ASSESSMENT OF ORGANIC WEED MANAGEMENT PRACTICES FOR PROFITABILITY AND ENERGETICS OF MAIZE-BASED CROPPING SYSTEM IN NORTH-WESTERN HIMALAYAN REGION

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(Received 30th Jan 2023; accepted 27th Apr 2023)

Abstract. Weeds have emerged as a problem and their control is the most expensive input for sustainable organic crop production. We are constantly looking for ways to increase organic crop yields while using less energy and resources. The evaluation work was therefore undertaken from 2017-19 in an on-going trial commenced since 2016 under AICRP-WM (All India Coordinated Research Project on Weed Management) at Palampur, Himachal Pradesh. There were ten treatments viz., hoeing, stale seed bed + hoeing, raised stale seed bed + hoeing, mulch, stale seed bed + mulch, raised stale seed bed + mulch, intercropping, crop rotation, intensive cropping and chemical check, tested in maize based cropping system. The highest green cob yield of maize was produced under the chemical check treatment (10323 kg/ha). Statistically equivalent green cob yield was produced under RSSB + hoeing, that was 9208 kg/ha. While considering the system as a whole, it was found that intercropping followed by chemical control and RSSB + hoeing produced the most energy from the crops' primary products. Crop rotation treatment combined with RSSB resulted in significantly greater energy use efficiency (12.3%). Intercropping had the highest energy intensity (2.39 MJ/rupees), followed closely by crop rotation (2.37 MJ/rupees), while SSB + hoeing had the lowest energy intensity (1.74 MJ/rupees).
Keywords: *organic farming, sustainable, yield, economics, energetic*

Introduction

India is bestowed with a lot of potential to produce all varieties of organic products due to its diverse agro-climatic conditions. In several parts of the country, the inherited tradition of organic farming is an added advantage and the state of Himachal Pradesh is one amongst those. Today, the public demand for organic produce and profile of organic food has increased. But, some farmers are reluctant to convert because of the perceived higher costs and risks involved due to the certification costs and tiresome procedure. Obtaining higher yields with lesser energy consumption has always been one of the most important objectives of scientific studies. The net energy of a cropping system can be quantified for sound planning of sustainable cropping systems (Choudhary et al., 2018). By using optimal level of energy input, yield of different crops can be increased up to 30%.

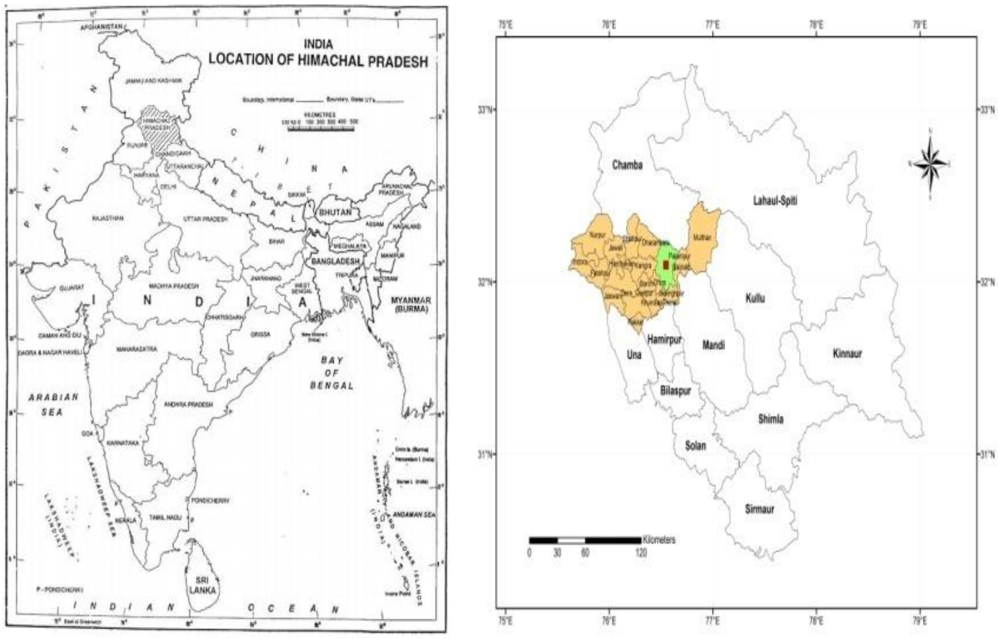
The key feature of organic farming is its lower input of chemicals, which should lead to a lower burden on the land (Stein-Bachinger et al., 2021). This reduction could be partially compensated by higher labor input; however, it is not possible to completely avoid the use of non-labor inputs. Regarding the energy consumption per unit of production, on an average, organic farming consumes more direct energy than conventional farming to produce the same amount of production. This is also valid for

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2104_34033417

individual production groups, with the highest energy consumption required in the case of cereals and oilseeds, however, its direct energy consumption per one USD of production is 1.7-fold higher. In Indian context, without human labor, we will have no production however, in some countries exclude human labor because of its marginal energetic value (Maraseni et al., 2015). In addition, for example, an organic produce is more expensive as more energy in the form of human labor for carrying out different operations like manual weeding, hoeing etc. is required than a conventional farm produce (FAO, 2021; Dragomir, 2021). From this it can be deduced that the energy consumption is higher per unit of production in organic farming but one's organic produce is sold at a higher price. Therefore, taking into account the higher prices of organic products, the results for one piece of organic production are even less favorable in terms of direct energy consumption. Therefore, the present study focuses on the issues like economics and energy efficiency of organic farming in North Western region of India under organic maize-based production system.

