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RESEARCH ARTICLE

Economic sustainability and energy efficiency of irrigated urdbean [*Vigna mungo*] under different sowing methods and weed management practices

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Abstract

A field experiment was conducted at the Pulse Farm of Tamil Nadu Agricultural University, Coimbatore, India, during the summer season of 2024 to evaluate the energetics and economic viability of summer irrigated urdbean (*Vigna mungo*) under different sowing and weed management methods. A split-plot design was employed and treatments were replicated thrice. The results indicated that sowing in Furrow Irrigated Raised Bed (FIRB) and weed management through pre-emergence application of herbicides, followed by mechanical weeding (baby weeder) at 20 days after sowing (DAS), produced the highest yields of 833 kg/ha and 850 kg/ha, respectively. In terms of energy productivity, sowing in FIRB with the weed-free plot achieved 0.63 kg/MJ, followed by the same method of planting with the pre-emergence application of herbicides followed by one-hand weeding at 20 DAS (0.57 kg/MJ). A similar trend was observed in energy use efficiency, with values of 9.22 and 8.35, respectively. Economically, urdbean sowing by seed drill and pre-emergence application of herbicides followed by mechanical weeding at 20 DAS resulted in the highest benefit-cost ratio of 2.01, followed by the sowing in FIRB with the pre-emergence application of herbicides followed by mechanical weeding at 20 DAS. Hence, the study concluded that sowing in furrow irrigated raised beds with weed management through hand weeding and mechanical weeding at 20 DAS provides higher energy use efficiency and economic sustainability.

Keywords: energetic; FIRB; seed drill sowing; urdbean; weed management

Introduction

Urdbean (*Vigna mungo* L.) is one of the primary pulse crops in India, cultivated over 45.83 lakh hectares, with an annual production of 25.55 lakh tonnes and a productivity of 558 kg/ha. Among Indian states andhra Pradesh has the highest productivity of 1057 kg/ha (1). In Tamil Nadu, urdbean is grown over 3.97 lakh hectares, with a total production of 2.68 lakh tonnes and productivity of 675 kg/ha (2). The low production of pulse crops can be attributed to several factors, including inappropriate sowing techniques and timing, poor crop stand management, over-irrigation, delays in the control of weeds and inadequate intercultural operations (3). The sowing technique significantly impacts yield and production in pulses. Planting pulses in the furrow irrigated raised bed (FIRB) system is a viable method for minimizing water losses while offering several other benefits, *viz.,* maximizing productivity, preventing water logging, serving as a drainage channel, increasing nitrogen (N) use efficiency and reducing lodging (4). Raised bed planting also enhances crop establishment weed control, reduces soil compaction and improves the availability of nutrients to crop roots (5).

Energy plays a crucial role in agriculture, impacting crop production and agro-processing to enhance value (6). Energetic is a technique for evaluating and quantifying the relationship between inputs and outputs to enhance energy efficiency and improve crop productivity (7). Energy use in agriculture has evolved due to growing populations, a limited amount of arable land and the need for higher living standards. In response, societies have increased energy inputs to boost crop yields, reduce labour-intensive practices, or achieve both objectives (8). Modern agriculture depends on various locally available energy sources, both commercial and non-commercial. These include diesel, electricity, fertilizers, plant protection chemicals, irrigation water, machinery and animals. Proper utilization of these resources enhances production, productivity, economic growth and profitability and boosts competitiveness, all essential for sustaining rural communities (9). Considering these factors, the current experiment examined the energy consumption and cost-effectiveness of urdbean production concerning different sowing methods and weed management practices.

Materials and Methods

A field experiment was conducted at a pulse farm, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu (11° 1'N, 76° 55'E, altitude 434 m) during the summer of 2024. The red sandy loam soil at the experimental site had a composition of 55.45 % sand, 24.25 % silt and 9.40 % clay. Its chemical composition is as follows pH is 8.61, organic carbon 0.36 % and the available N, P and K contents are 334 kg/ha, 17.3 kg/ha and 611 kg/ha, respectively.

