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Energy and Economic Budgeting of Pigeonpea Genotypes (*Cajanus cajan* L.) at Various Sowing Dates

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ABSTRACT

Background: Early duration pigeonpea genotypes a boon as the crop needs a very little amount of inputs, survives well even under available water conditions because of its Bio-tillage in nature. There are many causes of low productivity of pigeonpea, using long duration genotypes, using convention varieties, non monitored input like sowing date and management practice and short duration genotypes play a very important role in productivity as well as production in Rajasthan.

Methods: A two-year field experiment was conducted at the Agricultural Research Station, Sriganganagar Rajasthan, during the *Kharif* season of the year 2018 and 2019. The experiment is laidout with a split plot design with thrice replication, in the main plot four dates of sowing allotted *viz*: D_1: 25th May, D_2: 10th June, D_3: 25th June and D_4: 10th July and in subplot five genotypes allotted *viz*: V_1: UPAS-120, V_2: ASJ-105, V_3: Pant- 291, V_4: PUSA- 992, V_5: ICPL- 88039.

Result: Field experiments resulted, the Sowing date D_2: 10th June (1451 kg ha^{-1}), is best suitable as compared to others in terms of yields, its attributes and B:C ratio both the years. In the short duration varieties V_4: PUSA-992 (1586 kg ha^{-1}) superior to others. In respect of different sowings dates the energy budgeting *viz*: energy use efficiency varies from D_1: 25th May (9.80) and (5.99) to D_4: 10th July (8.14) and (4.95), energy productivity (kg MJ^{-1}) varies from D_1: 25th May (0.164) and (0.104) to D_4: 10th July (0.126) and (0.078) in both the years. In respective of genotypes the higher energy use efficiency found in V_4: PUSA-992 (10.34), (6.56), energy productivity in V_4: PUSA-992 (0.171 kg MJ^{-1}), (0.111 kg MJ^{-1}) which was superior with others in all aspect in both the years respectively.

Key words: Date of sowing, Energy, Economic, Genotypes, Pigeonpea, Yield.

INTRODUCTION

Pigeonpea (*Cajanus cajan* L.) is the second most important pulse crop next only to chickpea in India. From the nutritional point of view, vegetable proteins play an important role especially in rural areas, which house over 70% of the population in Rajasthan. Among the pulses pigeonpea is the second most important *Kharif* grain legume after chickpea in India and is grown predominantly under rainfed conditions. The kernels are nutritionally rich containing 20-22% protein. Its cultivation would be able to provide 40-60 kg N/ha to the subsequently grown crop (Sarkar *et al* 2020).It is known to improve soil nutrition through nitrogen fixation and physical structure by adding organic matter from fallen leaf mass.

In the zone 1b under irrigated area major crops are cotton, cluster bean and some extent green gram during *kharif* (rainy*)* season. The introduction of pigeonpea in this canal irrigated area may be useful to farmers as follows, crop diversification by introducing new high yielding varieties and short duration pigeonpea varieties in the zone. Sowing time, a non-monetary input, has considerable influence on the growth and yield of pigeonpea crop. In addition, genotypes may vary in productivity (Umesh *et al.* 2013). However, with the changing climate, the optimum time of sowing may vary. Furthermore, when the crop is sown during the first fortnight of June, many times the maturity of the crop is delayed (Ram *et al.* 2011).

Energy use and output production knowledge in different cropping systems is needed to investigate how to improve EUE while maintaining crop production to free up land for energy crops. Agriculture in a ways an energy conversion industry. Energy use in agricultural production has been increasing faster than that of in many other sectors of the world economy because agricultural production has become more mechanized and commercial fertilizers dependent by the Shilpha *et al.,* (2018).

