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Effect of tillage and nutrient levels on energetics of lathyrus in rice fallows

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Abstract
A field study on "Effect of tillage and nutrient levels on energetics of lathyrus in rice fallows" was conducted during *rabi* season of 2022-23 and 2022-24 at Agriculture farm, Palli Siksha Bhavana (Institute of Agriculture), Visva-Bharati, Sriniketan, in Red and Lateritic zone of West Bengal, India. The experiment comprised of 12 treatment combinations laid out in a split–plot design with three replications. The main–plot treatments included two different tillage practices Zero tillage and Conventional tillage. Sub–plot treatments included six nutrient levels *viz.* soil application of RDF N: P: K @20-40- 20 kg ha^{-1} , foliar spray of DAP @ 2% at 30 and 45 DAS, N: P: K (19:19:19) @ 2% at 30 and 45 DAS, N: P: K (19:19:19) @ 2% at 30 and 45 DAS + $ZnSO_4$ @ 0.5% at 40 DAS, N: P: K (19:19:19) @ 2% at 30 and 45 DAS+ $ZnSO_4$ @ 0.5% at 40 DAS+ Boron @ 0.1% at 50 DAS, Results revealed that, among different tillage practices Energy indices *viz*., energy use efficiency, specific energy, net energy, energy productivity, energy intensiveness was found non- significant. Among different nutrient levels, Energy indices *viz*., energy use efficiency, and energy productivity was found to be the best in foliar spray of DAP @ 2% at 30 and 45 DAS. Whereas total output energy and energy intensiveness in economic terms was found to be best with foliar spray of N: P: K (19:19:19) @ 2% at 30 and 45 DAS+ $ZnSO_4$ @0.5% at 40 DAS+ Boron @0.1% at 50 DAS. However, energy indices like energy intensiveness in physical terms showed non-significant effect on different nutrient levels. The interaction effect due to tillage and nutrient levels on energy indices was found non- significant.

Keywords: Lathyrus, rice fallow, zero tillage, conventional tillage, foliar spray, energetics

1. Introduction

In India, about 80% of the 12 million hectares of rice fallow land is concentrated in eastern regions such as Assam (1.04 million hectares), West Bengal (1.16 million hectares), Bihar (0.05 million hectares), Jharkhand (0.48 million hectares), Chhattisgarh (2.86 million hectares), Odisha (2.96 million hectares), parts of Madhya Pradesh, and the North East Hill states. Implementing effective management practices in these areas can significantly enhance productivity and profitability by optimizing the use of residual soil moisture (Yadav *et al*., 2015) [37]. Addressing the biotic, abiotic, and social constraints (Anonymous, 2013, Chowdhury *et al*., 2020; Deka *et al*., 2020) [1, 6, 9] and incorporating pulses into the existing monocropping systems can tackle nutrient depletion issues and convert these areas into double-cropped zones, thereby improving total output and energy efficiency.

Lathyrus (*Lathyrus sativus* L.), a prominent rabi-season pulse crop in West Bengal, spans 97.1 thousand hectares with a production of 85.9 thousand tonnes in 2019–20 (Anonymous, 2022) [2]. Farmers often experience reduced yields from second crops grown on residual moisture due to water scarcity in later growth stages (Sorokhaibam *et al*., 2016; Jana *et al*., 2018; Deka *et al*., 2021) [35, 16, 8]. As Indian agriculture advances from the green revolution era, sustainable agriculture is developing as a critical method for increasing resource conservation, economic efficiency, and sustainability. (Nazeer *et al*., 2012; Grace *et al*., 2012; Corsi *et al*., 2012; Behera *et al*., 2014; Bhan and Behera, 2014; Saha *et al*., 2020; Yadav *et al*., 2020) [23, 13, 7, 4, 5, 29, 36]. Conservation tillage, although still developing in India, needs adaptation for rabi pulses to optimize soil moisture and improve energy efficiency, which is crucial for increasing net energy output and reducing energy intensiveness (Sharma *et al*., 2016; Ramesh *et al*., 2019; Kumar *et al*., 2019) [32, 8, 19].

