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Energy usage and Economic Analysis of Pigeonpea Alternate to Cotton System under Semiarid Conditions of Telangana

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ABSTRACT: The aim of the study is assessment of the energy requirements and economics was carried out at the during the year of 2017-18 and 2018-19 involving four plant geometries under rainfed and one life saving irrigation were taken up in pigeonpea (medium duration) under semiarid conditions at Warangal, Telangana, India. Results revealed that pigeonpea cultivated in square seeding (180 × 60 cm), the net profit from pigeonpea was ₹47 × 10^3 ha^{-1} under rainfed conditions compared to rainfed cotton, while pigeonpea cultivated under one protective irrigation at bud initiation stage gave ₹65 × 10^3 ha^{-1} more net profit than the irrigated cotton (irrigation at boll development stage). Pigeonpea and cotton systems were subjected to energy use and out put assessment, net return of energy and income.The highest energy use efficiency (2.88) and net energy (15771 MJ ha^{-1}) and energy productivity (0.20 kg MJ^{-1}) while, lowest energy intensiveness (0.32 MJ $₹^{-1}$) and specific energy (5.11 MJ kg^{-1}) were reported in pigeonpea production system under irrigated conditions at 180 × 60 cm plant geometry when compared with cotton production system.

Keywords: Critical stages, pigeonpea, energetics, spacing, cotton, irrigation.

INTRODUCTION

Cultivation of cotton under rainfed conditions is a common practice in Telangana region. Its performance is extremely variable due to the extreme variations in amount of rainfall and distribution pattern. Pigeonpea could be an alternative to rainfed cotton which is becoming less profitable due to shortage and high escalating labour costs. Different management practices *viz.,* planting, fertilizer, herbicides, pesticides, irrigation, spraying and seeds are not possible due to labour shortages and involvement in paddy transplanting at the same time. Mechanized control methods appear to be very simple, time-consuming, in expensive and provide better crop growthstarting form the early critical stages of various crops. Intensive cultivation of pigeonpea with square planting facilitating two way intercultivation helps in effective weed control, earthing up, moisture retention, more light interception and vigorous plant growth which manifest in yield enhancement.

Higher productivity with sustainability remains the major concern of any crop planning. Any system which requires less input and contributes more is considered to be the efficient. In recent years, oilseeds and legumes are receiving more attention owing to limited production and higher prices. Inclusion of these crops in the sequence changes the economics of the cropping system (Chauhan *et al.*, 2001; Tuti *et al.*, 2013). There is a closer relationship between cropping system productivity, economics, energy and environment. The net energy and monetary return of a cropping system can be quantified for sound planning of sustainable systems (Tuti *et al.*, 2012). Higher the productivity ratio the faster would be the development of sustainable agriculture, conversely, the lower the ratio, results in faster destruction of environment and ecological instability Mirasi *et al.,* (2015).

Agricultural practices in many developing countries continue to depend heavily on animal and human energy levels. Modern mechanical and electrical energy services are not being available in agriculture sector, if available also insufficiently used and hence their deployment for potential gains in agricultural productivity. The increase in area under various crops has placed a great deal of demand on limited renewable energy sources in post independence period through introduction of high yielding varieties and leading to exhaustive usage of non-renewable energy sources. Human labour, irrigation water, seeds and non-chemical fertilizers were being included in renewable energy while non-renewable energy consists of fossil fuels, pesticides, chemical fertilizers and machinery (Mohammadi *et al.*, 2008). As the efficient use of energy resources is essential for productive production, productivity, agricultural competitiveness and the sustainability of rural life. Energy auditing is one of the most common ways to assess energy efficiency and the environmental impact of a production system. Measuring these energy forms is very helpful in determining the intensity of inputs on yield and production (Hatirli *et al.,* 2006). Hence, the present investigation was undertaken to evaluate the productivity, profitability and energy–use efficiency of pigeonpea cropping systems in comparison with the traditional cotton cropping system in semiarid conditions of Telangana as an alternate option.

