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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*: $D_1$: 25$^{th}$ May, $D_2$: 10$^{th}$ June, $D_3$: 25$^{th}$ June and $D_4$: 10$^{th}$ 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 $D_2$: 10$^{th}$ 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 $D_1$: 25$^{th}$ May (9.80) and (5.99) to $D_4$: 10$^{th}$ July (8.14) and (4.95), energy productivity (kg MJ$^{-1}$) varies from $D_1$: 25$^{th}$ May (0.164) and (0.104) to $D_4$: 10$^{th}$ 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, Economic, Energy, 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 3 × 6 m, crop geometry of 50 cm × 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 $ha^{-1}$) =

Energy output (MJ / ha) - Energy input (MJ / ha)

$$(2)\quad \text{Energy productivity (kg MJ}^{-1}) = \frac{\text{Yield}\left(\frac{\text{kg}}{\text{MJ}}\right)}{\text{Energy input}\left(\frac{\text{MJ}}{\text{ha}}\right)}$$

$$(3)\quad \text{Energy use efficiency} = \frac{\text{Energy output}\left(\frac{\text{MJ}}{\text{ha}}\right)}{\text{Energy input}\left(\frac{\text{MJ}}{\text{ha}}\right)}$$

**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 1).

**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 1.

**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 1.

**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

**Table 1:** 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 (×10³ ` ha⁻¹) | | Net return (×10³ ` ha⁻¹) | | Cost of cultivation (×10³ ` 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 | - | - | - | - | - | - | - | - |

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 1), 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 1). 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 1). 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 $\times 10^3$ ` ha$^{-1}$) and (28.50$\times 10^3$ ` ha$^{-1}$) in both years respectively (Table 1).

### 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 $\times 10^3$ ` ha$^{-1}$) and (55.38 $\times 10^3$ ` ha$^{-1}$) to $D_4$: 10th July (60.76 $\times 10^3$ ` ha$^{-1}$) and (42.46 $\times 10^3$ ` 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 $\times 10^3$ ` ha$^{-1}$), (59.59 $\times 10^3$ ` ha$^{-1}$), which was significantly superior with others followed by $V_2$: ASJ-105 (78.06 $\times 10^3$ ` ha$^{-1}$) (54.34 $\times 10^3$ ` ha$^{-1}$) and $V_5$: ICPL-88039 recorded minimum seed yield (56.83 $\times 10^3$ ` ha$^{-1}$) (38.52 $\times 10^3$ ` ha$^{-1}$), in both the years 2018 and 2019 respectively (Table 1).

### 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 $\times 10^3$ ` ha$^{-1}$) and (26.88 $\times 10^3$ ` ha$^{-1}$) to $D_4$: 10th July (32.66 $\times 10^3$ ` ha$^{-1}$) and (13.96 $\times 10^3$ ` 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 $\times 10^3$ ` ha$^{-1}$), (31.09 $\times 10^3$ ` ha$^{-1}$), which was significantly superior with others followed by $V_2$: ASJ-105 (49.96 $\times 10^3$ ` ha$^{-1}$) (25.84 $\times 10^3$ ` ha$^{-1}$), $V_3$: Pant-291 (40.06 $\times 10^3$ ` ha$^{-1}$) (19.16 $\times 10^3$ ` ha$^{-1}$) and $V_5$: ICPL-88039 recorded lessnet returns (28.73 $\times 10^3$ ` ha$^{-1}$) (10.02 $\times 10^3$ ` ha$^{-1}$), in both the years respectively (Table 1).

### 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 1). 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 2) in all treatment is workout is (11.17$\times 10^3$ MJ ha$^{-1}$) and (11.34$\times 10^3$ MJ ha$^{-1}$) in both the year respectively in all treatment same.

**Table 2:** 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. |
| **II. Output** | |
| 12. Pigeonpea (Seed) | 14.07 MJ/kg |
| 13. Residues (Straw) | 19.4 MJ/kg |

**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 |

### Energy output (× $10^3$ 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 ($109.45\times10^3$ MJ $ha^{-1}$) and ($67.99\times10^3$ MJ $ha^{-1}$) to $D_4$: 10th July ($90.97\times10^3$ MJ $ha^{-1}$) and ($56.13\times10^3$ 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 ($115.49\times10^3$ MJ $ha^{-1}$), ($74.47\times10^3$ MJ $ha^{-1}$), which was superior with others followed by $V_2$: ASJ-105 ($111.69\times10^3$ MJ $ha^{-1}$) ($68.08\times10^3$ MJ $ha^{-1}$) and $V_5$: ICPL-88039 recorded less energy output ($84.43\times10^3$ MJ $ha^{-1}$) ($50.40\times10^3$ 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 ($98.28\times10^3$ MJ $ha^{-1}$) and ($56.65\times10^3$ MJ $ha^{-1}$) to $D_4$: 10th July ($79.79\times10^3$ MJ $ha^{-1}$) and ($44.79\times10^3$ 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 ($104.31\times10^3$ MJ $ha^{-1}$), ($63.13\times10^3$ MJ $ha^{-1}$), which was superior with others followed by $V_2$: ASJ-105 ($100.51\times10^3$ MJ $ha^{-1}$) ($56.74\times10^3$ MJ $ha^{-1}$) and $V_5$: ICPL-88039 recorded less energy balance ($73.25\times10^3$ MJ $ha^{-1}$) ($39.06\times10^3$ 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.

### Conflict of interest

All authors declared that there is no conflict of interest.

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