Energy dynamics of aerobic rice cultivation in India

Abstract

Aerobic rice needs 30% less total water for land preparation, 50% saving on labour requirement and 50% less GHG emission compared to transplanted rice.Energy use efficiency of aerobic rice cultivation also varies due to varieties. However, a detailed study on various energy inputs components of aerobic rice cultivation (variety, water management, spacing, fertilizer dose and weed management) is lacking. To confirm the energy dynamics of aerobic rice cultivation, a combined study was taken up to find out the energy input, output and energy use efficiency of aerobic rice cultivation consisting of various trials conducted at research farm of ICAR-Indian Institute of Rice Research and few other trials conducted at other places. Gayatri variety performed well in terms of higher energy use efficiency at eastern part of India. Further higher energy use efficiency (output/input ratio) was recorded at 100% RFD. Crop spacing also affects the total energy output of aerobic rice. It was seen that the total output energy is highest at optimum spacing of 20 x 10 cm compared to 25 x 10 and 30 x 10 cm. Apart from need based hand weeding, Pendimethalin 1.0 kg /ha + Bispyribac sodium 35 g/ha resulted higher energy use efficiency (2.75) compared to those of other chemical weed management practices.It was observed that aerobic rice based systems maintained higher productivity and profitability in comparison to transplanting based rice cropping systems. The study revealed that varieties, fertilizer dose and spacing played crucial role in enhancing the energy use efficiency of aerobic rice cultivation. So, farmers have to strike a balance among the input resourcesspecially variety, water, fertilizerto achieve higher energy use efficiency in aerobic rice based cropping systems.

Key words: Crop establishment methods, Energy use efficiency, Integrated weed management, Spacing

1. INTRODUCTION

Aerobic system of rice cultivation is growing as an economically feasible, water-labor-energy saving, mechanized, and climate smart agricultural practice to ensure food security. Seven to ten days early maturity of the aerobic rice crop compared to transplanted rice allows timely planting of the succeeding crop in addition to the improvement in nutrient availability and soil conditions (Kumar and Ladha, 2011). Earlier aerobic rice varieties were developed with the aim to replace the lowyielding rice varieties of upland ecosystem (Nie et al., 2012). In the last decade, aerobic rice has not become popular among farmers due to high weed infestation and high cost to control weeds under aerobic situation as compared to transplanted rice. With the availability of appropriate weed control measures, mechanization reducing labour requirements from 11 to 66% compared to transplanted rice (Rashid et al., 2009) and improved agronomic management practices; aerobic rice cultivation is being successfully implemented in rainfed shallow lowland ecosystem. In recent years, aerobic cultivation has gained momentum in irrigated lowlands where rainfall is not sufficient and pumping water from deep well is expensive, delta regions with delayed water supplies and upland system with supplemental irrigation. Aerobic rice needs 30–51% less total water for land preparation depending upon the soil types providing 32–88% higher crop productivity, 50% saving on labour (Wang et al., 2002) and can have 50% reduced GHG emission (Weller et al., 2016) compared to transplanted rice (Bouman et al., 2005).

Agricultural food production is the process of converting the energy of solar radiation into metabolisable forms of energy and nutrients through photosynthetic pathways, aided by agronomic inputs in the form of seeds, nutrients, tillage, water, weed, pest control and other practices aimed at improving the growing environment for the crop. Energy efficiency has been crucial for sustainable development in agriculture systems (Nirmala et al., 2021). The energy balance approach fordetermination of agronomic efficiency requires quantification ofthe total energy of external inputs expended on crop productionand the energy yield in the form of human appropriated yield.External agronomic energy inputs (AEI) to agricultural fieldsinclude the direct energy utilised from fossil fuels consumed during mechanical operations, the energy expended in manual labour, the energy embedded in agronomic inputs such as fertilisers,crop protection products and seed. Embedded energy in agronomicinputs is the total energy cost incurred in the production, throughout the supply-chain, in the storage of all manufactured orrefined products, inputs and fossil fuels utilised in crop production.The AEI of a product can change over time with efficiency gains inthe manufacturing or distribution process of the product. However,changes in the AEI are uniformly distributed across all users of theproduct. The energy costs of transport can vary among agriculturalregions leading to variation in the embodied energy of agronomicinputs, but excluding this variation from energy efficiency analysis allows comparison of the efficiency of farming systems both spatially and temporally. Energy is a critical aspect of a national development process. It is expended in agricultural operation in food processing and transportation, in the production of fertilizers, pesticides and farm equipments. It is necessary for industrial operations that provide jobs. It is required for cooking, for household lighting, heating, construction and operation of the infrastructure needed for schools, health centres and water supply. To obtain an understanding of energy matters, it is essential to convert energy rapidly to a common equivalent.

