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ENERGY BUDGETING OF INTEGRATED WEED MANAGEMENT IN *RABI* GROUNDNUT USING NEW GENERATION HERBICIDES

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ABSTRACT

A field experiment was conducted to study the effect of integrated weed management practices on energetics in groundnut at College of Agriculture, Professor Jayashankar Telangana State Agricultural University, Hyderabad, during *rabi* 2020-21. The experiment consisted of ten treatments laid out in randomized block design replicated thrice. The treatments comprised of diclosulam 84% WDG 26 g ha^{-1} PE *fb* intercultivation at 20 DAS, imazethapyr 2% EC + pendimethalin 30% EC 960 g ha^{-1} PE *fb* intercultivation at 20 DAS, pyroxasulfone 85 % WDG 127.5 g ha^{-1} PE *fb* intercultivation at 20 DAS, propaquizafop 2.5% + imazethapyr 3.75% w/w ME 125 g ha^{-1} PoE *fb* intercultivation at 40 DAS, imazethapyr 35% + imazamox 35% WG 70 g ha^{-1} PoE *fb* intercultivation at 40 DAS, sodium acifluorfen 16.5% EC + clodinafop propargyl 8% EC 250 g ha^{-1} PoE *fb* intercultivation at 40 DAS, imazethapyr 10% SL 100 g ha^{-1} PoE *fb* intercultivation at 40 DAS, intercultivation (20 and 40 DAS), intercultivation *fb* hand weeding (20 and 40 DAS) (Weed-free) and unweeded control. Among all the weed management practices, maximum energy input was required for inter cultivation *fb* hand weeding at 20 and 40 DAS. Highest pod energy output (EOp), total energy output (EOt) and net energy was observed with inter cultivation *fb* hand weeding at 20 and 40 DAS and was on par with diclosulam 26 g ha^{-1} PE *fb* intercultivation at 20 DAS and sodium acifluorfen + clodinafop propargyl at 250 g ha^{-1} PoE *fb* intercultivation at 40 DAS. Significantly highest EUE of pods, total output EUE, energy productivity of pods and total output energy productivity was recorded in diclosulam 26 g ha^{-1} PE *fb* intercultivation at 20 DAS and this was at par with imazethapyr + pendimethalin 60 g ha^{-1} PE *fb* intercultivation at 20 DAS.

Key words : Energy budget, Energy equivalent, Energy output, Energy productivity, Energy use efficiency.

Introduction

Groundnut (*Arachis hypogaea* L.) is an important oilseed crop in India, which is known as "king of oil seeds" or "wonder nut" or "poor man's cashew nut". Weed infestation is one of the major constraints in the cultivation of groundnut. If weeds are not controlled during critical periods of crop-weed competition, reduction in the yield of groundnut to the tune of 13 to 80% has been recorded depending upon the type and intensity of weeds (Yadav and Singh, 2005). Hand weeding is a traditional and effective method of weed control, but unavailability of labour during peak period of demand and hindrance for manual weeding due to continuous rains in the growing period is the main limitations of hand weeding. Thus, the herbicidal weed control either alone or in integrated manner remains the only choice under such situations to minimize the weed menace effectively and economically. Sole application of herbicide as pre emergence fails to control subsequent flushes of weeds. So, there is need to apply pre- and post emergence herbicides in a sequential manner to reduce weed menace and keep the crop free from weed competition during entire critical period of crop growth (Tuti and Das, 2011). Energy budgeting of weed management is also important because energy and economics are mutually dependent. There is a close relationship between agriculture, economics and energy. Very scanty information is available on this aspect. Therefore, the present study was undertaken to assess the energy budgeting of weed management in groundnut.