MATERIALS AND METHODS

A field experiment was laid out at Regional Agricultural Research Station, Warangal (17^o 58$'$ N, 79^o 28$'$ E with an altitude of 270 m mean sea level) consecutively for two years during 2017-19 with an objective of studying the effect of supplemental irrigation in a medium duration pigeonpea during its most important critical stages, *viz.,* bud initiation (120 days) and boll development (120 days) combined with different plant geometries.

The experimental site was Vertisols sandy loam (TypicHaplusterts) in texture soils and slightly alkaline (pH 8.01) reaction with low in N (175 kg ha^{-1}) and SOC (0.40 %), medium in P (40 kg ha^{-1}), K (355 ha^{-1}) and S (15.0 kg ha^{-1}) at the surface depth (0–15 cm). The climate of the location is tropical semiarid receives an annual rainfall of 823 mm with mean annual maximum and minimum temperatures of 31°C and 21°C respectively (Table 2). Sowing of medium duration pigeonpea 'Rudreshwara' (WRG-65) during during both the years of experimentation (2017-19). Besides resistant to *Fusarium* wilt and Phytophthora blight, this pigeonpea variety matures at around 170-180 days.

The experiment was laid out in a factorial randomized block design with three replications having factor A with supplemental irrigations and four plant geometries in Factor B. Four plant geometries with pigeonpea at 90 × 60 cm (18519 plants ha^{-1}), 120 × 60 cm (13889 plants ha^{-1}), 150 × 60cm (11111 plants ha^{-1}), 180 × 60 cm (9259 plants ha^{-1}), with cotton at 90 × 60 cm (18519 plants ha^{-1}) whereas irrigations included rainfed and one irrigation supplemental life saving irrigation at pod initiation stage in pigeonpea and boll development stage in cotton. Sowing of long duration pigeonpea 'WRG-65' was carried out during 24 June and 11 July during 2017 and 2018 respectively. The crop received the recommended dose of fertilizer 20: 50: 20 kg N, $P_2O_5$and K_2O ha^{-1} *i.e.,* (45 kg Urea ha^{-1}, 300 kg SSP-P_2O_5 ha^{-1} and 35 kg K_2O ha^{-1}) with complete dose basally. The quantity of irrigation water applied was 50 mm for both pigeonpea and cotton at each critical stages coinciding with rainless period during 120-130 days after sowing (DAS). Water stagnation dur to heavy rains in August while one life saving irrigation as per treatrment is given at bud initiation stage to avoil terminal moisture stress. Weeds were controlled by pendimethalin was applied as preemergence immediately after sowing and persuit as post emergence along with hand weeding twice and intercultivation twice with tractor. Pests and diseases were managed by sparying chlorpyriphos against *Helicoverpa* at flowering and chloranthroniliprole against *Helicoverpa* at pod development stage. Application of multi-K or 19:19:19 @ 1 kg ha^{-1} to avoid the terminal stress at bud initiation to pod development stage. Crop was harvested during January (*i.e.,* 9 January 2017 and 22 January 2019) in both the years (2017-2018). Normal practice of crop production was followed for a successful crop raising. Seed yield was arrived from finally harvested plants from the net plot during the experimentation of respective years.

In addition to the field experimentation, different energy efficiency parameters were determined to assess the relationship between energy consumption and total output and production per hectare. Energy ratio, specific energy, energy productivity, energy intensiveness and net energy yield were calculated for pigeonpea and cotton production systems by following equations (Banaeian *et al.,* 2011; Ghorbani *et al.,* 2011).

$$\text{Energy ratio} = \frac{\text{Energy output (MJ ha}^{-1})}{\text{Energy input (MJ ha}^{-1})}$$

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$$\text{Specific energy} = \frac{\text{Energy input (MJ ha}^{-1})}{\text{Output (kg ha}^{-1})}$$

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

$$\text{Energy intensiveness} = \frac{\text{Energy input (MJ ha}^{-1})}{\text{Cost of production (Rs ha}^{-1})}$$

Net energy yield = Energy output (MJ ha^{-1}) – Energy input (MJ ha^{-1}).

