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Energy auditing and microbial activity influenced by agronomic practices in hybrid pigeonpea

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Abstract

Background: In general, conventional sown (Dibbling) pigeonpea performance was inferior over transplanting due to late sowing. In the way of corroborate above statement an experiment was conducted at International Crops Research Institute for Semi-Arid Tropics (ICRISAT), Patancheru, Hyderabad, during *kharif*, 2021 and 2022.

Methods: Hence, we evaluated two planting methods (dibbling and transplanting) along with three plant geometry (100 ×100, 120 × 120 and 150 ×60 cm). In order to find out the ecologically sustainable and economically viable nutrient dose for hybrid pigeonpea under square geometry nutrient management practices were included under present investigation.

Result: From this investigation it was found that, transplanted pigeonpea recorded more net energy output, energy efficiency and energy productivity due to higher microbial population and activity over transplanting with 100 ×100 cm plant geometry. Among nutrient management practices integrated nutrient management of 100 % STB NPK + vermicompost + PSB + Seed treatment (ST) with *Rhizobium* got registered higher energy indices and microbial population and enzymatic activity.

Keywords: Dehydrogenase activity, energy indices, hybrid pigeonpea, microbial population, square geometry and transplanting

Introduction

In India generally pigeonpea (*Cajanua cajan* L.) is cultivated in marginal lands under rainfed situations with poor resources (Tiwari and Namrata. 2020) [11]. But, now a day's due to monsoon aberrations farmers are unable to sow the pigeonpea in correct window as a result vegetative period is restricting (Susithra *et al*., 2019) [10]. In order to avoid such source-sink imbalance the concept of transplanting is brought into picture. Due to correct time of sowing there is scope for development of higher number of branches and better plant architecture and to avoid not only competition but also to provide sufficient space for optimum expression of the plant, geometry component was included.

Under wider plant geometry and hybrid, the nutrient demand under transplanting conditions was not developed so far. From most of the research findings it was concluded that, transplanted pigeonpea performance was higher over dibbling. In the process of increasing yield of pigeonpea the effect of agronomic practices on energy indices and soil health in terms of dehydrogenase activity and microbial population data also generate through this investigation.

Material and Methods

Experimental site: A field study was conducted with an objective of Energy auditing and microbial activity influenced by agronomic practices at International Crops Research Institute for Semi-Arid Tropics (ICRISAT), Patancheru, Hyderabad, during *kharif*, 2021 and 2022. The rainfall received during experimental periods was 998.4 mm in 55 rainy days and 1000 mm in 53.1 rainy days in 2021 and 2022, respectively. Soil belongs to clay soil type with its particle distribution and it can be grouped as moderately alkaline in reaction with pH of 8.1 and EC is 1.94 dSm^{-1}. Status of available primary nutrients in the soil *viz*., N, P_2O_5 and K_2O and organic carbon content is low (231.1 kg ha^{-1}), medium (29.8 kg ha^{-1}), high (350.5 kg ha^{-1}) and low (0.42 %), respectively.

Treatment and experimental design

Field study was laid out in split-split plot design with two planting methods of pigeonpea in the main plots (M_1: Dibbling, M_2: Transplanting), three crop geometry in sub-plots as {S_1: 100 cm × 100 cm (10,000 plants ha^{-1}), S_2: 120 cm ×120 cm (6,944 plants ha^{-1}), S_3: 150 cm × 60 cm(11,111 plants ha^{-1}) (Normal transplanting)} and five nutrient management options in sub-sub plots as N_1: Control, N_2:100 % soil test-based (STB) NPK (25:37.5:8.5 kg ha^{-1}), N_3: 100 % STB NPK + vermicompost + PSB + Seed treatment (ST) with *Rhizobium*, N_4: 150 % STB NPK , N_5: 150 % STB NPK + vermicompost + PSB + ST with *Rhizobium.* Dibbling was done on the same day of transplantation at 23 days and 25 days old seedlings in *kharif*, 2021 and 2022, respectively.

Data collection

Energy input for crop production was estimated by using direct and indirect energy by multiplying with corresponding coefficients. Direct energy inputs include total quantity of fossil fuel used in land preparation, harvesting, human labour and electricity. While indirect energy inputs are, energy used in production of machinery and raw materials like mineral fertilizers, pesticides and seed energy inputs and transportation. A complete inventory of all crop inputs (fertilizers, seeds, plant protection chemicals, fuels, human labour and machinery power) and outputs were recorded.

Net Energy (MJ ha^{-1})

It is the subtraction of energy input from the energy output. It is expressed in MJ ha^{-1} (Mandal *et al*., 2002) [6].