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MATERIALS AND METHODS

Field experiment

The two-year field experiment was conducted during the *Kharif* season of the year 2018 and 2019 at Agricultural Research Station, Sriganganagar, Rajasthan, (S.K. Rajasthan Agricultural University Bikaner) on pigeonpea to find out the suitable date of sowing and suitable early maturing varieties of pigeonpea for Zone Ib of Rajasthan India. It is a canal irrigated area located between 28.4° to

30.6° North latitude and 72.3° to 75.30° East longitude under North-Western Plain Zone (1b). The soil of the experimental site was sandy loam in texture, low in organic carbon (0.19%), medium in available P_2O_5 (33 kg/ha) and high in available K_2O (330 kg/ha). The pH (1:2) and EC (1:2) of the soil were 8.1 and 0.20 dS/m, respectively. A uniform basal dose of 20 kg N/ha + 40 kg P_2O_5 /ha was applied at the time of sowing. The experiment is laid out with a split-plot design with thrice replication, in the main plot four dates of sowing allotted *viz*: D_1: 25th May, D_2: 10th June, D_3: 25th June and D_4: 10th July and in subplot five genotypes allotted *viz*: V_1: UPAS-120, V_2: ASJ-105, V_3: Pant- 291, V_4: PUSA- 992, V_5: ICPL-88039. The plot size 3x6 m, crop geometry of 50 cm x 30 cm were maintained.

Energetic budgeting

Based on the energy inputs and output, energy use efficiency, energy productivity in physical terms and economic terms (Mittal and Dhawan 1989; Shilpha *et al.* 2018) were calculated.

(1) Energy balance (MJ ha^{-1}) =

$$\text{Energy output (MJ / ha)} - \text{Energy input (MJ / ha)}$$

$$\text{(2) Energy use efficiency} = \frac{\text{Energy output}\left(\frac{\text{MJ}}{\text{ha}}\right)}{\text{Energy input}\left(\frac{\text{MJ}}{\text{ha}}\right)}$$

$$\text{(3) Energy productivity (kg MJ}^{-1}) = \frac{\text{Yield}\left(\frac{\text{kg}}{\text{MJ}}\right)}{\text{Energy input}\left(\frac{\text{MJ}}{\text{ha}}\right)}$$

Table 1: Energy input and output equivalent value.

Particulars	Energy equivalent
I. Inputs (Used in Pigeonpea cultivation)	
1. Human labor (Women)	1.57 MJ/ Women-hour
2. Diesel	56.31 MJ/L
3. Water	1.02 MJ/M^3
Equipment	
4. Tractor	332 MJ/hr
5. Heavy-duty cultivator	220 MJ/ha
6. Plough	180 MJ/ha
7. Disc plough	149 MJ/ha
Chemical fertilizers and manure	
8. Nitrogen	60.60 MJ/kg
9. Phosphate (P_2O_5)	11.1 MJ/kg
10. F.Y.M	0.30 MJ/kg (dry mass)
Pesticide	
11. Insecticide	237 MJ/kg a.i.
2. Output	
12. Pigeonpea (Seed)	14.07 MJ/kg
13. Residues (Straw)	19.4 MJ/kg

Economics

Cost of cultivation

The expenditure incurred on raising the crop from sowing to harvesting and recorded as cost of cultivation or gross expenditure per hectare (` ha^{-1}) for an individual crop of the sequence.

Gross returns

Total income obtained from seed and stover of the crop was worked out using the MSP expressed as ` ha^{-1}.

Net returns

The net returns were computed by subtracting the cost of cultivation from gross returns and expressed as ` ha^{-1}.

Returns per rupee invested (B:C ratio)

This was calculated as follows:

$$\text{B:C ratio} = \frac{\text{Net returns (` / ha)}}{\text{Cost of cultivation (` / ha)}}$$

Statistical analysis

Data from experiment were analyzed as two-way ANOVA. All the values presented here represent the mean values of three replications. Significance was tested using F-test at a 5% level of probability (P< 0.05). The standard error of the mean (SEm+), the critical difference (CD) at 5% level of probability (P< 0.05) were worked out for the study of each parameter by Gomez and Gomez 1984.

RESULTS AND DISCUSSION

Yield parametersof pigeonpea

Seed per pods

The number of seed par pods recorded in sowing of D_1: 25th May and gradually decrease in numbers by delayed in sowings from D_1: 25th May (5.17) and (5.64) to D_5: 10th July (4.01) and (4.62) in both the years respectively. In respective of genotypes, the maximum Seed par pods found in genotype V_4: PUSA-992 (5.0), (5.56) and V_5: ICPL-88039 recorded minimum Seed par pods (4.26) and (4.90) respectively in both the years (Table 2).