Energy Sources

The energy sources can be classified in a number of ways based on the nature of their transaction, as commercial and non-commercial sources of energy. All energy resources, particularly the commercial ones, are natural. Coal, oil and nuclear sources constitute commercial sources, while firewood, biomass and animal dung constitute non- commercial sources. Also, the energy sources are classified based on animate and inanimate characteristics. Energy sources could also be classified as exhaustible / non - renewable or non - depletable / renewable resources. The distinguishing feature of an exhaustible resource is that, it gets exhausted when used as an input of a production process, and at the same time, its undisturbed role of growth is nil. That is, the temporal services provided by a given stock of an exhaustible resource are finite. Further, based on conventionality in deriving energy, energy sources could be classified as conventional (coal, oil, hydro, nuclear, etc.) and non-conventional (solar, wind, tidal, geothermal, biogas, etc.) sources. They are also classified as primary types (coal, firewood) or secondary types (electricity). Energy in its primary form can be of different kinds. The main types are chemical (fossil fuels, coal, oil, natural gas, peat; biomass - wood, agricultural residues, etc.), potential (water at a certain height), kinetic (wind, waves), radiation (sun), heat (geothermal reservoirs, ocean thermal reservoirs) and nuclear (uranium). The primary form of energy must generally be converted into secondary or final forms of energy before it can be used. For instance, the potential energy of a waterfall (primary energy) is converted into electricity (secondary energy), which is transmitted and transformed to supply (final) energy to a factory, where it is converted into mechanical energy (useful energy) for productive operations. Important types of secondary energy are electricity and mechanical energy. But chemical energy is also important as a secondary energy, for instance, refined oil products. Final energy is the energy that reaches the consumer. This can be electricity at a suitable voltage or chemical energy in kerosene or batteries. Most of the energy sources are substitutable to each other due to the fact that some form of energy can be converted to other - such as coal to electricity, use of photo-electricity to drive a chemical reaction, wind energy to pump and store water that could be used to produce electricity when required, or solid biomass to produce liquid or gaseous fuels of higher calorific value. All forms are ultimately converted into heat. This gives rise to the inter-fuel substitution process with which an economy can substitute its abundantly available resources to the scarcely endowed one.

Classification of energy

On the basis of source, the energy can be classified as direct and indirect energy.

Direct source of energy

The direct sources of energy are those that release the energy directly-like man power, bullocks, stationary and mobile mechanical or electric power units, viz., diesel engines, electric motor, power tiller and tractors. The direct energy may be further classified as renewable and non-renewable sources of energy depending upon their replenishment. Renewable direct sources of energy, the energy sources, which are direct in natural but can be subsequently replenished, are grouped. The energies which may fall in this group are human beings, animals, solar and wind energy, fuel wood, agricultural wastesetc. Non-renewable direct sources of energy, direct energy sources which are not renewable (at least in near further say next 100 years) are classified. Coal and fossil fuels exemplify non-renewable direct sources of energy.

Indirect source of energy

The indirect sources of energy are those which do not release energy directly but release it by conversion process. Some energy is invested in producing indirect sources of energy. Seeds, manures (farmyard and poultry), chemicals, fertilizers and machinery can be classified under indirect sources of energy. Again, on the basis of their replenishment, these can be further classified into renewable and non-renewable indirect source of energy. Renewable indirect source of energy: Seeds and manures can be termed as renewable indirect source of energy as they can be replenished in due course of time. The energy sources that are not replenished come under non-renewable indirect sources of energy. Chemicals, fertilizers and machinery manufacturing are the non-renewable indirect sources of energy. On the basis of comparative economic value the energy may be classified as commercial and non-commercial.