Materials and Methods

The field experiment was carried out at College Farm, College of Agriculture, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad, Telangana State. The farm is geographically situated at an altitude of 542.3 m above mean sea level at 17˚19' N latitude and 78°23' E longitude in the Southern Telangana agro-climatic zone of Telangana and it is classified under semi-arid tropics (SAT) according to Troll's classification. The experiment was planned in a randomized block design with three replications of 10 treatments; which included diclosulam 84% WDG 26 g ha^{-1} PE *fb* intercultivation at 20 DAS (T_1), imazethapyr 2% EC + pendimethalin 30% EC 960 g ha^{-1} PE *fb* intercultivation at 20 DAS (T_2), pyroxasulfone 85% WDG 127.5 g ha^{-1} PE *fb* intercultivation at 20 DAS (T_3), propaquizofop 2.5% + imazethapyr 3.75% w/w ME 125 g ha^{-1} early PoE *fb* intercultivation at 40 DAS (T_4), imazethapyr 35% + imazomox 35% WG 70 g ha^{-1} early PoE *fb* intercultivation at 40 DAS (T_5), sodium acifluorfen 16.5% EC + clodinafop propargyl 8% EC 250 g ha^{-1} PoE *fb* intercultivation at 40 DAS (T_6), imazethapyr 10% SL 100 g ha^{-1} PoE *fb* intercultivation at 40 DAS (T_7), intercultivation (20 and 40 DAS) (T_8), intercultivation *fb* hand weeding (20 and 40 DAS) (Weed-free) (T_9) and Unweeded control (T_{10}). Groundnut crop (variety kadiri-9) was sown on 8th October 2020 at spacing of 30×10 cm using a seed rate of 300 kg ha^{-1}. Herbicides were applied using a Knap sack sprayer fitted with flat fan nozzle calibrated to deliver 500 litres of water per hectare. Cultural practices recommended for groundnut were adopted during the crop growth period. The crop was supplied with recommended fertilizer dose of fertilizers with 20 kg N, 40 kg P_2O_5 and 50 kg K_2O ha^{-1} through urea, single super phosphate and muriate of potash, respectively to all the plots as basal. Top dressing of 10kg of N was applied in form of urea at 25 DAS. Crop was harvested on 12th February 2021.

Methods of energy budgeting

The inputs and the energy requirements of each input for groundnut production including weed management were collected, determined and presented. General inputs in groundnut production were machinery, human labor, chemical fertilizers, irrigation water, fuel, pesticide and seed. Output was groundnut pod and haulm as a product. The energy equivalent of different inputs and output were used to determine the energy values (Table 1). The human energy as an energy input was calculated by multiplying the number of man-hours (hr/ha) by estimated power rating of human labor (MJ/ha) from (Table 1). Energy used by woman labor was converted into human energy with suitable factors. Energy used by farm machinery was calculated by methodology given by Kitani (1999). ME = M × G × T.

Where, ME is the machinery energy (MJ), E the production energy of machine, G the mass of machine (kg), and T is the economic life of machine (year). Other inputs like fuel, seed, pesticide and chemical fertilizers used in groundnut production were converted into energy value (MJ/ha) by multiplying the quantity of the material used in the production process by the energy equivalent of each material. For example, energy consumption of chemical fertilizer (nitrogen) was

Table 1 : Energy equivalents of inputs and outputs in soybean production.

Energy source	Equivalent energy	
Input energy		
Seed	14.70 MJ kg^{-1}	Mittal and Dhawan (1988)
Adult man	1.96 MJ h^{-1}	Mittal and Dhawan (1988)
Women	1.57 MJ h^{-1}	Mittal and Dhawan (1988)
Farm machinery (Tractor)	64.80 MJ kg^{-1}	Devasenapathy *et al.* (2009)
Power weeder	4.75 MJ kg^{-1}	Devasenapathy *et al.* (2009)
Sprayer	0.94 MJ h^{-1}	Pimentel (1993)
Diesel	56.31 MJ lt^{-1}	Devasenapathy *et al.* (2009)
Chemical fertilizers		
N	60.60 MJ kg^{-1}	Devasenapathy *et al.* (2009)
P_2O_5	11.10 MJ kg^{-1}	Devasenapathy *et al.* (2009)
K_2O	6.70 MJ kg^{-1}	Devasenapathy *et al.* (2009)
Pesticides		
Diclosulam	691 MJ kg^{-1}a.i.	Green (1987)
Pendimethalin	421 MJ kg^{-1}a.i.	Chaudary *et al.*, 2017
Imazethapyr	518 MJ kg^{-1}a.i.	Audsley *et al.* (2009)
Propaquizafop	561 MJ kg^{-1}a.i.	Audsley *et al.* (2009)
Pyroxasulfone	620 MJ kg^{-1}a.i.	Green (1987)
Imazamox	518 MJ kg^{-1}a.i.	Green (1987)
Sodium acifluorfen	568 MJ kg^{-1}a.i.	Green (1987)
Clodinofop propargyl	561 MJ kg^{-1}a.i.	Green (1987)
Imidacloprid	199 MJ kg^{-1}a.i.	Guzman and Alanso (2008)
Output energy		
Groundnut Pods	25 MJ kg^{-1}	Mittal and Dhawan (1988)
Groundnut haulm	12.50 MJ kg^{-1}	Mittal and Dhawan (1988)
MJ = 0.001 GJ		