The field experiment was laid out in a split-plot design with three methods of sowing in the main plot and five weed management practices in the subplot and it was replicated three times. Treatments comprised in main plots are M_1- manual sowing in flat bed, M_2- manual sowing in furrow irrigated raised bed (FIRB), M_3 - Seed drill sowing in flat bed and subplots are S_1- PE (Pre-emergence) application of Pendimethalin 30 % + Imazethapyr 2 % EC (Ready mix) *fb* (followed by) one hand weeding, S_2 - PE application of Pendimethalin 30 % + Imazethapyr 2 % EC (Ready mix) *fb* Baby weeder, S_3 - PE application of Pendimethalin 30 % + Imazethapyr 2 % EC (Ready mix)*fb* EPoE (Early post-emergence) application of Sodium Acifluorfen 16.5 % + Clodinafop-Propargyl 8 % EC (Ready mix), S_4- Weed free, S_5- Weedy check. PE herbicide was applied on 3 DAS. Hand weeding, mechanical weeding and application EPoE were done on 20 DAS (Fig. 1). FIRB was formed using a raised bed former. The width of the raised bed was 60 cm. Seeds were dibbled manually in M_1 and M_2 treatment. Meanwhile, in M_3, an inclined plate seed drill was used for sowing. Row spacing of 30 cm and a plant spacing of 10 cm was maintained in all plots. Urdbean variety VBN-11 was used with a 20 kg/ha seed rate. The basal application of 25 kg N, 50 kg P_2O_5, 25 kg K_2O and 20 kg S was applied through urea, single super phosphate and muriate of potash. The energy input from seeding to harvest was measured per the established standards and presented in Table 1. The total energy equivalent of inputs and outputs per unit (MJ/ha) was used to calculate energy use efficiency, energy productivity, specific energy and net energy, as depicted in Table 2. The current input prices and the minimum support price (MSP) of the output (seed yield) were used for the economic analysis. The statistical analysis of the data was conducted at a 5 % significance level (16).

Fig. 1. Seed drill sowing and flatbed sowing.

Results

Economic yield and harvest index

The data on seed yield, haulm yield and harvest index are shown in Table 3. Sowing methods and weed management significantly influenced the seed and haulm yields of urdbean. Furrow irrigated raised bed recorded a higher seed yield of 833 kg/ha and haulm yield of 2270 kg/ha over other treatments. This could be due to the favourable soil conditions. The plant more effectively collects and translocates photosynthates from source to sink and a lesser weed population was recorded in furrow-irrigated raised beds, increasing all growth and yield qualities. A similar finding was reported in cowpeas with superior yield under the broad bed and furrow method of sowing (17). Concerning weed management, the highest seed yield

Table 1. Equivalent energy (MJ)

S.NO	Particulars	Units	Equivalent energy (MJ)	Reference
	Input			
1.	Human labour			(10)
	Man	Man/hr	1.96	
	Woman	Woman/hr	1.57	
2.	Diesel	L	56.31	
3.	Petrol	L	48.23	
4.	Farm Machinery	Hr	62.70	
5.	Chemical fertilizers			(9)
	N	kg	60.60	
	P_2O_5	kg	11.10	
	K_2O	kg	6.70	
	Biofertilizers	kg	10.00	
	Others	kg	0.30	
6.	Chemicals			(11)
	Herbicides	L	120	
	Insecticides	L	120	
7.	Seed	kg	14.70	(12)
	Output			
1.	Seed	kg	14.70	(12)

Table 2. Different energy indices

Energy indicies	Reference
Energy use efficiency = $\frac{\text{Energy output (MJ/ ha)}}{\text{Energy input (MJ/ha)}}$	(13)
Energy productivity = $\frac{\text{Crop output (kg/ha)}}{\text{Energy input (MJ/ ha)}}$	(13)
Specific energy = $\frac{\text{Energy input (MJ/ ha)}}{\text{Seed yield (kg/ha)}}$	(14)
Net energy = Energy output (MJ/ha) - Energy input (MJ/ha)	(15)