Commercial energy

The energy sources like petroleum products (diesel, petrol and kerosene oil) and electricity, which are capital intensive, exemplify commercial sources of energy. Considering the fact that most of the commercial sources are also non-renewable and to some extent are imported to India, efforts are made to conserve such sources of energy.

Non-commercial energy

Each and every energy source has some economic value. Some energy sources are available comparatively at low cost whereas others are capital intensive. The energy sources which are available cheaply are called non-commercial sources of energy whereas the ones which are capital intensive are called commercial energy sources. Human labour and bullocks exemplify the category of non-commercial source of energy. Human labour and animals are readily available and can be used as a source of power directly. The commonly available and less expensive materials like fuel wood, twigs, leaves agro-wastes and animal dung, etc. are also classified as non-commercial sources of energy.

Energy input from various sources

Direct sources

The energy input of human labour and a pair of large bullocks (having a body weight of 450 kg) may be assumed to be 1.96 MJ / man-hr and 14.05 MJ / pair-hr, respectively. The specific fuel consumption of the mechanical power source (obtained from the test report) can be used to find energy inputs.

Indirect sources

The energy requirement in producing seeds, fertilizers, pesticides, weedicides, etc.

Calculation of energy requirements for a field operation

The energy requirements for a particular field operation may be calculated as the summation of human, bullock and mechanical and / or electric energy consumed.

Operational costs for various power sources

Manual power: In case of human labour, the wages of an unskilled labour on the basis of hour or day (as prevailing in a particular locality) are charged.

Animal power

The charges for operating a pair of bullocks are calculated on the basis of the cost of a pair of bullocks, wages of an operator and cost of the feed for bullocksalongwith any other expenses (as enforced in a particular locality) in research farms. However, for the farmers' fields, the actual hiring charges are taken as the basis. By considering all these factors multiple trials were conducted at ICAR-IIRR, Hyderabad and data from other trials conducted elsewhere were reported here to come out with complete understanding of energy dynamics of aerobic rice cultivation. The objective of the study was to find out the energy input, output and energy use efficiency of aerobic rice cultivation from various trials conducted at research farm of ICAR-Indian Institute of Rice Research and few other trials conducted at other places.

2. MATERIALS AND METHODS

Total four trials on aerobic rice were conducted at Rajendranagar farm of ICAR-Indian Institute of Rice Research, Hyderabad. The first trial laid out in randomised block design with 5 replications. It was consisted of four level of fertilizer dose {(0, 50% recommended fertilizer dose (RFD), 100% RFD and 150% RFD)}. The second trial was also laid out in randomized block design and replicated thrice. Seven varieties (Sampada, MTU 1010, IR 64, IET 20653, GK 5003, PA 6444 and DRRH 3) consisting of HYV and hybrid taken as treatments. The third trial was taken up with 3 different spacing (20 x 10, 25 x 10 and 30 x 10 cm), laid out in randomized block design with 5 replications. The fourth trial consisted of 11 weed management treatments, laid out in randomized block design and replicated thrice. Recommended package and practices were followed except the imposed treatments. Similarly, data were collected from other studies conducted at different places to make it a comprehensive analysis and to come out with a valid energy dynamics status of aerobic rice cultivation.

3. RESULT AND DISCUSSION

Transplanted rice resulted total energy output ranged from 1, 04, 163 to 1, 74, 953 MJ/ha (Table 1). The energy use efficiency varied from 5.43 to 12.85. The lower energy use efficiency recorded in transplanted rice was due to high energy input. Similarly,trials conducted at various placed under rainfed conditions revealed that among rice varieties,Gayatri variety performed well in terms of higher energy use efficiency (13.97) at eastern part of India (Table 1). It was confirmed that variety and water management played crucial role in enhancing the energy use efficiency of aerobic rice cultivation.