Materials and methods

The experimental farm was located at 32°6′ N latitude, 76°3′ E longitude and 1290 m above mean sea level. It lies in North-West Himalaya in the Palam Valley of Kangra district of Himachal Pradesh, India (*Figs. 1–2*). The soil of the experimental field was silty clay loam in texture, low in organic carbon (7.2 g/kg) and available N (270.5 kg/ha), high in available P (41.1 kg/ha) and medium in available K (198.7 kg/ha). The study was conducted in an ongoing experiment which commenced from *kharif* 2016. The experiment was conducted in a randomized complete block design with three replications. There were 10 treatments which involved different cultural practices and their combinations. The details of the treatments have been given in *Table 1*.



Map of India

Map of Himachal Pradesh (red dot shows the study area)

Figure 1. *Maps of the study area*

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DOI: http://dx.doi.org/10.15666/aeer/2104_34033417

Figure 2. *A general view of experimental field during rabi and Kharif season*

Table 1. *Treatment details*

Treatment	*Kharif* (maize green cob)	*Rabi* (garlic/peas)	Short title
T_1	One hoeing followed by (fb) earthing up at knee high stage	Hoeing (twice) at 30 and 60 days after sowing (DAS)	Hoeing
T_2	Stale seed bed (SSB) + hoeing + earthing up	SSB + hoeing + hand weeding (HW)	SSB + hoeing
T_3	Raised stale seed bed (RSSB) + hoeing + earthing up	RSSB + hoeing + HW	RSSB + hoeing
T_4	Mulch @ 5 t/ha	Mulch @5 t/ha	Mulch
T_5	SSB + mulch @ 5 t/ha	SSB + mulch@ 5 t/ha	SSB + mulch
T_6	RSSB + mulch @ 5 t/ha	RSSB + mulch @ 5 t/ha	RSSB + mulch
T_7	Intercropping (soybean) + hoeing	Intercropping (fenugreek) + hoeing	Intercropping
T_8	*Maize/soybean + hoeing + earthing up	*Pea/sarson + hoeing + HW	Crop rotation
T_9	Maize + mulch + manual weeding fb autumn crop of mustard greens	Peas + mulch + manual weeding fb summer crop of buckwheat for greens	Intensive cropping
T_{10}	Herbicide + HW	Herbicide + HW	Chemical check

*Based on crop rotation, maize-peas in the first year and soybean-sarson in the second year i.e. In kharif, maize/soybean and in rabi peas/sarson alternatively; T_9 was based on intensive cropping; T_{10} was based on recommended dose of fertilizers and herbicides (conventional farming)

Hoeing was carried out using manually operated wheel-hoe. *Lantana* (*Lantana camara*) leaves from the nearby wasteland and forests were collected and used for mulching at the rate of 5 t/ha, which formed a thickness of about 5–6 cm on the soil surface. This was done with the prime objective of weed suppression, taking into account the allelopathic properties of *Lantana* that suppress weed growth. Allelochemicals of *Lantana* inhibits the germination, growth and metabolism of weeds (Mishra, 2015). In stale seedbed plots, one irrigation was given 15 days prior to sowing to allow the germination of weeds, and the first flush of emerged weed seedlings were removed by disturbing the surface soil (up to 2 cm) at the time of crop sowing using a manually operated harrow. In raised stale seedbed plots, all conditions were similar to stale seedbed except that the seedbed was raised up to 12-15 cm height for providing proper drainage. Intercropping with soybean in case of maize and fenugreek in pea/garlic was done in order to check weed growth and get additional yields. The concept of rotating crops with different life cycles was used, as earlier in 2017-18 *rabi* season garlic was sown which was later rotated by pea. In case of intensive cropping, incorporation of pulse- soybean, oilseed- brown sarson, green manure crop- buckwheat

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were taken up. Herbicides *viz*., pendimethalin (1.0 kg/ha) in pea and atrazine (0.75 kg/ha) in maize were used in chemical control treatments.

Farmyard manure (0.86% N, 0.33% P, and 0.65% K) at the rate of 10 t/ha was applied 15 days before sowing in *kharif* season and vermicompost at the rate of 15 t/ha during *rabi* season was thoroughly incorporated into soil (based on availability). During *rabi* (2017-18) maximum temperature ranged between 15.6 to 28.9°C. The minimum temperature ranged between 6.1 to 19.9°C. In next year, the maximum temperature ranged between 12.7°C to 32.5°C and minimum temperature ranged between 3.4 to 19.9°C. Total amount of rainfall received and relative humidity observed was highest during the month of July during both the years (*Table 2*).