calculated by multiplying the amount of nitrogen used (kg/ha) by energy coefficient of nitrogen fertilizer (60.60 MJ/kg from Table 1); hence the result is the energy consumption of nitrogen fertilizer (MJ/ha) in groundnut production. Also, energy used by other inputs can be determined by applying same methods as suggested for nitrogen. The amount of output energy (MJ/ha) was estimated by multiplying the groundnut pod and haulm yield (kg/ ha) by groundnut energy equivalent (MJ/kg).

Energy indices

On the basis of energy input and output; total net energy, energy use efficiency and energy productivity were calculated by using the following formulae as suggested by Mittal and Dhawan (1988) and Burnett (1982).

Total net energy

NEt = Energy output - Energy input

Total pod energy use efficiency

$$\text{EUEt} = \frac{\text{Total pod energy output (MJ ha}^{-1}\text{)}}{\text{Energy input (MJ ha}^{-1}\text{)}}$$

Total energy use efficiency

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

Total pod energy productivity

$$\text{EPp} = \frac{\text{Total pod yield (kg ha}^{-1}\text{)}}{\text{Energy input (MJ ha}^{-1}\text{)}}$$

Total energy productivity

$$\text{EPt} = \frac{\text{Total yield (kg ha}^{-1}\text{)}}{\text{Energy input (MJ ha}^{-1}\text{)}}$$

Results and Discussion

The input of support energy for the crop production differs to a great extent. Modern crop production is

Table 2 : Energetics in groundnut as influenced by weed management practices.

Treatments	EI	EOp	EOt	Net	EUEp	EUEt	EPp	EPt
	(MJ ha^{-1})						(kg MJ^{-1})	
Diclosulam 84% WDG 26 g ha^{-1} PE *fb* intercultivation at 20 DAS	15156	65994	105594	90438	4.35	6.97	0.17	0.38
Imazethapyr 2% EC+pendimethalin 30% EC 960 g ha^{-1} PE *fb* inter-cultivation at 20 DAS	16545	65260	104410	87865	3.94	6.31	0.16	0.35
Pyroxasulfone 85 % WDG 127.5 g ha^{-1} PE *fb* intercultivation at 20 DAS	15228	51769	83490	68262	3.40	5.48	0.14	0.30
Propaquizafop 2.5% + imazethapyr 3.75% ME 125 g ha^{-1} Early PoE *fb* intercultivation at 40 DAS	16215	54021	90934	74719	3.33	5.61	0.13	0.32
Imazethapyr 35% + imazamox 35% WG 70 g ha^{-1} Early PoE *fb* inter-cultivation at 40 DAS	15186	49906	86669	71483	3.29	5.71	0.13	0.33
Sodium acifluorfen 16.5% EC + clodinafop propargyl 8% EC 250 g ha^{-1} PoE *fb* intercultivation at 40 DAS	15773	61222	98972	83199	3.88	6.28	0.16	0.35
Imazethapyr 10% SL 100 g ha^{-1} PoE *fb* intercultivation at 40 DAS	15653	48161	81061	65408	3.08	5.18	0.12	0.29
Intercultivation (20 and 40 DAS)	18051	59709	97034	78983	3.31	5.38	0.13	0.30
Intercultivation *fb* hand weeding (20 and 40 DAS) (Weed free)	18224	68572	109201	90977	3.76	5.99	0.15	0.33
Unweeded control	10891	36505	60230	49339	3.35	5.53	0.13	0.31
S.Em ±	-	2324.21	1958.62	1958.62	0.17	0.24	0.01	0.01
CD (P = 0.05)	-	6743.19	5682.51	5682.51	0.50	0.69	0.02	0.04