Micronutrient deficiencies can severely impact pulse growth and productivity (Gupta *et al*., 2021) [14], with protein deficiency being a notable issue in India (Prasad and Shivay, 2019) [26]. Foliar sprays can improve yields by delaying senescence and converting late flower flushes into pods, thus enhancing energy productivity and reducing specific energy (MJ/kg) (Kumar and Padbhushan, 2013 [18]. Zinc (Zn) is essential for carbohydrate metabolism, cellular membrane integrity, protein synthesis, auxin regulation, and pollen formation, all of which affect energy efficiency (Hafeez *et al*., 2013; Karmakar *et al*., 2021) [15, 17]. Boron (B) supports flower production and retention, pollen tube elongation, germination, and seed and fruit development. Applying boron as a basal dose or foliar spray during the growing season can boost plant growth and yield, thereby improving total output, net energy (MJ/ha), energy productivity (kg/MJ), and reducing both energy intensiveness (MJ/Rs) and energy intensiveness (MJ/kg) (Nagula *et al*., 2015) [22]. Research in rice-fallow areas presents an exciting opportunity to expand cropping areas and optimize energy use (Pande *et al*., 2012; Barik, 2021) [13, 3]. This study aims to evaluate the effects of various crop establishment methods and foliar micronutrient applications on the growth, yield components, and energy metrics, including total output, energy efficiency, specific energy, net energy, energy productivity, and energy intensiveness, of grass pea in West Bengal's red and lateritic soils.

2. Materials and Methods

A two-year field experiment was carried out on sandy loam soil during rabi seasons (October– March) of 2022–23 and 2023–24 at Agriculture farm, Palli Siksha Bhavana (Institute of Agriculture), Visva-Bharati, Sriniketan, in Red and Lateritic zone of West Bengal, India. The farm was situated at 23°39´ North latitude and 87°42´ East longitude with an average altitude of 58.90 m above mean sea level. During the crop growing season the maximum temperature has been ranged from 22.19°C to 33.69 °C and minimum temperature has been varied from 9.6 °C to 19.74 °C respectively. The investigation involved different combination of tillage practices (main plot) i.e., Zero tillage and Conventional tillage and nutrient levels (sub plot) soil application of 100% RDF N: P: K, foliar spray of DAP @ 2% at 30 DAS and 45 DAS, foliar spray of N: P: K (19:19:19) @ 2% at 30 DAS and 45 DAS, foliar spray of N: P: K (19:19:19) @ 2% at 30 DAS and 45 DAS + $ZnSO_4$ @ 0.5% at 40 DAS, foliar spray of N: P: K (19:19:19) @ 2% at 30 DAS and 45 DAS+ Boron (20%) @ 0.1% at 50 DAS, foliar spray of N: P: K (19:19:19) @ 2% at 30 DAS and 45 DAS + $ZnSO_4$ @ 0.5% at 40 DAS + Boron (20%) @ 0.1% at 50 DAS. In total twelve treatment combinations were laid out with three replications in split plot design. The lathyrus variety BioL 212 (Ratan) was sown on 6th November and 8th November during 2022 and 2013, respectively and harvested on 6th March and 10th March during 2023 and 2024, respectively. Preparatory tillage was done as per treatments and seeds were sown @ 60 kg ha^{-1} with a spacing of 30×10 cm^2. Data were pooled and standard statistical methods were followed for analysing the experimental data (Gomez and Gomez, 1984).

3. Results and Discussion

3.1 Energy indices

3.1.1 Energy input

During 2022–23 and 2023–24 energy input in different crop establishment methods was studied and mean input energy was calculated over two years (Table 3.1). Among different crop establishment methods, conventional tillage exhibited the highest total input energy (2346.38 MJ ha^{-1}) and it was at par with zero tillage (2168.31 MJ ha^{-1}). Higher energy input in conventional method was due to energy requirement for machinery in conventional tillage for sowing. The results were at par with the findings of Sidhpuria *et al*. (2014) [34].