Table 2. *Weekly weather parameters at agro-meteorological observatory Palampur (October 2017 to September 2019)*

Month	Max temp. (°C)		Min temp. (°C)		Rainfall (mm)		RH (%)		Sunshine hours	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
October	20.1	19.4	7.5	6.65	0.2	5.5	58.0	75.5	7.0	6.8
November	18.1	15.4	6.1	3.4	23.6	2.5	59.3	67.3	6.5	6.3
December	18.1	14.3	6.8	3.45	2.3	4.5	52.9	69.5	8.3	4.8
January	19.6	15.3	7.4	5.4	39	9.6	58.6	73.6	5.9	4
February	24.1	20.3	10.7	8.2	7	0.9	44.8	64.5	8.7	6.5
March	26.5	26.4	14.7	13.8	16.7	2.1	50.6	58.6	7.5	7.9
April	28.9	28.9	17.7	16.4	27.6	1.5	54.8	52.1	6.5	8.1
May	28.5	32.5	19.5	19.9	91.2	0.8	70.3	45.6	5.1	9.3
June	27.5	28.9	19.9	19.8	208	9.9	89.4	77.7	3.5	4.9
July	25.6	26.1	16.9	19.8	230.2	22.3	91.3	92.1	2.6	2.6
August	25.2	27.6	12.1	18.9	116.6	11.5	82.3	91.5	4.7	5.1
September	15.6	12.7	6.3	8.15	0.4	4.2	68.6	45.3	8.9	2.1

The intensity and biomass of weeds were recorded at 30 days interval from the date of sowing by the least count quadrate method. The weed count and dry weight so obtained were converted to number and grams per square meter, respectively. Yield was recorded from the net plot. The energy input (MJ/ha) was worked out for different inputs used and operations that were carried out. The energy output of these systems includes energy from main and by product yields. The economic inputs include costs of human labor, fertilizers, hired machinery, seed, land, irrigation, fixed costs and agricultural machinery (*Table 3*). The economic output includes main and by product yields. The economic analysis includes ratio of total income to total expenses. The net returns (NR) of each treatment combination were calculated by deducting the total cost (TC) of cultivation from gross returns (GR) of respective treatments. The benefit cost ratio was calculated by dividing the net returns with total cost of cultivation. The energy output (MJ/ha) of each crop was obtained by multiplying the energy coefficients with grain and straw separately (*Table 4*) to get the total energy output. The energy equivalents for different inputs, main and by-products have been given below:

The data obtained were subjected to statistical analysis as per Gomez and Gomez (1984). The results were compared at 5 per cent level of significance to interpret the treatment differences. The weed count and weed dry weight data were analyzed after

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subjecting the original data to square root transformation [$\sqrt{x}+1$] and the treatment effects were compared using transformed means.

The standard formulae used for energetics calculation were:

$$\text{Energy efficiency} = \text{Energy output (MJ/ha)} / \text{Energy input (MJ/ha)}$$

$$\text{Net energy (MJ/ha)} = \text{Energy output (MJ/ha)} - \text{Energy input (MJ/ha)}$$

Table 3. *Energy equivalent for different inputs*

Particular	Units	Equivalent energy (MJ)	Reference
Tractor	Hour	59.04	Singh et al., 2002; Canakci and Akinici, 2006
Diesel	Liter	56.31	Hetz, 1998
Man (adult)	Man-hour	1.96	Mohammadi and Omid, 2010
Water pump charges	Hour	24.12	Pimentel and Pimentel, 1996
Seed	Kg	14.7	Singh and Mittal, 1992
a. Nitrogen	Kg	60.6	Erdal et al., 2007; Cetin and Vardar, 2008
b. P_2O_5	Kg	11.1	Erdal et al., 2007; Cetin and Vardar, 2008
c. K_2O	Kg	6.7	Erdal et al., 2007; Cetin and Vardar, 2008
Herbicide	Kg	120	GhasemiMobtaker et al., 2010
FYM	Ton	484.08	Canakci and Akinici, 2006
Vermicompost*	Ton	726.12	
Mulch**	Ton	2000.0	

*Calculated by energy consumed in the process of production, mainly raw materials and manpower used. **Calculated based on energy consumed in production and manpower for cutting *Lantana* twigs and transporting to the main field

Table 4. *Energy equivalents for crops*

Crop	Seed for sowing (MJ/kg)	Main product at harvest (Kcal/kg)	By product (dry mass) (MJ/kg)
Pea	14.7	810	10.0
Coriander	14.7	170	10.0
Buckwheat	14.7	170	10.0
Maize cob	14.7	900	10.0
Soybean	14.7	4410	10.0
Sarson (greens)	14.7	340	10.0
Garlic	14.7	1300	10.0

Source: Singh and Mittal, 1992; Dekamin et al., 2022

Results and discussion

Surveillance of weed flora

The experimental field was kept under meticulous care and observations during the different crop growth phases by daily farm visits. The dominant weed species in the experimental area are shown in *Figure 3*. The common weeds prevalent during *rabi*

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2017-18 and 2018-19 were *Phalaris minor*, *Anagallis arvensis*, *Euphorbia helioscopia*, *Vicia sativa*, *Coronopus didymus* and *Tulipa sp.* Some of the weed species such as *Asphodelus tenuifolius* Cav, *Chenopodium murale* L., *Chenopodium album* L., *Daucus carrota* L., *Digitaria sanguinalis* L., *Medicago denticulate* L., *Panicum dichotomiflorum* Michx. and *Rumex obtusifolius* L. were absent during the pea crop growth phase. Therefore, it may inferred be that *Phalaris minor*, *Stellaria media*, *Anagallis arvensis*, *Poa annua*, *Vicia sativa*, *Coronopus didymus*, *Allopecurus myosuroides* and *Avena ludoviciana* were the major weeds infesting the pea crop. These results are in line with the findings of Mawalia et al. (2015).