EI: energy input, EOp : energy output of pods, EOt: total energy output, NEt: total net energy, EUEp : pods energy use efficiency, EUEt : total energy use efficiency, EPp : pods energy productivity, EPt : total energy productivity.

characterized by the high input of fossil energy (fuel and electricity) which is utilized as direct energy and as indirect energy (fertilizers, pesticides, machinery, etc.). At present, productivity and profitability of agriculture depend on energy consumption. As a result of increasing inputs of agrochemicals and the use of more productive cultivars, crop yields increased constantly. This analysis is important to perform crucial improvements that will lead to a more efficient and eco-friendly production system. The data on energy balance studies is presented in Table 2.

The energy input varied among the different weed treatments, inter cultivation *fb* hand weeding at 20 and 40 DAS recorded highest energy input (18224 MJ ha^{-1}) which might be due to the energy required for the fuel and higher wages for human labour. This was followed by inter cultivation at 20 and 40 DAS (18051 MJ ha^{-1}), Imazethapyr + pendimethalin at 60 g ha^{-1} PE *fb* intercultivation at 20 DAS (16545 MJ ha^{-1}). While, the unweeded control recorded lowest energy input energy (10891 MJ ha^{-1}) as there were no operations done for weed control.

Higher pod energy output (EOp) was significantly recorded with intercultivation *fb* hand weeding at 20 and 40 DAS (68572 MJ ha^{-1}) and was on par with diclosulam at PE *fb* intercultivation at 20 DAS (65994 MJ ha^{-1}) and imazethapyr + pendimethalin PE *fb* intercultivation at 20 DAS (65260 MJ ha^{-1}). These were followed by sodium acifluorfen + clodinafop propargyl PoE *fb* intercultivation at 40 DAS and inter cultivation at 20 and 40 and were comparable with each other. Similar trend was recorded with total energy output (EOt).

Highest net energy was recorded with inter cultivation *fb* hand weeding at 20 and 40 DAS (90977 MJ ha^{-1}), which was statistically on par with diclosulam PE *fb* intercultivation at 20 DAS (90438 MJ ha^{-1}) and imazethapyr + pendimethalin PE *fb* intercultivation at 20 DAS (87865 MJ ha^{-1}). This was followed by sodium acifluorfen + clodinafop propargyl PoE *fb* intercultivation at 40 DAS and was on par with inter cultivation at 20 and 40 DAS. Significantly lowest net energy output was observed with unweeded control (49339 MJ ha^{-1}).

Significantly superior EUE of pods and total output was recorded with diclosulam PE *fb* intercultivation at 20 sDAS and this was at par with imazethapyr + pendimethalin PE *fb* intercultivation at 20 DAS and sodium acifluorfen + clodinafop propargyl at PoE *fb* intercultivation at 40 DAS.

Significantly highest EP of both pods and total output was reported with diclosulam PE *fb* intercultivation at 20 DAS this was statistically on par with imazethapyr + pendimethalin PE *fb* intercultivation at 20 DAS and sodium acifluorfen + clodinafop propargyl PoE *fb* inter cultivation at 40 DAS. Similar results were obtained by Lal *et al*. (2016) and Deva and Kolhe (2018).

Conclusion

In case of energy balance studies, maximum energy input was required for inter cultivation *fb* hand weeding at 20 and 40 DAS. Highest pod energy output (EOp), total energy output (EOt) and net energy was observed in inter cultivation *fb* hand weeding at 20 and 40 DAS and was on par with diclosulam 26 g ha^{-1} PE *fb* intercultivation at 20 DAS and sodium acifluorfen + clodinafop propargyl at 250 g ha^{-1} PoE *fb* intercultivation at 40 DAS. Significantly highest EUE of pods, total output EUE, energy productivity of pods and total output energy productivity was recorded in diclosulam 26 g ha^{-1} PE *fb* intercultivation at 20 DAS and this was at par with imazethapyr + pendimethalin 60 g ha^{-1} PE *fb* intercultivation at 20 DAS.

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