During 2022–23 and 2023–24 A significant response was found from foliar spray of macro and micro nutrients on energy input and mean input energy was calculated over two years (Table 3.1). Among various treatments, FS1- 100% RDF (20:40:20) basal shows highest energy input followed by combined foliar spray of N: P: K (19:19:19) twice at 30 and 45 DAS with Zn @ 0.5% at 40 DAS and B @ 0.1% at 50 DAS. Treatment with 2% DAP foliar spray twice at 30 and 45 DAS was found with low energy input when compared with other treatments. and the findings were in corroboration with the findings of Meshram *et al*. (2016) [21] in rice.

The interaction effect due to tillage and nutrient levels on energy input was found non- significant.

3.1.2 Gross energy output

Among, different crop establishment methods, conventional tillage showed the highest gross energy output of lathyrus cultivation during both the years (39041.42 MJ ha^{-1} and 39124.71 MJ ha^{-1}, in 2022-23 and 2023-24, respectively) and in pooled data (39083.07 MJ ha^{-1}) which was at par with zero tillage (35858.16 MJ ha^{-1})

A significant response was found from foliar spray of macro and micro nutrients on Gross energy output and mean gross energy output was calculated over two years (Table 3.1). Among various treatments, combined foliar spray of N: P: K (19:19:19) twice at 30 and 45 DAS with Zn @ 0.5% at 40 DAS and B @ 0.1% at 50 DAS produced gross energy output (42198.65) followed by foliar spray of N: P: K (19:19:19) twice at 30 and 45 DAS with and B @ 0.1% at 50 DAS (39696.28) which is at par with N: P: K (19:19:19) twice at 30 and 45 DAS with Zn @ 0.5% at 40 DAS (38017.60). Treatment with 2% DAP foliar spray twice at 30 and 45 DAS was found to produce significantly lowest mean gross energy output. Patil and Ramesha (2018) [25] was also in conformity with these findings.

The interaction effect due to tillage and nutrient levels on mean gross energy output was found non- significant.

3.1.3 Net energy output

Among, different crop establishment methods, conventional tillage showed the highest net energy output of lathyrus cultivation during both the years (36695.03 MJ ha^{-1} and 36778.33 MJ ha^{-1}, in 2022-23 and 2023-24, respectively) and in pooled data (36736.68 MJ ha^{-1}) followed by zero tillage (33689.85 MJ ha^{-1}). The results were in line with the findings of Kumar *et al*. (2015) [20].

A significant response was found from foliar spray of macro and micro nutrients on net energy output and mean net energy output was calculated over two years (Table 3.1). Among various treatments, combined foliar spray of N: P: K (19:19:19) twice at 30 and 45 DAS with Zn @ 0.5% at 40 DAS and B @ 0.1% at 50 DAS produced net energy output (40400.24 MJ ha^{-1}) followed by foliar spray of N: P: K (19:19:19) twice at 30 and 45 DAS with and B @ 0.1% at 50 DAS (37900.90 MJ ha^{-1}) which is at par with N: P: K (19:19:19) twice at 30 and 45 DAS with Zn @ 0.5% at 40 DAS (36222.04 MJ ha^{-1}). Treatment with 2% DAP foliar spray twice at 30 and 45 DAS was found to produce significantly lowest mean gross energy output. The results were at par with the findings of Sharma *et al*. (2019) [33].

The interaction effect due to tillage and nutrient levels on mean net energy output was found non- significant.

3.1.4 Energy use efficiency (%)

During 2022–23 and 2023–24 energy use efficiency in different crop establishment methods was studied and mean energy use efficiency was calculated over two years (Table 1). Among different crop establishment methods, zero tillage, exhibited the highest energy use efficiency of lathyrus cultivation in both the years (19.82% and 19.88%, respectively) and in pooled data (19.85%). Which is at par with conventional tillage (19.55%).

During 2022–23 and 2023–24 A significant response was found from foliar spray of macro and micro nutrients on energy use efficiency and mean energy use efficiency was calculated over two years (Table 1). Among various treatments, Treatment with 2% DAP foliar spray twice at 30 and 45 DAS was found to produce significantly highest energy use efficiency (24.08%). which is at par with combined foliar spray of N: P: K (19:19:19) twice at 30 and 45 DAS with Zn @ 0.5% at 40 DAS and B @ 0.1% at 50 DAS. and the findings were in corroboration with the findings of Meshram *et al*. (2016) [21] in rice.