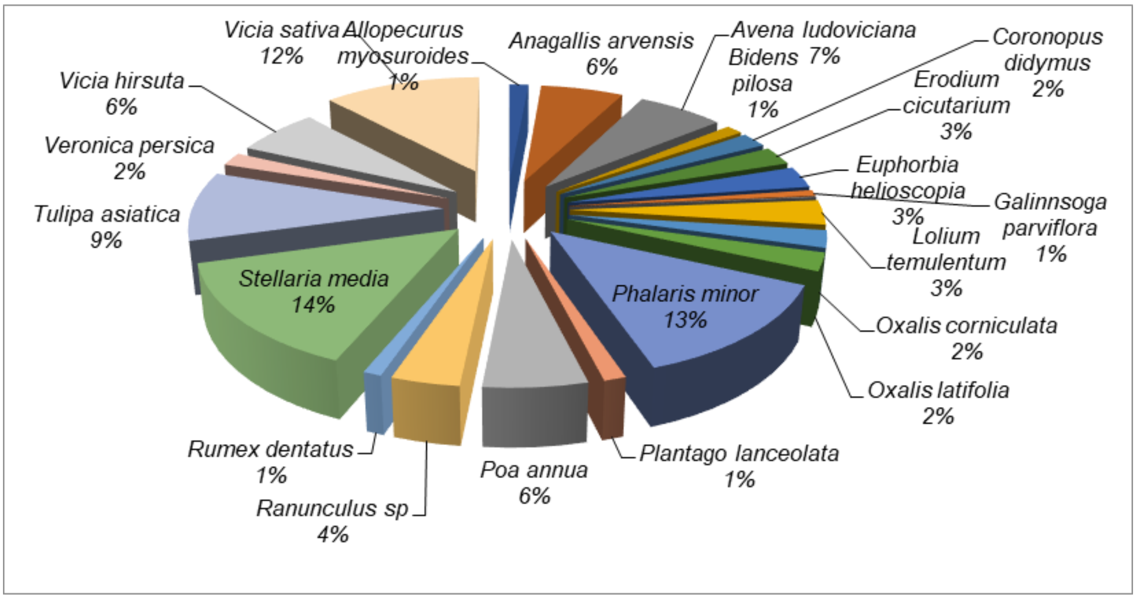

Figure 3. *Distribution of weed species in rabi (2019)*

During *kharif* 2019, thirteen weed species were found associated in maize crop. *Echinochloa colona* (24%) was the most dominant weed followed by *Cyperus sp* (22%), *Commelina benghalensis* (17%), *Polygonum alatum* (11%), *Galinsoga parviflora* (11%) and *Digitaria sanguinalis* (5%). The other weeds were *Eleusine indica*, *Euphorbia geniculata*, *Ipomoea sp*, *Panicum distichum*, *Phasalis minima*, *Aeschynomene indica* and *Alternanthera philoxeroides*, as a whole constituted 10% of the total weed flora. *Alternenthera philoxeroides* also invaded the field but with a low proportion (0.3%) which may prove to be a potential future threat. Weed flora during *kharif* 2018 was dominated by *Commelina benghalensis* (20.5%), *Galinsoga parviflora* (17.4%), *Ageratum* sp. (*Ageratum conyzoides* and *Ageratum houstonianum*) (10.7%), *Cyperus* sp. (9.5%), *Digitaria sanguinalis* (7.3%), *Paspalum scrobiculatum* (6.6%), *Polygonum alatum* (5.4%), *Phyllanthus niruri* (4.7%), *Panicum dichotomiflorum* (4.5%), *Bidens pilosa* (3.7%) and *Aeschynomene indica* (2.7%). *Bidens pilosa*, *Eleusine indica*, *Galinsoga parviflora*, *Pasapalum scrobiculatum*, *Phyllanthus niruri*, *Physalis minima*, *Setaria viridis* and *Trifolium repens* were recorded only during *kharif* 2018. Weeds such as *Commelina benghalensis*, *Digitaria sanguinalis*, *Cyperus* sp., *Polygonum alatum*, *Panicum dichotomiflorum* and *Aeschynomene indica* invaded the field in both seasons as depicted in *Figure 4*. These results are in conformity with earlier findings of Chopra and Angiras (2008).