Pods per plants

The number of pods recorded in maximum in the sowing of D_1: 25th May and gradually decrease in numbers by delayed in sowings from D_1: 25th May (97.55) and (100.54) to D_4: 10th July (85.18) and (87.44) in both the years respectively. In respective of genotypes the maximum pods recorded in genotype V_4: PUSA-992 (101.27), (104.17) and V_5: ICPL-88039 recorded minimum Seed par pods (84.91) and (87.86) respectively in both the years according to Table 2.

Seed index (g)

It is the 100-seed weight in gram of respective genotypes. The 100-seed weight recorded in maximum in the early sowing of D_1: 25th May and gradually decrease in numbers by delayed in sowings from D_1: 25th May (10.85 g) and (11.13 g) to D_4: 10th July (10.03 g) and (10.31 g) in both the years respectively. In respective of genotypes, the maximum seed index found in genotype V_4: PUSA-992 (10.95 g), (11.25 g) and V_5: ICPL-88039 recorded minimum Seed index (9.59 g) and (9.86 g) respectively in both the years according to Table 2.

Seed yield and stover yield

Seed yield

It is the economically imported harvest from the crop's respective genotypes. The seed yields recorded higher numerically in the early sowing of D_1: 25th May and gradually decrease by delayed in sowings from D_1: 25th May (1831 kg ha^{-1}) and (1179 kg ha^{-1}) to D_4: 10th July (1411 kg ha^{-1}) and (887 kg ha^{-1}) in both the years respectively. Both sowing of D_1: 25th May and D_2:10th June are statistically at par in yield, D_2: 10th June (1773 kg ha^{-1}) (1129 kg ha^{-1}) is significantly superior with references to D_3: 25th June (1503 kg ha^{-1}) (966 kg ha^{-1}) and D_4: 10th July (1411 kg ha^{-1}) (887 kg ha^{-1}), in the seed yield percent reduction by (3.17%) (2.24%) in D_2:10th June, by the (17.91%) (18.07%) in D_3: 25th June and (22.94%) (24.77%) in D_4: 10th July recorded as compared with D_1: 25th May sowing dates was in both the years respectively (Table 2), these same work and results reported by Singh *et al.,* (2016) and Ram *et al.* (2011). In respective of genotypes, the maximum seed yield found in genotype V_4: PUSA-992 (1910 kg ha^{-1}), (1263 kg ha^{-1}), which was significantly superior with others followed by V_2: ASJ-105 (18.38 kg ha^{-1}) (1151 kg ha^{-1}) and V_5: ICPL-88039 recorded minimum Seed yield (1323 kg ha^{-1}) (807 kg ha^{-1}), in the seed yield percent reduction by (3.77%) (8.87%) in V_2: ASJ-105, in V_3: Pant-291 (16.34%) (20.35%) and maximum loss recorded V_5: ICPL-88039 (30.73%) (36.10%) recorded as compared to V_4: PUSA-992 in both the year respectively (Table 2). These finding are correlated with Umesh *et al.,*(2013).

Stover yield

The stover yields recorded higher numerically in the early sowing of D_1: 25th May and gradually decrease by delayed in sowings from D_1: 25th May (6695 kg ha^{-1}) and (4112 kg ha^{-1}) to D_4: 10th July (5689 kg ha^{-1}) and (3492 kg ha^{-1}) in both the years respectively. Both sowing of D_1: 25th May and D_2:10th June is statistically at par in stover yield, D_2: 10th June (6615 kg ha^{-1}) (4043 kg ha^{-1}) is significantly superior over to D_3: 25th June (5873 kg ha^{-1}) (3639 kg ha^{-1}) and D_4: 10th July, both the years respectively. In respective of genotypes, the maximum stoveryield found in genotype V_4: PUSA-992 (7089 kg ha^{-1}), (4536 kg ha^{-1}), which was significantly superior with others followed by V_2: ASJ-105 (6866 kg ha^{-1}) (4151 kg ha^{-1}) and V_5: ICPL-88039 recorded minimum stover yield (5265 kg ha^{-1}) (3124 kg ha^{-1}), in both the years respectively (Table 2). Similar results were found by Kumar *et al.,*(2008).