Energy ratio between output and input were used to evaluate energy use efficiency of different crops. For estimation of energy ratio various energy input values for human labor, machinery, diesel fuel, fertilizers, pesticides and seed and the energy output value of crop yield were used to (Alam *et al.,* 2005). The farm produce (grain yield + straw/stalk yield) was also converted into energy in terms of energy output (MJ) by using two years (2017-18 and 2018-19 average seed and kapas yield. Total energy input was estimated by summing up the energy equivalents for all inputs (Table 1). Output energy from the end product (seed/kapas) was calculated by multiplying the amount of production and its corresponding energy equivalent. Energy output from the by-product (stalk) was estimated by multiplying the amount of by product and its corresponding equivalent. Amount of energy invested to produce unit quantity of the product is the specific energy (MJkg^{-1}) which is being widely used in energy analysis. The quantity of product produced per unit of input energy (kg MJ^{-1}) measures the energy productivity which is the inverse of specific energy. Energy productivity gives a clue about how well-used energy in a production system produces a particular product. Based on the energy equivalents of inputs and output (Table 1) the above calculations were carried out based on experimental results during *Kharif* 2017-18 and 2018-19.

The data collected were subjected to statistical analysis of variance (ANOVA). The least significant difference (LSD) test was carried out for analyzed mean square errors. The procedure provides for a single LSD value at 5% level of significance, which serves as a boundary between significant and non-significant differences between any pair of treatment means.

Table 1: Energy content of pigeonpea and cotton production inputs and outputs and total energy equivalents per unit area.

Inputs	Energy equivalent (MJ $unit^{-1}$)	Cotton		Pigeonpea	
		Quantity per unit area (ha)	Total energy equivalent (MJ)	Quantity per unit area (ha)	Total energy equivalent (MJ)
Human labour (h)	1.96	165	2587	150	2352.00
Machinery					
Tractor 50 kW (h)	41.4	6.25	258.75	6.25	258.75
Plough (h)	22.8	20	456	20	456
Sprayer (h)	23.8	15	357	10	238
Pump (h)	2.4				
Diesel (l)	56.31	23.98	1350.31	20.98	1181.38
Chemical					
N (kg)	60.6	150	9090	20	1212
P (kg)	11.1	60	666	50	555
K(kg)	6.7	60	402	20	134
Farmyard manure (kg dry mass)	0.3	500	150	500	150
Chemicals					
Insecticides (kg)	278	2	556	1.25	347.5
Fungicides (kg)	276				
Herbicides (kg)	288	3	864	3.25	936
Electricity (kWh)	11.93	24	286.32	20	238.6
Water for irrigation (m^3)	0.63				
Seed (kg)	25	1.125	28.12	10	281.2
Outputs					
Cotton seed yield (kg)	11.8				
Pigeonpea grain yield (kg)	14.7				
Stalks (kg dry mass)	18				

(Devasenapathy *et al.*, 2009; Tsatsarelis, 1993; Fluck, 1985; Walker *et al.*, 1977).

RESULTS AND DISCUSSION

Performance of pigeonpea equivalent yields (Table 2) with pooled data of two years revealed that have shown that grain yield of pigeonpea was also higher in 180 × 60 cm spacing (1424 kg ha^{-1}) among the pigeonpea plant geometries tested followed by cotton crop (1322 kg ha^{-1}) in 120 × 60 cm spacing with 13889 plants ha^{-1}. This may be because the pigeonpea plant shows great plasticity by adjusting its branching behavior depending on the available space between plants leading to increase in number of branches per plant compensating the lesserplant population.

Table 2: Influence of different plant geometries on grain yield of direct sown Pigeonpea and cotton, under rainfed and protective irrigation.