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DOI: http://dx.doi.org/10.15666/aeer/2104_34033417

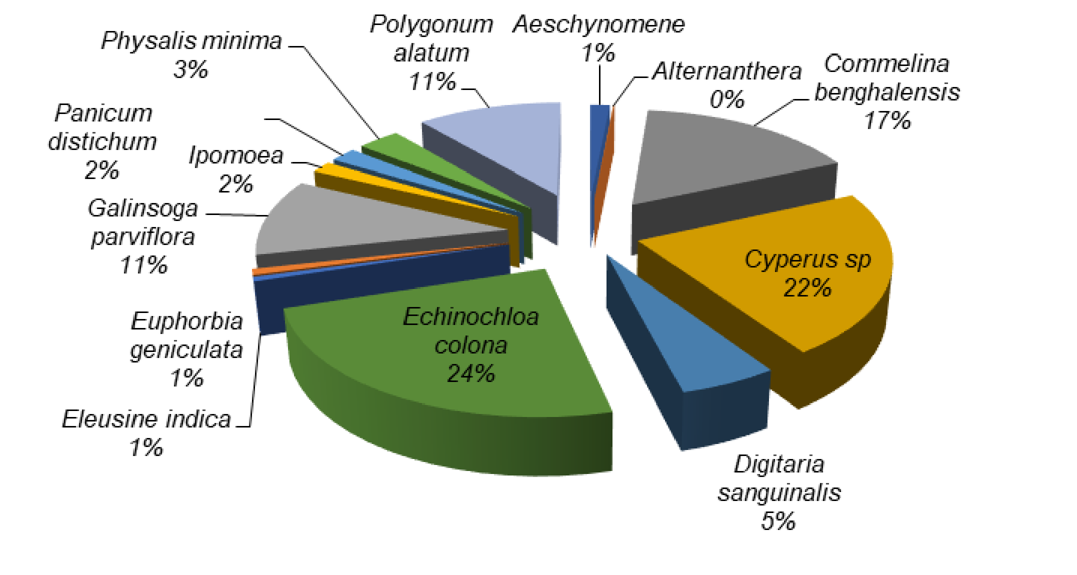

Figure 4. *Distribution of weed species during kharif 2019*

Category-wise weed count (No./m^2)

During *kharif* 2018, RSSB + hoeing (T_3) being at par with mulch (T_4), intensive cropping (T_9), SSB + mulch (T_5) and intercropping (T_7) gave significantly lower count of sedges over other treatments. Sindhu et al. (2010) also reported superiority of stale seed bed over other weed control methods for controlling sedges. Grasses and broad-leaved weeds were not significantly affected due to treatments (*Table 5*).

Table 5. *Effect of treatments on category-wise weed count in maize (seasonal average)*

Treatments		Maize-garlic (2017-18)				Maize-pea (2018-19)				
		Grasses	Sedges	Broad-leaved	Total	Grasses	Monocots	Sedges	Broad-leaved	Total
T_1	Hoeing	6.1 (42)	4.1 (16)	8 (64)	11 (122)	6.6 (44.5)	8.3 (70.5)	5.1 (40.8)	6.6 (45.0)	12.4 (156.3)
T_2	SSB + hoeing	7.8 (64)	5.1 (30)	7.4 (54)	12.1 (148)	6.2 (43.0)	8.8 (83.3)	6.6 (48.5)	6.9 (46.8)	13.2 (178.7)
T_3	RSSB + hoeing	7.5 (59)	0.7 (0)	8.5 (74)	11.3 (133)	7.0 (49.2)	8.7 (76.2)	6.2 (42.2)	7.2 (52.2)	13.1 (170.5)
T_4	Mulch	6 (36)	1.6 (4)	5.8 (36)	8.6 (75)	7.5 (64.7)	9.1 (93.7)	3.5 (17.0)	8.0 (65.3)	13.1 (176.0)
T_5	SSB + mulch	7.8 (60)	2.7 (9)	8.9 (80)	12.2 (149)	6.8 (47.5)	7.5 (58.0)	5.3 (30.0)	7.3 (53.8)	11.7 (141.8)
T_6	RSSB + mulch	7.9 (62)	3.2 (10)	6.9 (48)	10.9 (120)	7.6 (63.8)	8.8 (85.8)	6.8 (47.2)	6.1 (37.7)	12.9 (170.7)
T_7	Intercropping	4.7 (22)	3.0 (11)	8.3 (79)	10.3 (112)	6.3 (39.3)	7.5 (56.2)	4.9 (23.7)	5.2 (26.7)	10.3 (106.5)
T_8	Crop rotation	6.2 (38)	3.3 (14)	7.1 (52)	10.1 (104)	7.8 (60.5)	9.4 (89.5)	5.2 (29.7)	5.7 (33.3)	12.3 (152.5)
T_9	Intensive cropping	6.5 (42)	1.8 (5)	8.2 (68)	10.7 (115)	6.0 (36.3)	8.4 (71.8)	7.7 (65.5)	7.1 (52.8)	13.5 (190.2)
T_{10}	Chemical check	5.2 (27)	3.3 (14)	5.6 (31)	8.5 (72)	8.3 (71.2)	10.1 (107.5)	4.3 (31.2)	7.3 (53.8)	13.7 (192.5)
SE (m±)		1	0.8	1	1.1	1.1	1.1	1.3	0.8	0.9
LSD (*P*=0.05)		NS	2.4	NS	NS	NS	2.4	NS	NS	NS

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However, during *kharif* 2019, the total weed count was more in number than the previous year. Monocots had the maximum count than other weeds. Treatments RSSB + hoeing (T_3) and mulch (T_4) were found to be at par with each other. Raised stale seedbed provides improved weed control by causing more warming up of the seed bed and efficient drainage of the excess water, thereby reducing weed population and lowering of the crop weed competition, by shifting the balance in favor of crop in utilization of nutrients, moisture, light and space (Akhtar et al., 2015).