Economics

Cost of cultivation

It is the total expenditure to produce as the seeds term known as cost of cultivation.It is found constant in all dates of sowing and genotypes (28.10 x10^3 ` ha$^{-1}$) and (28.50 x10$^3$ ` ha^{-1}) in both years respectively (Table 2).

Gross return

It is the total return from the seed as well as stover yields. It found differ from high to low in early to late sown redgram *viz:* D_1: 25th May (77.47 x10^3 ` ha$^{-1}$) and (55.38 x10$^3$ ` ha^{-1}) to D_4: 10th July (60.76 x10^3 ` ha$^{-1}$) and (42.46 x10$^3$ ` ha^{-1}) in both the years respectively (Table 3). In respective of genotypes the higher gross return found in genotype V_4: PUSA-992 (81.02 x10^3 ` ha$^{-1}$), (59.59 x10$^3$ ` ha^{-1}), which was significantly superior with others followed by V_2: ASJ-105 (78.06 x10^3 ` ha$^{-1}$) (54.34 x10$^3$ ` ha^{-1}) and V_5: ICPL-88039 recorded minimum seed yield (56.83 x 10^3 ` ha$^{-1}$) (38.52 x10$^3$ ` ha^{-1}), in both the years 2018 and 2019 respectively (Table 2).

Net return

It is the return from the seed after the deducted cost of cultivation. It is found high to low in different sowing dates, *viz:* D_1: 25th May (49.37 x 10^3 ` ha$^{-1}$) and (26.88 x 10$^3$ ` ha^{-1}) to D_4: 10th July (32.66 x 10^3 ` ha$^{-1}$) and (13.96 x 10$^3$ ` ha^{-1}) in both the year 2018 and 2019 respectively. In respective of genotypes the highest net returns found in genotype V_4: PUSA-992 (52.92 x 10^3 ` ha$^{-1}$), (31.09 x 10$^3$ ` ha^{-1}), which was significantly superior with others followed by V_2: ASJ-105 (49.96 x 10^3 ` ha$^{-1}$) (25.84 x10$^3$ ` ha^{-1}), V_3: Pant-291 (40.06 x10^3 ` ha$^{-1}$) (19.16 x10$^3$ ` ha^{-1}) and V_5: ICPL-88039 recorded lessnet returns (28.73 x10^3 ` ha$^{-1}$) (10.02 x10$^3$ ` ha^{-1}), in both the years respectively (Table 2).

B:C ratio

It is the ratio between benefit to cost of cultivation of pigeonpea crop. B:C ratio is recorded higher in early planted/ sown conditions of redgram to less in late planted/sown conditions, *viz:* D_1: 25th May (1.76) and (1.69) to D_4: 10th July (1.16) and (1.05) in both the years respectively. In respective of genotypes the highest B:C ratio found in genotype V_4: PUSA-992 (1.88), (1.89), which was significantly superior with others followed by V_2: ASJ-105 (1.78) (1.63) and V_5: ICPL-88039 recorded less net returns (1.02) (0.86), in both the years respectively (Table 2). Similar results were reported by Kumar *et al.,* (2008).

Energy dynamics

Different energy index and efficiency described inTable 3.

Energy input

It is the energy derives by different sources to cultivation *viz*: manpower, machine water, *etc.* were calculated and multiply with the equivalent unit (Table 1) in all treatment is workout is (11.17×10^3 MJ ha^{-1}) and (11.34×10^3 MJ ha^{-1}) in both the year respectively in all treatment same.

Energy output (x 10^3 MJ ha^{-1})

It is energy output that includes energy produced in the form of seed and stover.In the sowing dates the energy output varies from D_1: 25th May (109.45×10^3 MJ ha^{-1}) and

Table 2: Effect of sowing dates and different varieties on yield and economics in years 2018 and 2019.