Treatment	Pigeonpea equivalent yields (Kg ha^{-1})		
	2017-18	2018-19	Pooled
Plant geometries			
90 × 60 cm (18519 Pl ha^{-1})	1284	1078	1181
120 × 60 cm (13889 Pl ha^{-1})	1319	1172	1245
150 × 60 cm (11111 Pl ha^{-1})	1383	1168	1276
180 × 60 cm (9259 Pl ha^{-1})	1497	1351	1424
Cotton 120 × 60 cm (13889 Pl ha^{-1})	1254	1389	1322
LSD at 5%	61	74	48
Water management practices			
Rainfed	1024	1046	1035
One irrigation	1671	1417	1544
LSD at 5%	39	47	30
Geometries × Water management practices			
LSD at 5%	87	105	NS

Among irrigations, pigeonpea cultivated in square seeding (150-180 cm × 60 cm spacing), the net profit (Table 3) from pigeonpea was ₹19162 ha^{-1} under rainfed conditions compared to rainfed cotton, while pigeonpea cultivated under one protective irrigation at bud initiation stage gave ₹22962 ha^{-1} more net profit than the irrigated cotton (irrigation at boll development stage).

Table 3: Influence of different plant geometries on economics of Pigeonpea and cotton, under rainfed and protective irrigation.

Treatment	Cost of Cultivation (x10^3 ₹ ha^{-1})	Net returns (x 10^3 ₹ ha^{-1})	B:C *
Rainfed Pigeonpea- 90 × 60 cm	25.0	26	2.03
Rainfed Pigeonpea- 120 × 60 cm	24.8	30	2.22
Rainfed Pigeonpea- 150 × 60 cm	24.6	31	2.24
Rainfed Pigeonpea-180 × 60 cm	24.5	42	2.72
Rainfed Cotton 120 × 60 cm	36.2	23	1.64
Irrigated Pigeonpea- 90 × 60 cm	27.0	53	2.96
Irrigated Pigeonpea- 120 × 60 cm	26.8	56	3.09
Irrigated Pigeonpea- 150 × 60 cm	26.6	59	3.22
Irrigated Pigeonpea-180 × 60 cm	26.5	65	3.43
Irrigation Cotton 120 × 60 cm	40.3	47	2.17

*B:C-Benefit: Cost ratio.

The objective of energy usage to determine the energy efficiency indices under different plant geometries under rainfed and irrigated conditions of pigeonpea and cotton crop. Different inputs to calculate energy use in the agricultural sector include labor, machinery, electricity, diesel oil, fertilizer, herbicides, pesticides, seeds,while grain yield of pigeonpea and kapas yield for cotton was included in the output. The results showed that about 1320 h human labor, 500 kg farmyard manure, 270 kg chemical fertilizers (including 150 kg nitrogen, 60 kg phosphorus and 60 kg potassium), 6.25 h machinery, 23.98 L diesel fuel, 5 kg chemicals (pesticides and herbicides) and 1.125 kg seed were used per hectare cotton production system while, 1200 h human labor, 500 kg farm yard manure, 80 kg chemical fertilizers (including 20 kg nitrogen, 50 kg phosphorus and 20 kg potassium), 6.25 h machinery, 20.98 L diesel fuel, 4.5 kg chemicals (pesticides and herbicides) and 10 kg seed were used per hectare pigeonpea production system (Table 1). Amount of seed under different plant geometries used in this study was varied from 10 to 14 kg depending upon the treatments used. Total energy consumption of pigeonpea under various plant geometries varied in between 8340 $MJha^{-1}$ to 8478 $MJha^{-1}$ while, rainfed and irrigated cotton varied from 17691 MJ ha^{-1} and 17115 MJ ha^{-1} respectively (Table 4). Efficiency of energy input and also marginal increase of output due to per unit increase in energy input was estimated by energy output-input ratio.