The lowest total weed count was found in intercropping treatment (T_7) and was similar to 2018. Treatments with mulch provided effective weed suppression during initial 30 DAS but later this positive influence weakened with time for the entire vegetative period. With the onset of monsoon, *Lantana camara* got decomposed and added organic matter to the soil which was even utilized by weeds, leading to increase in their population.

Yields

The economic yields of crops (cob, greens, or pod) under different treatments were converted to their maize equivalents based on the prevailing market price of each product to facilitate the overall comparison among cultural weed management treatments. Maize equivalent yield (MEY) values of these treatments have been presented in *Table 6*. During the first year, intercropping followed by intensive cropping gave the higher yields during rabi season compared to other weed management treatments. It may be due to inclusion of more crops in the system. However, during *kharif* season in maize crop, higher yields were obtained in RSSB + mulch treatment followed by intensive cropping. Raised stale seedbed does not allow water to stagnate in the beds during heavy rains at Palampur and thus might have resulted in higher yield. During the successive year intensive cropping where short duration crop of buckwheat greens was grown in the summer resulted in comparable maize equivalent yield as the chemical check in the *rabi* season. However, RSSB + hoeing, intercropping, RSSB + mulch and SSB + hoeing was equally good as the chemical check treatment. Similarly, the additional crop of mustard greens after the harvest of maize in the autumn resulted in significantly higher maize equivalent yield under intensive cropping in the *kharif* season. Chemical check was the next superior treatment and RSSB + hoeing and intercropping treatments were at par to it. Intensive cropping because of more yield from additional crops resulted in 10.4% higher overall system's maize cob equivalent yield than the chemical check. RSSB + hoeing and intercropping resulted in comparable yields as chemical check. The other treatments owing to lower crop yields were having low maize green cob equivalent yield as compared to the chemical check. Hugar and Palled (2008) found that vegetable crops (cowpea, French-bean, coriander) intercropped with maize reduced the weed density and dry weight accumulation by weeds and resulted in higher maize equivalent yield at Dharwad, Karnataka.

Energetics

Energy holds a key role in production systems. Cultivation is based on conversion of solar energy into biomass of interest. Different cultural weed management practices showed marked variation across the cropping system (*Table 6*). It is evident from both year's data that the total energy input per hectare in maize was lesser than the *rabi* season's input. In *rabi* 2017-18, when garlic crop was taken as the main crop; more

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energy input was required as compared to 2018-19, where pea was taken as the main crop during *rabi* season. The reason for the differences was owing to managerial practices and the amount of input consumption. In maize-garlic cropping system, the maximum energy input was in stale seedbed + mulch treatment (60.714 GJ/ha) followed by raised stale seedbed + mulch (57.249 GJ/ha) during 2017-18. Similar trend was followed in maize-pea cropping system during the next year with 48.629 GJ/ha input in RSSB + mulch and 48.515 GJ/ha in SSB + mulch treatment. This could be related particularly to high weed pressure that required more effort for weedings (*Table 3*). It is well known that organic mulch helps to reduce the impact of weeds but application of mulch in Palampur region which receives high rainfall led to more energy input. This was followed by RSSB + hoeing, intercropping, SSB + hoeing and intensive cropping. SSB/RSSB + hoeing and intercropping required more labor for field preparation and weed management i.e., high energy intensive-practice (compared to hoeing alone) while in case of intensive cropping, it was the highly intensified system, involved more labor and other costs on management of the crops throughout the year. Next was in chemical check certainly due to more energy of recommended dose of fertilizer (RDF), herbicides to check weed growth and manual weeding to take care of rest of the weeds. A study by Michigan State University also found a lower fuel use for a corn, soybean, wheat rotation under conventional no till, compared to the same rotation under low-input and organic conditions, although the savings were offset by the energy associated with fertilizer and lime inputs (Robertson et al., 2000*)*.

Table 6. *Effect of treatments on Maize equivalent yield from 2017-19*

Treatments	Maize equivalent yield (kg/ha)					
	2017-18			2018-19		
	Rabi	***Kharif***	**System's**	***Rabi***	***Kharif***	**System's**
Hoeing	3357	3941	7298	5093	5760	10853
SSB + hoeing	3121	2552	5673	12273	5781	18054
RSSB + hoeing	4263	3959	8222	13546	9208	22755
Mulch	2896	5451	8347	3412	5229	8641
SSB + mulch	2732	3108	5840	8861	4292	13153
RSSB + mulch	3958	6944	10902	12477	6510	18987
Intercropping	5044	4919	9963	12750	9331	22081
Crop rotation	4070	2626	6696	6366	8042	14407
Intensive cropping	4628	5479	10107	15380	12816	28196
Chemical check	4253	4253	8506	15227	10323	25550
SE (m±)	320	430	639	1015	569	1260
LSD (P = 0.05)	952	1278	1900	3017	1689	3744