Table 3. Effect of sowing method and weed management on seed yield, haulm yield and harvest index

Treatment	Seed yield (kg/ha)	Haulm yield (kg/ha)	Harvest index
Sowing methods			
M_1	773	1778	30
M_2	833	2270	27
M_3	744	1757	30
CD (P =0.05)	49.30	120.09	0.28
Weed Management			
S_1	838	2038	29
S_2	850	2072	29
S_3	783	1782	30
S_4	900	2283	28
S_5	544	1500	27
CD (P =0.05)	50.59	121.81	0.48
Interaction	NS	NS	NS

(900 kg/ha) and haulm yield (2283 kg/ha) was obtained in the weed-free plot and it was comparable to the pre-emergence application of Pendimethalin 30 % + Imazethapyr 2 % EC at 3 DAS, followed by mechanical weeding with a baby weeder (850 kg/ha and 2072 kg/ha, respectively). The unmanaged weedy check plot resulted in the lowest seed yield (544 kg/ha) and haulm yield (1500 kg/ha). The increased seed and haulm yields observed in weed management practices can be attributed to timely and efficient weed management. These treatments reduced weeds' dry weight and density, allowing the crop plants to access adequate light, space, nutrients and moisture. Consequently, this increased the number of pods per plant and overall yield. Similarly, higher seed and haulm yields in pigeon peas were reported (18).

Energetics

The data in Table 4 showed that different sowing methods and weed management strategies caused variations in the energy of the urdbean crop. Among the different sowing methods and weed management practices, M_2S_2 - sowing in furrow irrigated raised bed with pre-emergence application of Pendimethalin 30 % + Imazethapyr 2 % EC at 3 DAS *fb* mechanical weeding with baby weeder at 20 DAS utilized the highest energy of 6221.62 MJ/ha followed by M_3S_2 - Seed drill sowing with pre-emergence application of Pendimethalin 30 % + Imazethapyr 2 % EC at 3 DAS *fb* mechanical weeding with baby weeder at 20 DAS (6070.90 MJ/ha). This might be due to the higher cost and quantity of herbicides, increased manual labour, the use of tractor-drawn implements, raised bed former, seed drill and the increased time and energy usage associated with mechanical weeding are the causes of the higher energy usage. The highest energy output and net energy were measured in M_2S_4 - sowing in furrow irrigated raised bed with weed-free plot (52023.30, 46378.85 MJ/ha) followed by M_2S_2 - sowing in furrow irrigated raised bed with PE application of Pendimethalin 30 % + Imazethapyr 2 % EC fb mechanical weeding with baby weeder (49872.20, 43650.58 MJ/ha, 40271.09 MJ/ha). This might be due to higher seed and haulm yield in this treatment. The lowest energy output and net energy were observed at sowing with seed drill with a weedy check plot (M_3S_5) (27841.80, 22649.51 MJ/ha).

The data on energy productivity and energy use efficiency indicated that sowing in furrow irrigated raised bed with the weed-free plot (M_2S_4) (0.63 kg/MJ, 9.22) recorded the highest value of energy productivity and energy use efficiency followed by M_2S_1- sowing in furrow irrigated raised bed with PE application of Pendimethalin 30 % + Imazethapyr 2 % EC *fb* one hand weeding (0.57 kg/MJ, 8.35) and the lowest was found in M_3S_5- seed drill with a weedy check (0.55 kg/MJ, 8.14).

Data on specific energy revealed that under weed-free conditions, specific energy requirements for different sowing methods in the range of manual sowing in flatbed < FIRB < seed drill sowing. The lower specific energy can be attributed to manual labour, which reduces overall energy consumption.