Treatments	Seed /pods (no.)		Pods/plant (no.)		Seed index (g)		Seed yield (kg/ha)		Stover yield (kg/ha)		Gross return (x10^3 ` ha^{-1})		Net return (x10^3 ` ha^{-1})		Cost of cultivation (x10^3 ` ha^{-1})		B:C ratio	
	Year 2018	Year 2019	Year 2018	Year 2019	Year 2018	Year 2019	Year 2018	Year 2019	Year 2018	Year 2019	Year 2018	Year 2019	Year 2018	Year 2019	Year 2018	Year 2019	Year 2018	Year 2019
Sowing dates																		
D_1: 25th May	5.17	5.64	97.55	100.54	10.85	11.13	1831	1179	6695	4112	77.48	76.61	49.38	48.11	28.10	28.50	1.76	1.69
D_2: 10th June	4.61	5.22	96.84	99.43	10.73	11.03	1773	1129	6615	4043	75.29	73.57	47.19	45.07	28.10	28.50	1.68	1.58
D_3: 25th June	4.39	5.00	93.57	96.30	10.71	11.01	1503	966	5873	3639	64.35	63.31	36.25	34.81	28.10	28.50	1.29	1.22
D_4: 10th July	4.01	4.62	85.18	87.44	10.03	10.31	1411	887	5689	3492	60.76	58.43	32.66	29.93	28.10	28.50	1.16	1.05
SEm±	0.28	0.25	4.97	5.24	0.18	0.20	141	48	329	142	-	-	-	-	-	-	-	-
CD (P=0.05)	0.69	0.62	12.15	12.83	0.45	0.48	345	118	805	348	-	-	-	-	-	-	-	-
Genotypes																		
V_1: UPAS-120	4.37	4.91	87.61	90.29	10.67	10.95	1480	973	5752	3587	63.30	63.61	35.20	35.11	28.10	28.50	1.25	1.23
V_2: ASJ-105	4.68	5.20	98.25	100.46	10.91	11.21	1838	1151	6866	4151	78.06	75.06	49.96	46.56	28.10	28.50	1.78	1.63
V_3: Pant- 291	4.43	5.03	94.39	96.86	10.79	11.09	1598	1006	6118	3712	68.17	65.77	40.07	37.27	28.10	28.50	1.43	1.31
V_4: PUSA-992	5.00	5.56	101.27	104.17	10.95	11.25	1910	1263	7089	4536	81.03	82.33	52.93	53.83	28.10	28.50	1.88	1.89
V_5: ICPL-88039	4.26	4.90	84.91	87.86	9.59	9.86	1323	807	5265	3124	63.30	63.61	35.20	35.11	28.10	28.50	1.02	0.86
SEm±	0.15	0.16	4.96	5.00	0.17	0.17	82	42	200	129	-	-	-	-	-	-	-	-
CD (P=0.05)	0.34	0.36	11.20	11.31	0.38	0.39	186	095	453	292	-	-	-	-	-	-	-	-

Table 3: Effect of sowing dates and different Varieties on energetic of pigeonpea years 2018 and 2019.

Treatments	Energy input ($x10^3$ MJ ha^{-1})		Energy output ($x10^3$ MJ ha^{-1})		Energy balance ($x10^3$ MJ ha^{-1})		Energy use efficiency		Energy productivity (kg MJ^{-1})	
	Year 2018	Year 2019	Year 2018	Year 2019	Year 2018	Year 2019	Year 2018	Year 2019	Year 2018	Year 2019
Sowing dates										
D_1: 25th May	11.17	11.34	109.45	67.99	98.28	56.65	9.80	5.99	0.164	0.104
D_2: 10th June	11.17	11.34	107.63	66.42	96.46	55.08	9.63	5.86	0.159	0.100
D_3: 25th June	11.17	11.34	94.56	59.08	83.39	47.74	8.46	5.21	0.135	0.085
D_4: 10th July	11.17	11.34	90.97	56.13	79.79	44.79	8.14	4.95	0.126	0.078
Genotypes										
V_1: UPAS-120	11.17	11.34	92.72	58.53	81.55	47.18	8.30	5.16	0.132	0.086
V_2: ASJ-105	11.17	11.34	111.69	68.08	100.51	56.74	10.00	6.00	0.164	0.101
V_3: Pant- 291	11.17	11.34	98.96	60.55	87.79	49.21	8.86	5.34	0.143	0.089
V_4: PUSA-992	11.17	11.34	115.49	74.47	104.31	63.13	10.34	6.56	0.171	0.111
V_5: ICPL-88039	11.17	11.34	84.43	50.40	73.25	39.06	7.56	4.44	0.118	0.071