Talking about the output, in both the years; more energy output was obtained during the *Kharif* season as compared to the *rabi* season. The weed control treatments significantly influenced the total energy output (*Table 7*). During 2017-18; RSSB + mulch (296.68 GJ/ha) and intensive cropping (285.877 GJ/ha) had the maximum energy output. However, in the next year, the season-wise and total system's values of energy output were significantly higher in chemical check treatment (389.781 GJ/ha) followed by RSSB + hoeing (359.068 GJ/ha) and crop rotation (337.505 GJ/ha) (*Table 7*). This was because of higher maize equivalent yield under

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DOI: http://dx.doi.org/10.15666/aeer/2104_34033417

these treatments. It is important to note that mulch and SSB + mulch produced lower output energy as compared to RSSB + mulch and RSSB + hoeing because of lower yields as a matter of poor plant stand.

Table 7. *Energy of the main product and total output energy from different crops under treatments during 2017-19*

Treatment	Total energy input (GJ/ha)						Total energy output (GJ/ha)					
	***Rabi* (2017-18)**	***Kharif* (2018)**	***System' s***	***Rabi* (2018-19)**	***Kharif* (2019)**	***System' s***	***Rabi* (2017-18)**	***Kharif* (2018)**	***System' s***	***Rabi* (2018-19)**	***Kharif* (2019)**	***System' s***
Hoeing	32.4	10.3	42.7	16.8	10.4	27.3	25.4	169.5	194.8	36.7	268.5	305.2
SSB + hoeing	32.2	7.7	39.9	17.6	11.1	28.6	27.3	163.9	191.5	48.8	230.8	279.6
RSSB + hoeing	32.6	11.3	43.9	17.9	11.4	29.4	35.8	221.6	257.4	53.7	305.3	359.1
Mulch	34.2	20.3	54.5	26.7	20.4	47.2	20.6	257.5	278.1	16.0	234.6	250.6
SSB + mulch	39.7	21.0	60.7	27.5	21.1	48.5	26.2	252.1	278.3	41.7	231.2	273.0
RSSB + mulch	42.5	14.7	57.2	27.6	21.0	48.6	27.9	268.7	296.7	57.7	265.7	323.5
Intercropping	14.8	11.2	26.0	16.9	11.2	28.1	27.2	146.8	174.1	38.9	255.5	294.5
Crop rotation	30.1	10.4	40.5	16.9	10.4	27.3	55.1	30.5	85.6	35.4	302.1	337.5
Intensive cropping	26.7	20.2	46.9	26.8	20.2	47.0	27.9	257.9	285.8	42.1	239.6	281.7
Chemical check	23.7	18.9	42.7	19.8	18.9	38.8	25.5	177.2	202.7	58.0	331.7	389.7
SE (m±)	0.4	2.3	2.3	0.02	0.01	0.021	4.5	26.5	17.2	3.9	15.5	16.2
LSD (P = 0.05)	1.2	6.8	6.9	0.06	0.01	0.06	13.4	78.9	51.1	11.6	46.1	48.1

A system is considered more efficient when it produces higher output energy per unit energy consumed (*Table 8*). In the maize–pea cropping system under study, significantly higher energy use efficiency (12.3%), i.e., the ratio of energy output to energy input was recorded with crop rotation treatment followed by RSSB + hoeing over other treatments. This was because maximum energy was produced in these treatments with least expenses of energy. Thus, targeting the higher productivity is one of the options for enhancing energy efficiencies of maize based system which was also reported by Parihar et al. (2011).

Table 8. *Net energy, energy efficiency and energy productivity during 2017-19*

Treatment	Net energy (GJ/ha)		Energy output: input (Energy efficiency)		Energy productivity (Kg maize cob equivalent/MJ)	
	2017-18 System's	**2018-19 System's**	**2017-18 System's**	**2018-19 System's**	**2017-18 System's**	**2018-19 System's**
Hoeing	42.7	277.9	16.3	11.2	0.2	0.4
SSB + hoeing	43.2	251.0	14.9	9.8	0.1	0.6
RSSB + hoeing	43.9	329.6	19.6	12.2	0.2	0.7
Mulch	54.5	203.4	12.7	5.3	0.1	0.1
SSB + mulch	60.7	224.4	12.0	5.6	0.1	0.3
RSSB + mulch	57.2	274.9	12.8	6.6	0.2	0.4
Intercropping	26.0	266.3	13.1	10.5	0.4	0.8
Crop rotation	40.5	310.1	2.9	12.3	0.1	0.5
Intensive cropping	46.9	234.7	12.8	6.0	0.2	0.6
Chemical check	42.6	351.0	6.4	10.1	0.2	0.7
SE (m±)	1.9	16.1	1.4	1.0	0.01	0.03
LSD (P = 0.05)	5.9	48.1	4.0	2.9	0.04	0.10

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In case of mulch, the inclusion of *Lantana camara* leaves produced least output in comparison with other treatments. This was owing to the fact that incorporation of *Lantana* mulch produced marginal effect on the total energy output. In the first year RSSB + hoeing, hoeing and SSB + hoeing proved to be the most energy efficient treatment in maize-garlic production system whereas in case of maize-pea production system, crop rotation was found at par with RSSB + hoeing treatment followed by hoeing and intercropping as the most efficient. Hence, in an overall scene we can say that RSSB + hoeing treatment was the most energy efficient treatment in maize based cropping system.

