87) in flatbed with mulch in respective years. The maximum value: cost ratio was got with the application of 15 kg N+30 kg P_2O_5+ PSM/ha (3.01 and 2.57) followed by 15 kg N+30 kg P_2O_5/ha and minimum with control (2.11 and 1.72) in the first and second year. These result corroborated by Kumar and Rana, 2007 [3]

Conclusion

In green gram, broadbed-furrow brought the maximum grain and stover yield, net return, B: C ratio, and return ₹/day/ha. The 15 kg N+30 kg P_2O_5+PSM/ha registered the highest grain and stover yield, net return, B: C ratio, and return₹/day/ha. The broadbed-furrow recorded higher energy output, energy efficiency, and energy productivity in green gram as compared to other land configuration. The 15 kg N+30 kg P_2O_5 +PSM/ha dose found higher energy output, energy efficiency, and energy productivity over lower levels of fertility.

Table 1: Effect of land configuration and nutrient management on grain yield and stover yield of green gram

Treatment	Grain yield (t/ha)		Stover yield (t/ha)	
	Ist yr	IInd yr	Ist yr	IInd yr
Land configuration				
Flatbed	0.82	0.74	3.42	3.36
Flatbedwith mulch	0.87	0.79	3.63	3.56
Ridge-furrow	1.11	0.95	4.46	3.92
Broadbed-furrow	1.19	1.00	4.73	4.09
SEm±	0.04	0.03	0.09	0.09
CD (P=0.05)	0.13	0.10	0.28	0.25
Fertility levels				
Control	0.75	0.64	3.14	2.84
15kgN+30kgP_2O_5/ha	1.09	0.96	4.44	4.14
15kgN+30kgP_2O_5 +PSM/ha	1.16	1.02	4.60	4.22
SEm±	0.04	0.03	0.08	0.07
CD (P=0.05)	0.11	0.09	0.24	0.22

Table 2: Effect of land configuration and nutrient management on input and output and net energy of green gram

Treatment	Energy input (x 10 ^{3} MJha^{-1})		Energy output (x 10 ^{3} MJha^{-1})		Net energy (x 10 ^{3} MJha^{-1})	
	Ist yr	IInd yr	Ist yr	IInd yr	Ist yr	IInd yr
Land configuration						
Flatbed	4.3	4.3	54.8	52.9	50.48	48.60
Flatbed with mulch	66.9	66.9	58.2	56.1	-8.63	-10.71
Ridge-furrow	4.3	4.3	72.0	62.9	67.68	58.61
Broadbed-furrow	4.3	4.3	76.7	65.9	72.34	61.55
SEm±			1.2	1.3	1.18	1.25
CD (P=0.05)			3.5	3.7	3.45	3.67
Fertility levels						
Control	19.2	19.2	50.3	44.8	31.10	25.60
15 kgN+30 kg P_2O_5/ha	20.3	20.3	71.4	65.8	51.09	45.46
15 kgN+30 kg P_2O_5/ha +PSM	20.3	20.3	74.5	67.8	54.22	47.47
SEm±			1.0	1.1	1.02	1.08
CD (P=0.05)			3.0	3.2	2.99	3.18

Table 3: Effect of land configuration and nutrient management on energy productivity and energy intensity of green gram

Treatment	Energy productivity (kg /MJ)		Energy intensity (MJ/`)		Energy efficiency	
	Ist yr	IInd yr	Ist yr	IInd yr	Ist yr	IInd yr
Land configuration						
Flatbed	12.60	12.16	3.82	3.69	2.75	2.50
Flatbed with mulch	0.87	0.83	3.46	3.33	0.19	0.18
Ridge-furrow	16.57	14.44	4.69	4.10	3.74	3.20
Broadbed-furrow	17.60	15.09	5.00	4.29	4.03	3.38
SEm±	0.28	0.27	0.08	0.08	0.16	0.12
CD (P=0.05)	0.81	0.80	0.23	0.24	0.46	0.36
Fertility levels						
Control	11.07	9.69	3.40	3.03	2.44	2.06
15 kg N+30 kg P_2O_5/ha	12.05	10.95	4.58	4.22	2.69	2.37
15 kg N+30 kg P_2O_5/ha +PSM	12.60	11.25	4.74	4.31	2.90	2.52
SEm±	0.24	0.23	0.07	0.07	0.14	0.11
CD (P=0.05)	0.70	0.69	0.20	0.21	NS	0.31

Table 4: Effect of land configuration and nutrient management on economics of greengram

Treatment	Cost of cultivation (x 10 ^{3}₹ /ha)		Gross return (x 10 ^{3}₹/ha)		Net return (x 10 ^{3}₹/ha)		Net B:C ratio	
	Ist yr	IInd yr	Ist yr	IInd yr	Ist yr	IInd yr	Ist yr	IInd yr
Land configuration								
Flatbed	12.29	14.14	29.3	29.4	17.05	15.28	1.39	1.07
Flatbed with mulch	14.79	16.64	31.3	31.2	16.51	14.59	1.11	0.87
Ridge-furrow	13.29	15.14	39.6	37.2	26.28	22.05	1.98	1.44
Broadbed-furrow	13.29	15.14	42.5	39.2	29.23	24.02	2.20	1.57
SEm±			1.3	1.2	1.34	1.19	0.11	0.08
CD (P=0.05)			3.9	3.5	3.94	3.49	0.31	0.24
Fertility levels								
Control	12.85	14.70	26.9	25.1	14.09	10.44	1.11	0.71
15kgN+30kgP_2O_5/ha	13.62	15.47	38.9	37.6	25.23	22.15	1.87	1.44
15kgN+30kgP_2O_5/ha +PSM	13.76	15.61	41.3	40.0	27.49	24.37	2.02	1.56
SEm±			1.2	1.0	1.16	1.03	0.09	0.07
CD (P=0.05)			3.4	3.0	3.42	3.02	0.27	0.20

Table 5: Effect of land configuration and nutrient management on Return (₹/ha/day) and Value: cost ratio of green gram

Treatment	Return (₹/ha/day)		Value: cost ratio	
	Ist yr	IInd yr	Ist yr	IInd yr
Land configuration				
Flatbed	187.42	152.79	2.38	2.07
Flatbedwith mulch	181.47	145.92	2.11	1.87
Ridge-furrow	288.74	220.54	2.96	2.45
Broadbed-furrow	321.26	240.17	3.19	2.58
SEm±	14.78	11.89	0.10	0.08
CD (P=0.05)	43.34	34.87	0.31	0.24
Fertility levels				
Control	154.85	104.37	2.11	1.72
15kgN+30kgP_2O_5/ha	277.22	221.51	2.86	2.44
15kgN+30kgP_2O_5/ha +PSM	302.09	243.68	3.01	2.57
SEm±	12.80	10.30	0.09	0.07
CD (P=0.05)	37.53	30.20	0.27	0.21

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