(67.99×10^3 MJ ha^{-1}) to D_4: 10th July (90.97×10^3 MJ ha^{-1}) and (56.13×10^3 MJ ha^{-1}) in both the year 2018 and 2019 respectively. Similar findings are the same by Mittal and Dhawan 1989. In respective of genotypes, the higher energy output found in genotype V_4: PUSA-992 (115.49×10^3 MJ ha^{-1}), (74.47×10^3 MJ ha^{-1}), which was superior with others followed by V_2: ASJ-105 (111.69×10^3 MJ ha^{-1}) (68.08×10^3 MJ ha^{-1}) and V_5: ICPL-88039 recorded less energy output (84.43×10^3 MJ ha^{-1}) (50.40×10^3 MJ ha^{-1}), in both the year 2018 and 2019 respectively (Table 3). Similar research found by the Shilpha *et al.* (2018).

Energy balance

It is the balance between energy inputto energy output in the cultivation of pigeonpea. In the sowing dates the energy balance varies from D_1: 25th May (98.28×10^3 MJ ha^{-1}) and (56.65×10^3 MJ ha^{-1}) to D_4: 10th July (79.79×10^3 MJ ha^{-1}) and (44.79×10^3 MJ ha^{-1}) in both the year 2018 and 2019 respectively. In respective of genotypes the higher energy balance found in genotype V_4: PUSA-992 (104.31×10^3 MJ ha^{-1}), (63.13×10^3 MJ ha^{-1}), which was superior with others followed by V_2: ASJ-105 (100.51×10^3 MJ ha^{-1}) (56.74×10^3 MJ ha^{-1}) and V_5: ICPL-88039 recorded less energy balance (73.25×10^3 MJ ha^{-1}) (39.06×10^3 MJ ha^{-1}), in both the year 2018 and 2019 respectively. (Table 3) similar results reported by Chaudhary *et al.,* (2006).

Energy use efficiency

It is the ratio of energy output to energy input in the cultivation of pigeonpea. In the sowing dates, the energy use efficiency varies from D_1: 25th May (9.80) and (5.99) to D_4: 10th July (8.14) and (4.95) in both the years 2018 and 2019 respectively. In respective of genotypes the higher energy use efficiency found in genotype V_4: PUSA-992 (10.34), (6.56), which was superior with others followed by V_2: ASJ-105 (10.0) (6.0) and V_5: ICPL-88039 recorded less energy use efficiency (7.56) (4.44), in both the years respectively. (Table 3). Similar results were found by Kumar *et al.* (2008).

Energy productivity (kg MJ^{-1})

It is the ratio of seed yield to energy input used in the cultivation of pigeonpea. In the sowing dates the energy productivity (kg MJ^{-1}) varies from D_1: 25th May (0.164) and (0.104) to D_4: 10th July (0.126) and (0.078) in both years respectively. In respective of genotypes the higher energy productivity found in genotype V_4: PUSA-992 (0.171), (0.111), which was superior with others followed by V_2: ASJ-105 (0.164) (0.101) and V_5: ICPL-88039 recorded less energy productivity (0.118) (0.071), in both the year 2018 and 2019 respectively (Table 3). Similar results were found by Chaudhary *et al.*(2006).

CONCLUSION

For the NWPZ zone of Rajasthan, based on two years of fixed land experimentation, it was revealed that the first fortnight of June suitable for the sowing of pigeonpea for good harvesting of seed yield. The most promising genotypes PUSA-992 are found economically in terms of production and profitability.

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