Table 1. Energy use and energy productivity of differentrice production system in India

Rice establishment methods	Total energy input (MJ/ha)	Total energy output (MJ/ha)	References
Irrigated rice			
transplanting	19,170	1,04,163	Soni and Soe(2016)
	13,616	1,74,953	Pradhan et al (2015)
	18,718	1,68,266	Tuti et al. (2012)
Rainfed rice	11,031	65,033	Soni and Soe (2016)
Naveen variety	11,261	1,41,375	Lal et al (2015)
Gayatri variety	11,521	1,60,916	
Swarna variety	11,484	1,43,502	
Annada variety	8,396	52,204	

Similarly, a trial conducted at ICAR-IIRR research farm (Rajendranagar) revealed that total output energy increases with increased application of recommended fertilizer dose (Fig.1.). However, the increase was not significant beyond 100% of RFD. It indicates higher energy use efficiency (output/input ratio) at 100% of RFD.

Fig.1.Total energy output (MJ/ha) of aerobic rice system under different level of RFD

Another trial at same experimental farm showed hybrids are better performer interms of energy use efficiency than high yielding varieties under aerobic system (Fig. 2). This was due to higher grain yield recorded under hybrids. Similarly, energy use efficiency also varies among the varieties.

Fig.2. Total energy output (MJ/ha) of different varieties and hybrid under aerobic rice system

Crop spacing also affected the total energy output of aerobic rice. It was seen that the total output energy is highest at optimum spacing of 20 x 10 cm compared to 25 x 10 and 30 x 10 cm (Fig.3). The highest grain yield was recorded under 20 x 10 cm spacing compared to those under other spacing. Optimum spacing directly impacted grain yield which ultimately resulted the higher energy use efficiency.

Fig. 3. Effect of crop spacing on total energy output of aerobic rice cultivation

Weed management also played a major role for enhancing the energy use efficiency of aerobic system. Apart from need based hand weeding, Pendimethalin 1.0 kg/ha+ Bispyribacsodium 35 g/ha resulted the higher energy use efficiency (2.75) compared to those of other chemical weed management practices. So resource inputs such as variety, fertilizer, seed rate, spacing, weed management (Table 2), etc. influence the energy efficiency of aerobic rice cultivation.

Table 2. Energy use efficiency of weed control management in aerobic rice

Treatment	Grain Yield (t/ha)	Weed control efficiency	Energy input (MJ/ha))	Energy output (MJ/ha)	Energy ratio
Pendimethalin 1.0 kg /ha+ Bispyribacsodium 35 g/ha	4.88	72.80	20714.4	57036	2.75
Pendimethalin1.0 kg/ha+2,4 D,Na salt 0.06 kg/ha	4.51	65.33	20786.1	51597	2.48
Pendimethalin 1.0 kg/ha + Ethoxysulfuron 15 g/ha	4.41	64.78	20845.6	50127	2.40
Pendimethelin 1.0 kg/ha + (Chorimuron + Metsulfuronmethyl) 40 g/ha	4.38	69.94	20647.36	49686	2.41
Butachlor1.5 kg/ha + Bispyribacsodium 35 g/ha	4.76	70.55	20714.4	55270	2.67
Butachlor1.5 kg/ha + 2,4-D,Na salt 0.06 kg/ha	4.35	56.15	20786.1	49245	2.37
Pretilachlor 1.0 kg/ha + Ethoxysulfuron 15 g/ha	4.33	55.89	20845.6	48951	2.35
Pretilachlor 1.0 kg/ha + (Chorimuron + Metsulfuronmethyl) 40 g/ha	4.37	65.75	20647.36	49539	2.40
Mechanical weeding/weeders at 20 and 45 DAS	4.48	75.19	19943.78	51156	2.57

Need based hand weeding (4 at 15 days interval)	5.03	81.22	20866.22	59241	2.84
Unweeded	1.92	0	19770.18	28224	1.43
CD (p=0.05)	0.28	NA	NA	NA	NA

(Source: Sreedevi et al., 2015)

Conclusion

The study evaluated energy dynamics of aerobic rice production in different aerobic rice basedcroppingsystem. It was observed that aerobic rice based systems maintained higher energy use efficiency in comparison to transplanting based rice cropping systems provided suitable variety, water management practices, spacing and weed management practices are followed. Therefore, farmers have to strike a balance among theseresource inputs to achieve higher energy efficiency in aerobic rice based cropping systems.

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