Net energy = Output energy – Input energy

Energy efficiency (%)

The energy efficiency (EE) was calculated as suggested by Veeranna *et al*. (2021) [12].

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

Energy Productivity (Kg MJ^{-1})

The crop yield obtained was divided by the input energy to get the energy productivity. It was expressed as kg MJ^{-1} (Mandal *et al*., 2002) [6].

$$\text{Energy productivity} = \frac{\text{Crop yield (kg)}}{\text{Energy input (MJ)}}$$

Soil microbial populations were enumerated from the samples collected at 0-15 cm depth. The serial dilution was made to determine the microbial population in different treatments. One gram of soil was suspended in 10 ml of sterile 0.85 % saline solution and swirled for 5 minutes. The dilutions were made by transferring 1ml of this suspension to subsequent 9 ml of sterile solution which shows 10^{-1} dilution. The dilutions were made 10^{-6}.

Number of bacteria/fungi free living in 1 gm soil =

No. of CFU × dilution Dry weight of 1 gm moist soil × aliquot taken

Soil dehydrogenase activity (μg TPF g^{-1} soil 24 hr^{-1})

In screw-caped test tubes one gram of soil was taken. 2.5 ml of distilled water, 50 mg of $CaCO_3$, and 1 ml of 3% TTC were then added. The mixture was stirred and incubated for 24 hours at room temperature. A small amount of methanol was added to the mixture and agitated to dissolve the red precipitate. The mixture was filtered, and methanol was used to increase the volume to 25 ml. At 485 nm, the red colour intensity was measured (Casida *et al*., 1964) [1].

Statistical analysis

Data on energy indices, dehydrogenase activity and microbial population were subjected to analysis of variance procedures as outlined for spit-split plot design (Gomez and Gomez, 1984). Statistically significance was tested by F-value at p=0.05 (5 %) level of probability and critical difference was worked out where ever the effect was significant. Treatment differences that were non–significant were denoted as NS.

Results and Discussion

Net Energy (MJ ha^{-1})

Among the main plot treatments (planting methods) higher net energy was recorded with transplanting compared to dibbling in both years. The mean total net energy was 105642 and 128021 (MJ ha^{-1}) in dibbling and transplanted plot, respectively. There was significant variation in net energy with planting geometry. Higher net energy was obtained with 100 × 100 cm plant geometry and was statistically on par with 150 × 60 cm geometry. Lower net energy output was recorded with 120 × 120 cm plant geometry during *kharif*, 2021 and 2022. In consideration with nutrient management practices higher net returns was noticed with 150 % soil test based NPK + vermicompost 5 t ha^{-1} + vermicompost enriched with PSB + *Rhizobium* seed treatment which was statistically on par with 100 % soil test based NPK + vermicompost 5 t ha^{-1} + vermicompost enriched with PSB + *Rhizobium* seed treatment (pasha et al. (2020) [8] and Chaudhary et al (2006) [2].

Energy efficiency (%)

This parameter will show the how efficiency we had utilized the input energy in production process. Higher energy efficiency was registered with transplanting, among the plant geometry 100 × 100 cm. Among nutrient management practices energy efficiency was more in case of 100 % soil test based NPK but on par results were also registered with integrated nutrient approach 100 % soil test based NPK + vermicompost 5 t ha^{-1} + vermicompost enriched with PSB + *Rhizobium* seed treatment. Transplanting treatment recorded greater energy use efficiency, which might be attributed due to higher gross energy output recorded. And also, same way higher yield was recorded with optimum plant population (100 × 100 cm plant geometry) and 100 % soil test based NPK + vermicompost 5 t ha^{-1} + vermicompost enriched with PSB + *Rhizobium* seed treatment with minimum input energy. These findings were inconsistence with Veeranna *et al.* (2021) [12] and Maini and Sandhu (2022) [5].

Energy productivity (kg MJ^{-1})

This parameter will show the amount of output produced per unit of the input energy used in production process. Higher energy productivity was registered with transplanting, among the plant geometry 100 × 100 cm. Among nutrient management practices energy productivity was more in case of integrated nutrient approach 100 % soil test based NPK + vermicompost 5 t ha^{-1} + vermicompost enriched with PSB + *Rhizobium* seed treatment. Higher seed yield was obtained with optimum nutrient dose with integrated approach might provide constant nutrient supply until pod formation so, higher yields were recorded with integrated approach similarly the same has reflected with energy productivity. The results of investigation were in tune with findings of Singh *et al*. (2016) [9].