The interaction effect due to tillage and nutrient levels on energy use efficiency was found non- significant.

3.1.5 Specific energy (MJ kg^{-1})

Data pertaining to specific energy (MJ kg^{-1}) as influenced by tillage and nutrient levels is presented in Table 1.

Within the various tillage practices, zero tillage, exhibited the highest specific energy of lathyrus cultivation in both the years (0.832 MJ kg^{-1} and 0.826 MJ kg^{-1}, respectively) and in pooled data (0.829 MJ kg^{-1}). Which is at par with conventional tillage (0.825 MJ kg^{-1}). Similar results were reported by Priya *et al*. (2019) [27].

Various nutrient levels have exhibited a notable influence on the specific energy Among various treatments, FS1- 100% RDF (20:40:20) basal shows highest specific energy (1.90 MJ kg^{-1}) followed by foliar spray of N: P: K (19:19:19) twice at 30 and 45 DAS. Treatment with 2% DAP foliar spray twice at 30 and 45 DAS was found with low specific energy (0.56 MJ kg^{-1}) when compared with other treatments. This infers that 100% RDF application of chemical fertilizers increased the energy use for producing per unit seed yield and the findings were in corroboration with the findings of Meshram *et al*. (2016) [21] in rice.

The interaction effect due to tillage and nutrient levels on specific energy was found non- significant.

3.1.6 Energy productivity (kg MJ^{-1})

Among, different crop establishment methods, zero tillage showed the highest energy productivity of lathyrus cultivation during both the years (1.466 kg MJ^{-1} and 1.471 kg MJ^{-1}, in 2022-23 and 2023-24, respectively) and in pooled data (1.469 kg MJ^{-1}) followed by conventional tillage (1.449 kg MJ^{-1}). The results were in line with the findings of Kumar *et al*. (2015) [20].

Perusal of the data During 2022–23 and 2023–24 indicated that among various treatments energy productivity shows a significant response and mean energy productivity was calculated over two years (Table 1). Among various treatments, Treatment with 2% DAP foliar spray twice at 30 and 45 DAS was found to produce significantly highest energy productivity (1.79 kg MJ^{-1}). which is at par with combined foliar spray of N: P: K (19:19:19) twice at 30 and 45 DAS with Zn @ 0.5% at 40 DAS and B @ 0.1% at 50 DAS (1.74 kg MJ^{-1}). Similar findings reported by Sefeedpari *et al*. (2012) [31].

The interaction effect due to tillage and nutrient levels on energy productivity was found non- significant.

3.1.7 Energy intensiveness in economic terms (MJ Rs^{-1})

Data pertaining to energy intensiveness (MJ Rs^{-1}) as influenced by tillage and nutrient levels is presented in Table 3.1.

Examination of the data revealed that, tillage exerted a substantial impact on the energy intensiveness. Among the various treatments, zero tillage showed the highest energy intensiveness of lathyrus cultivation during both the years (1.44 MJ Rs^{-1} and 1.38 MJ Rs^{-1}, in 2022-23 and 2023-24, respectively) and in pooled data (1.41 kg MJ^{-1}) followed by conventional tillage (1.35 MJ Rs^{-1}). The higher value of energy intensity in economic terms under zero tillage might be attributed to higher biological yield and lower input energy consumption as evidenced from Devi *et al*. (2018) [10] in wheat.

A significant response was found from foliar spray of macro and micro nutrients on energy intensiveness and mean energy intensiveness was calculated over two years (Table 3.1). Among various treatments, combined foliar spray of N: P: K (19:19:19) twice at 30 and 45 DAS with Zn @ 0.5% at 40 DAS and B @ 0.1% at 50 DAS produced highest energy intensiveness (1.52 MJ Rs^{-1}) followed by foliar spray of N: P: K (19:19:19) twice at 30 and 45 DAS with and B @ 0.1% at 50 DAS (1.44 MJ Rs^{-1}) which is at par with N: P: K (19:19:19) twice at 30 and 45 DAS with Zn @ 0.5% at 40 DAS (1.39 MJ Rs^{-1}). The results were at par with the findings of Sharma *et al*. (2019) [33].