Higher energy use efficiency of 2.12 and 2.88 was observed with 180 × 60 cm plant geometry under rainfed and irrigated condition in pigeonpea however, 0.79 and 1.11 for cotton cultivated under 120 × 60 cm under rainfed and irrigated conditions. This showed that pigeonpea production is efficient in terms of energy consumption as than cotton as energy ratio of 0.9 (Rani *et al.,* 2016) in cotton production and 1.93 (Tuti *et al.,* 2013) were also reported for pigeonpea + lentil cropping system in mid-hills of North-West Himalayas.
The lowest amount of energy of 5.11 MJ was invested to produce unit quantity of the grain yield (kg) in 180 × 60 cm with one life saving irrigation in terms of specific energy. This resulted higher productivity with production of 0.18 kg MJ^{-1} of energy with same treatment. Pigeonpea with 18519 plants ha^{-1} and 13889 plants ha^{-1} under supplementary life saving irrigation at bud initiation stagehas reported the lowest energy intensiveness of 0.31 MJ $rupee^{-1}$. This treatment was followed by pigeonpea with 11111 plants ha^{-1} and 9259 plants ha^{-1} under supplementary life saving irrigation at bud initiation stage. However, net energy yield was higher in 180 × 60 cm spacing with 9259 plants ha^{-1} while negative net energy was obtained in cotton production due to the less kapas yield. Similarly, 93.7 MJ ha^{-1} net energy was obtained from pigeonpea + lentil cropping system (Tuti *et al*, 2013). Highest energy use efficiency was found in selective mechanization than conventional practice in castor mechanization (Ramanjaneyulu *et al.,* 2021).

Table 4: Energy input-output relationship for different plant geometries on pigeonpea and cotton, under rainfed and protective irrigation.

Treatment	Grain/Kapas yield (kg ha^{-1})	CC* ha^{-1}	Energy output (MJ ha^{-1})	Total energy input (MJ ha^{-1})	Energy ratio	Specific energy (MJ kg^{-1})	Energy productivity (kg MJ^{-1})	Energy intensiveness (MJ)	Net energy yield (MJ ha^{-1})
Rainfed Pigeonpea- 90 × 60 cm	917	25000	13473	8415	1.60	9.18	0.11	0.34	5058
Rainfed Pigeonpea- 120 × 60 cm	992	24840	14575	8390	1.74	8.46	0.12	0.34	6185
Rainfed Pigeonpea- 150 × 60 cm	996	24680	14641	8365	1.75	8.40	0.12	0.34	6276
Rainfed Pigeonpea-180 × 60 cm	1204	24520	17691	8340	2.12	6.93	0.14	0.34	9351
Rainfed Cotton 120 × 60 cm	1138	36250	13423	17052	0.79	14.99	0.07	0.47	-3630
Irrigated Pigeonpea- 90 × 60 cm	1446	27000	21256	8478	2.51	5.86	0.17	0.31	12778
Irrigated Pigeonpea- 120 × 60 cm	1499	26840	22028	8453	2.61	5.64	0.18	0.31	13575
Irrigated Pigeonpea- 150 × 60 cm	1555	26680	22851	8428	2.71	5.42	0.18	0.32	14423
Irrigated Pigeonpea-180 × 60 cm	1645	26520	24174	8403	2.88	5.11	0.20	0.32	15771
Irrigation Cotton 120 × 60 cm	1617	40375	19081	17115	1.11	10.58	0.09	0.42	1966

*CC- Cost of cultivation

CONCLUSION

The energy use efficiency, specific energy, energy intensiveness,energy productivity, net energy and of pigeonpea production system were 2.12, 6.93 MJ kg^{-1}, 0.34 MJ $₹^{-1}$, 0.14 kg MJ^{-1} and 9351 MJ ha^{-1} under rainfed conditions respectively. The results indicate that pigeonpea production is efficient system in terms of energy consumption. While, 0.79, 14.99 MJ kg^{-1}, 0.47 MJ $₹^{-1}$, 0.07 kg MJ^{-1} and -3630 MJ ha^{-1} of energy use efficiency, specific energy, energy intensiveness, energy productivity, net energy for cotton production system under rainfed conditions. Thus, indicating that the pigeonpea production system can replace cotton production system as it is with best fit crop under rainfed conditions producing increased the seed output, net profit, net energy yield, ultimately increased energy use efficiency of inputs.

FUTURE SCOPE

Systemic future research on soil moisture conservation and nutrient management, cultivars selection, and farm mechanization is needed that may further upscale the productivity and profitability of pigeonpea cropping systems in Telangana.

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