Microbial population and dehydrogenase activity

The microbial population and soil enzymatic activity are directly related each other. Greater microbial population was observed with transplanting compared to dibbling. Due to early sowing and vigorous growth of the plant, root growth also proportionally. So, the active root growth may release lot of root extrudates which might have encouraged the soil microbial population. Due to activity of microbes the dehydrogenase activity also increased. Among the plant geometry 100 × 100 cm plant geometry registered higher number of bacteria and fungi population over 120 × 120 cm and 150 × 60 cm. Under 100 × 100 cm square plant geometry was optimum plant population wherein optimum expression of hybrid pigeonpea in terms of number of branches and leaf area development due to microbial activity. With concern to nutrient management practices greater number of bacteria and fungal population was registered with integrated nutrient management over inorganic nutrient approach i.e. 100 % soil test based NPK + vermicompost 5 t ha^{-1} + vermicompost enriched with PSB + *Rhizobium* seed treatment. Vermicompost acts as food material for microbes so, the multiplication of microbes was might take place. And also, the organic matter addition act as substrate for microbial function. Oxidation of soil organic matter by dehydrogenase is linked to respiration pathway of microorganisms. Under transplanting conditions higher leaf fall and integrated nutrient management practices might be the reason for high dehydrogenase activity was observed. Similar sort of results was notified by Math *et al*. (2020) [7] and Hebbal *et al*. (2018) [4].

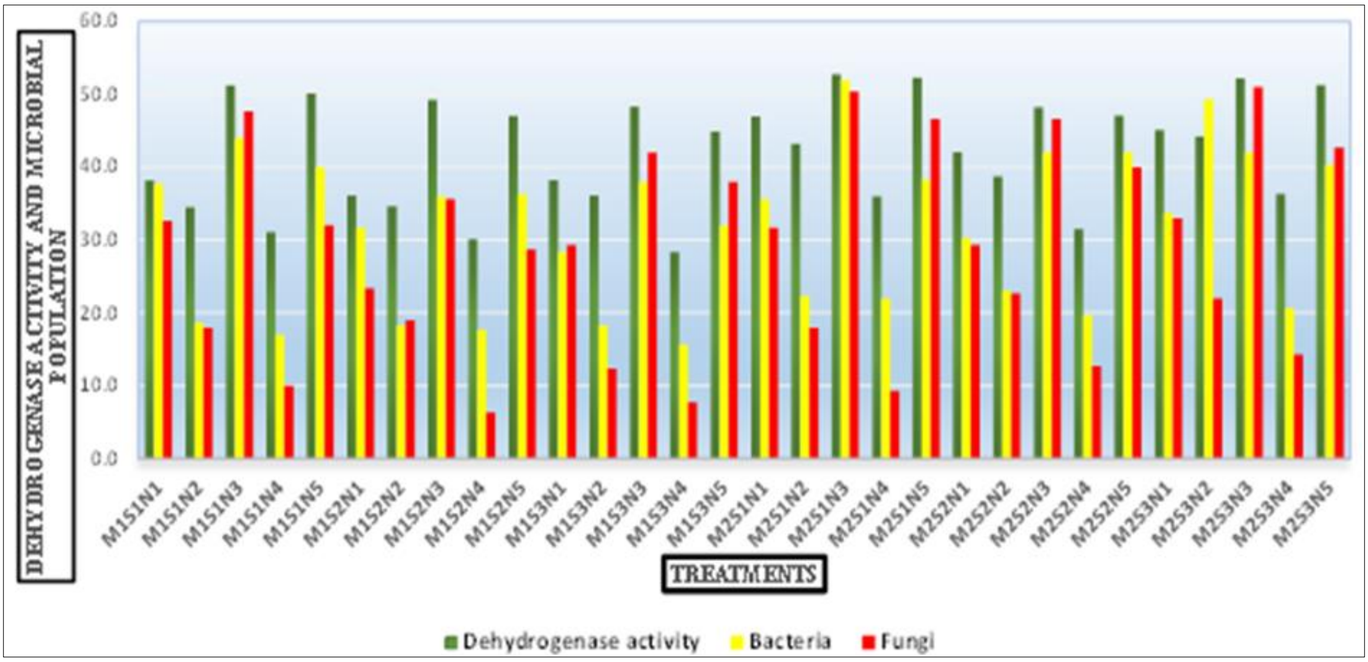

Fig 1: Relationship between soil dehydrogenase activity (µg TPF g^{-1} soil 24 hr^{-1}) and microbial population of hybrid pigeonpea influenced by agronomic practices

Table 1: Influence of agronomic practices on energy indices of hybrid pigeonpea during *kharif*, 2021 and 2022