The interaction effect due to tillage and nutrient levels on energy intensiveness was found non- significant.

3.1.8 Energy intensity in physical terms

Among various establishment methods, zero tillage exhibited the highest energy intensity in terms of physical terms in both the years (13.522 MJ kg^{-1} and 13.520 MJ kg^{-1}, in 2022-23 and 2023-24, respectively) and in pooled data of two years (13.521 MJ kg^{-1}) which was statistically at par with the treatment having conventional tillage (13.496 MJ kg^{-1}).

Different nutrient levels did not show any significant influence on energy intensiveness and the interaction effect was also non-significant.

Table 3: Effect of tillage practices and nutrient levels on energy indices of lathyrus in rice fallows

Treatment	Input (MJ ha^{-1})	Total Output (MJ ha^{-1})	Energy Efficiency (%)	Specific Energy (MJ kg^{-1})	Net Energy (MJ ha^{-1})	Energy productivity (kg MJ^{-1})	Energy intensiveness (MJ Rs^{-1})	Energy intensiveness (MJ kg^{-1})
	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled
Tillage practices (T)								
Zero tillage	2168.31	35858.16	19.85	0.83	33689.85	1.47	1.41	13.52
Conventional tillage	2346.38	39083.07	19.55	0.83	36736.68	1.45	1.35	13.50
Sem ±	-	235.49	0.14	0.01	235.49	0.01	0.01	0.01
CD (p=0.05)	-	NS	NS	NS	1432.73	NS	0.06	NS
CV %	-	2.67	3.04	4.32	2.84	3.33	2.84	0.28
Nutrient levels (FS)								
100% RDF N:P:K (20:40:20) basal	4982.28	35450.48	7.11	1.90	30468.20	0.53	1.27	13.53
2% DAP foliar spray twice at 30 and 45 DAS	1379.93	33126.77	24.08	0.56	31746.84	1.79	1.32	13.49
2% N:P:K (19:19:19) foliar spray twice at 30 and 45 DAS	1792.53	36333.91	20.28	0.67	34541.38	1.50	1.34	13.52
2% N:P:K (19:19:19) foliar spray twice at 30 and 45 DAS + 0.5%$ZnSO_4$ at 40 DAS	1795.56	38017.60	21.17	0.64	36222.04	1.57	1.39	13.51
2% N:P:K (19:19:19) foliar spray twice at 30 and 45 DAS + 0.1% Boron at 50 DAS	1795.38	39696.28	22.10	0.61	37900.90	1.64	1.44	13.50
2% N:P:K (19:19:19) foliar spray twice at 30 and 45 DAS + 0.5%$ZnSO_4$ at 40 DAS + 0.1% Boron at 50 DAS	1798.42	42198.65	23.46	0.58	40400.24	1.74	1.52	13.51
Sem ±	-	596.99	0.33	0.01	596.99	0.02	0.02	0.01
CD (p=0.05)	-	1760.85	0.96	0.04	1760.85	0.07	0.06	NS
CV %	-	3.90	4.05	4.21	4.15	4.11	3.87	0.19
Interaction (T×FS)								
Sem ±	-	876.50	0.48	0.02	876.50	0.04	0.03	0.02
C*F	-	NS	NS	NS	NS	NS	NS	NS
Interaction (FS×T)								
Sem ±	-	844.27	0.46	0.02	844.27	0.03	0.03	0.01
F*C	-	**NS**	NS	NS	NS	NS	NS	NS

NS: Not significant; DAS: Days after sowing; S: significant;

Conclusion

The results in present have revealed that among tillage practices zero tillage improved energy efficiency and productivity compared to conventional tillage. Foliar nutrient treatments, particularly the combined application of N: P: K with Zn and Boron, enhanced both gross and net energy outputs. The 2% DAP foliar spray was the most efficient in reducing specific energy requirements while maximizing energy productivity. Overall, zero tillage combined with optimized nutrient management practices demonstrated significant benefits in energy use and crop yield, suggesting a sustainable approach for the region. Interaction effects of different treatments of both factors were found to be non-significant.

These findings underscore the importance of sustainable practices and proper nutrient management in optimizing rice fallows and lathyrus production, though further research is needed for broader validation.

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