Table 4. Effect of sowing method and weed management of urdbean on input energy equivalents, output energy equivalents, total energy equivalents, energy productivity, specific energy, energy use efficiency and specific energy

Treatment	Input energy equivalents (MJ/ha)	Input energy equivalents (MJ/ha)	Total energy equivalent (MJ/ha)	Energy output (MJ/ha)	Energy productivity (kg/MJ)	Specific energy (MJ/kg)	Energy use efficiency	Net energy (MJ/ha)
M_1S_1	4654.2	689.7	5343.9	39205	0.50	6.51	7.34	33861
M_1S_2	4654.2	1029.3	5683.5	39793	0.48	6.82	7.00	34109
M_1S_3	4654.2	663.2	5317.4	35329	0.45	6.88	6.64	30012
M_1S_4	4654.2	452.2	5106.3	44673	0.60	5.67	8.75	39567
M_1S_5	4654.2	150.7	4804.9	28459	0.40	8.96	5.92	23654
M_2S_1	4654.2	1227.8	5881.9	49113	0.57	6.51	8.35	43231
M_2S_2	4654.2	1567.4	6221.6	49872	0.55	6.79	8.02	43651
M_2S_3	4654.2	1201.3	5855.5	43208	0.50	7.01	7.38	37353
M_2S_4	4654.2	990.3	5644.5	52023	0.63	6.08	9.22	46379
M_2S_5	4654.2	688.8	5343.0	33839	0.43	9.20	6.33	28497
M_3S_1	4654.2	1077.1	5731.3	38534	0.46	7.25	6.72	32802
M_3S_2	4654.2	1416.7	6070.9	39185	0.44	7.58	6.45	33114
M_3S_3	4654.2	1050.6	5704.8	34560	0.41	7.71	6.06	28855
M_3S_4	4654.2	839.6	5493.7	43674	0.54	6.31	7.95	38180
M_3S_5	4654.2	538.1	5192.3	27842	0.36	10.06	5.36	22650

Interpretation of pearson correlation analysis

Pearson Correlation Analysis of yield, energy use efficiency, energy productivity, specific energy and net energy was carried out and depicted in Fig. 2. Urd bean seed yield, energy use efficiency, energy productivity and net energy exhibited a negative correlation with the specific energy. However, energetic parameters such as energy use efficiency, productivity and net energy positively correlated with yield. This indicates that as specific energy increased, the growth and yield attributes of urdbean decreased accordingly.

Economics

The economic analysis (Table 5) indicated that the highest gross return of ₹76505 was obtained in sowing in FIRB with weed-free plots, followed by sowing in FIRB with application pre-emergence herbicides, followed by mechanical weeding at 20 DAS (₹75190/ha). All the weedy check plots had lesser gross returns. However, a higher net return was obtained in sowing under FIRB with an application of PE herbicides and mechanical weeding at 20 DAS ₹37506/ha), followed by sowing under FIRB with the weed-free plot. All the weedy check plots recorded lesser net returns. Regarding B:C ratio, seed drill in a flat bed with the pre-emergence application of herbicides followed by mechanical weeding at 20 DAS recorded a higher B: C ratio of 2.01 followed by sowing under FIRB with the pre-emergence application of herbicides followed by mechanical weeding at 20 DAS (2.00). This might be due to less cost of cultivation and higher net return.

Table 5. Effect of sowing method and weed management of urdbean on economics

Treatment	Total cost of cultivation (₹/ ha)	Gross return (₹/ ha)	Net return (₹/ ha)	B: C ratio
M_1S_1	40118	66292	26174	1.65
M_1S_2	36434	67264	30830	1.85
M_1S_3	36885	62069	25184	1.68
M_1S_4	41033	73088	32055	1.78
M_1S_5	30233	43864	13631	1.45
M_2S_1	41368	74136	32768	1.79
M_2S_2	37684	75190	37506	2.00
M_2S_3	37235	68127	30892	1.83
M_2S_4	42283	76505	34222	1.81
M_2S_5	31483	48157	16674	1.53
M_3S_1	35968	63978	28010	1.78
M_3S_2	32284	64844	32560	2.01
M_3S_3	32735	59593	26858	1.82
M_3S_4	36883	70754	33871	1.92
M_3S_5	26083	42318	16235	1.62