Treatment	Net energy (MJ ha^{-1})			Energy efficiency (%)			Energy productivity (kg MJ^{-1})		
	2021	2022	Mean	2021	2022	Mean	2021	2022	Mean
Planting method									
M_1: Dibbling	107808	103475	105642	18.0	17.5	17.8	0.21	0.20	0.21
M_2: Transplanting	130367	125675	128021	22.8	22.1	22.5	0.29	0.28	0.29
SEm±	1323	1900	-	0.4	0.3	-	0.01	0.01	-
CD (P=0.05)	8063	11560	-	2.3	1.9	-	0.05	0.06	-
Plant geometry									
S_1: 100 × 100 cm	124979	120325	122652	21.3	20.7	21.0	0.27	0.28	0.28
S_2: 120 × 120 cm	111538	105792	108665	19.2	18.4	18.8	0.23	0.21	0.22
S_3: 150 × 60 cm	120745	117609	119177	20.7	20.3	20.5	0.25	0.23	0.24
SEm±	1348	1146	-	0.3	0.2	-	0.01	0.01	-
CD (P=0.05)	4329	3737	-	1.0	0.8	-	0.02	0.02	-
Nutrient management									
N_1: Control	68324	67389	67857	21.9	21.6	21.8	0.20	0.20	0.20
N_2 :100 % STB RDF	117675	115326	116501	21.9	21.5	21.7	0.26	0.24	0.25
N_3: 100 % STB RDF + vermicompost + PSB + *Rhizobium*	142202	134937	138570	20.9	19.9	20.4	0.30	0.29	0.30
N_4: 150 % STB RDF	122417	118078	120248	18.9	18.5	18.7	0.23	0.22	0.23
N_5: 150 % STB RDF + vermicompost + PSB + *Rhizobium*	144818	137145	140982	18.4	17.5	18.0	0.26	0.25	0.26

SEm±	1711	1603	-	0.4	0.3	-	0.02	0.01	-
CD (P=0.05)	4810	4580	-	1.1	0.8	-	0.04	0.03	-
All (2 × 2), (3 × 3) interactions are Non-significant									

Table 2: Effect of agronomic practices on soil dehydrogenase activity (µg TPF g^{-1} soil 24 hr^{-1}) and microbial population during *kharif*, 2021 and 2022

Treatment	**Dehydrogenase activity**			**Bacteria (10^5 CFU g^{-1} soil)**			**Fungi (10^3 CFU g^{-1} soil)**		
	2021	**2022**	**Mean**	**2021**	**2022**	**Mean**	**2021**	**2022**	**Mean**
Planting method									
M_1: Dibbling	40.2	42.5	41.4	29	31	30	26	25	26
M_2: Transplanting	44.8	48.4	46.6	34	37	36	31	34	33
SEm±	0.5	0.6	-	0.5	0.4	-	0.4	0.2	-
CD (P=0.05)	3.2	3.9	-	3.0	2.3	-	2.3	1.1	-
Plant geometry									
S_1: 100 × 100 cm	43.9	47.4	45.7	33	36	35	30	32	31
S_2: 120 × 120 cm	40.8	42.7	41.8	30	32	31	26	27	27
S_3: 150 × 60 cm	42.8	46.3	44.6	32	35	34	29	30	30
SEm±	0.4	0.5	-	0.7	0.8	-	0.6	0.7	-
CD (P=0.05)	1.2	1.6	-	2.2	2.5	-	1.8	2.4	-
Nutrient management									
N_1: Control	41.4	44.2	42.8	35	37	36	30	34	32
N_2 :100 % STB RDF	38.9	41.9	40.4	25	30	27	19	20	20
N_3: 100 % STB RDF + vermicompost + PSB + *Rhizobium*	50.6	54.0	52.3	44	45	44	42	46	44
N_4: 150 % STB RDF	32.5	35.4	34.0	19	22	21	10	12	11
N_5: 150 % STB RDF + vermicompost + PSB + *Rhizobium*	49.1	51.9	50.5	38	36	37	32	36	34
SEm±	0.9	1.1	-	1.4	1.1	-	0.9	0.8	-
CD (P=0.05)	2.6	3.0	-	4.0	3.3	-	2.5	2.4	-
All (2 × 2), (3 × 3) interactions are Non-significant									

Conclusion

Pigeonpea nursery raised at end of May and its transplanting at the age of 21-25 old seedlings with on onset of south-west monsoons is a viable resource conservation technology to ensure optimum plant stand with 70% less seed rate (2-2.5 kg ha^{-1}) to harness significantly higher seed yield (25 %), net energy output (17.4 %) over dibbling. The hybrid pigeonpea performed optimistic level under 100 ×100 cm plant geometry due to higher root growth and root exudates secretion. With integrated nutrient approach with 100 % soil test based NPK + vermicompost 5 t ha^{-1} + vermicompost enriched with PSB + *Rhizobium* seed treatment which lead to higher microbial population, activity thereby higher dehydrogenase activity.

Conflict of interest

This article publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language.

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