Conclusion

Thus, it could be concluded from the study that cultivation of urdbean undersowing in furrow irrigated raised bed with the pre-emergence application of Pendimethalin 30 % + Imazethapyr 2 % EC at 3 DAS fbone hand weeding at 20 DAS is a more productive and energy efficient. Regarding economics, sowing with seed drill with an emergency application of Pendimethalin 30 % + Imazethapyr 2 % EC at 3 DASfb weeding with a baby weeder at 20 DAS gave higher profit.

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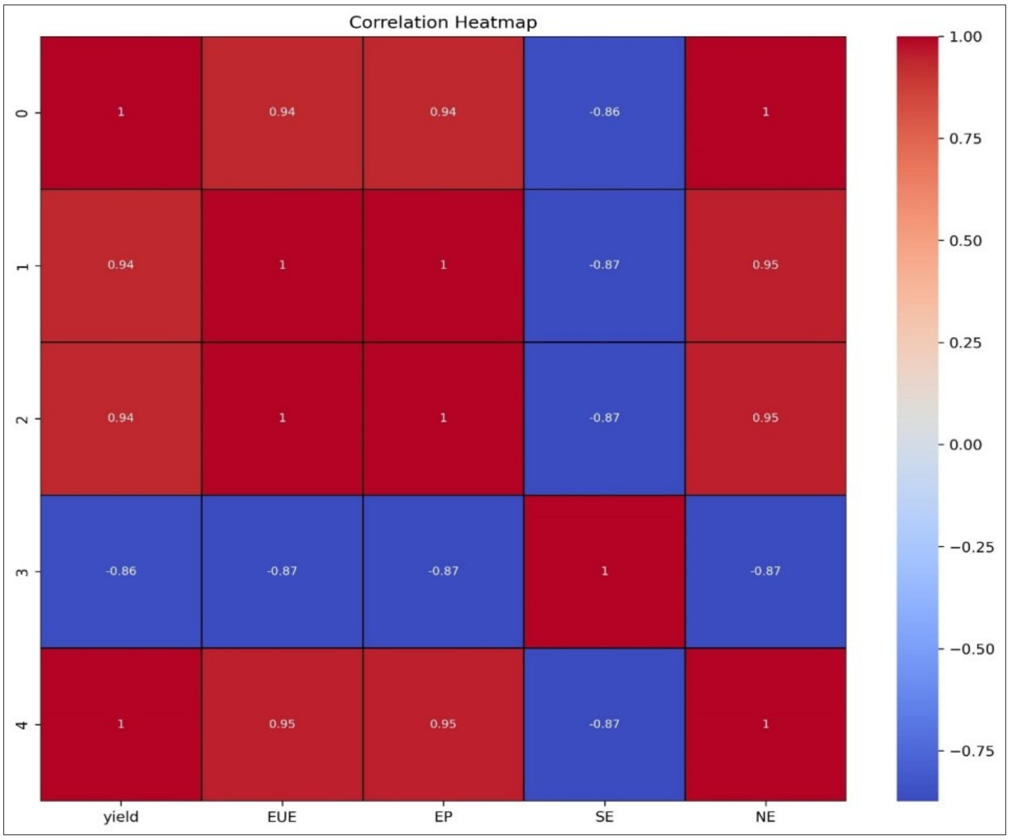

Fig. 2. Correlation heatmap for yield, energy use efficiency, energy productivity, specific energy, net energy.

Authors' contributions

SS performed the fieldwork, collected data, contributed to data analysis and interpretation and also drafted the manuscript. AF supervised the research, provided resources and technical support, assisted with the outline and edited the manuscript. MR and APM were involved in the manuscript correction and supervised the process. All the authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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