Analysis of energy efficiency in cropping systems is an important mechanism for achieving a green economy (Babu, Mohapatra, et al., 2020). The energy consumption positively correlated with the inputs and their corresponding energy value under the organic production system (Babu et al., 2016). Variations recorded in various weed management practices were mainly due to differences in weed population and productivity of crops under study. RSSB + hoeing and chemical check had higher energy productivity during 2018-19 over intercropping and chemical check in the previous season. This might have occurred because of better weed control in those plots. It can be seen from *Table 8* that variation in energy between different weed management practices was greatly wide during two years. The net energy during the second year i.e., 2018-19 was found to be nearly 5 times more than the preceding year. The net energy produced was higher as the yields of main and by products increased with time in organic maize- pea production system from the previous year. A positive correlation existed between system's equivalent energy (0.474 kg/ha) and weed count along with net energy (0.151GJ/ha) and system's energy efficiency. A significant positive correlation was obtained between net energy (0.818 GJ/ha) and system's energy efficiency at 1% level of significance. However, a negative weak correlation existed between weed count and system's energy efficiency (0.212%). The reduction in system's energy efficiency could be predicted by increase in weed count.

During 2017-19, the energy productivity, i.e., kg of maize cob produced per unit of energy invested was higher under intercropping (T_7) followed by RSSB + hoeing (T_3) (0.7 kg/MJ) and chemical check that were statistically at par with each other. This might have occurred because of better weed control in these treatments. The results indicated that the inclusion of soybean as an intercrop and the short duration winter crops such as buckwheat, mustard greens as weed control measures was an energy-saving and environment-friendly production system to intensify the farming under rainfed organic management in the North Western Himalayan region of India.

Economics

Cost of cultivation increased with increase in application of recommended dose of fertilizer (RDF) and herbicides along with manual weeding (*Table 9*). RSSB + hoeing/mulch was the most laborious. Among the weed control treatments, gross returns were accrued highest under intensive cropping. During 2017-18, intensive cropping was statistically at par with chemical check, intercropping and RSSB + mulch. However, during 2018-19, intensive cropping and chemical check were statistically at par with each other. In 2017-18, intercropping treatment was comparable to SSB + mulch. While for the year 2018-19, the gross returns in RSSB + hoeing was comparable to the chemical check and was followed by intercropping and RSSB + mulch due to higher yields under them. SSB + mulch had the lowest gross returns

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
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during 2017-18, while during the second year, treatments with mulch showed the lowest gross returns i.e., only 39.4% of that under the chemical check. Intercropping (T_7) gave highest net returns among all the weed control treatments. This weed control treatment was followed by chemical check (T_{10}) during 2017-18. During 2018-19, net returns were significantly higher under intensive cropping (T_9) (maize – mustard greens - peas-autumn buckwheat) followed by intercropping (T_7) (maize + soybean - peas + fenugreek). This was due to higher system's productivity owing to growing of a greater number of crops. Crop diversification and/or intensification shows lot of opportunities in alleviating a large number of problems besides fulfilling the needs of regulating farm income, withstanding weather aberrations, conserving natural resources, environmental safety and creating employment opportunities (Singh, 2010). Sunitha and Kalyani (2012) reported higher net returns in intercropping maize with soybean. The lowest net returns were obtained for SSB + hoeing during 2017-18. On the contrary, the lowest returns were recorded in treatments with mulch (T_4) and SSB + mulch (T_5) during the next year. This may be attributed to low yield and higher cost of cultivation. In the first year (2017-18), B:C followed the order of intercropping > intensive cropping > chemical check = RSSB + mulch > RSSB + hoeing. In the following year results indicated that B:C was in the order of intensive cropping > intercropping > chemical check > RSSB + hoeing > RSSB + mulch. It is clearly evident that higher system productivity of treatments with growing of more crops in a year was mainly attributable to have higher B:C ratio. On the other hand, the lowest B:C was recorded in treatments with mulch (T_4) and SSB + mulch (T_5) for both the years. This may be attributed to low yield due to poor results of mulch on crop stand without reducing the cost of cultivation.

Table 9. *Cost of cultivation, net returns and B:C from different crops under treatments during 2017-19*

Treatments	Cost of cultivation (Rs. ha^{-1})		Gross returns (Rs. ha^{-1})		Net returns (Rs. ha^{-1})		B-C ratio	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Hoeing	126520	133981	318611	221372	192091	87390	1.5	0.6
SSB + hoeing	130393	160143	299826	320885	169433	160742	1.3	1.0
RSSB + hoeing	134005	167187	408146	404271	274140	237084	2.0	1.4
Mulch	113197	128198	307806	178229	194608	50031	1.7	0.4
SSB + mulch	119429	152441	296229	249549	176800	97108	1.5	0.6
RSSB + mulch	124505	167811	394708	341684	270203	173873	2.2	1.0
Intercropping	115377	123216	439778	382087	324401	258871	2.8	2.1
Crop rotation*	139567	140136	346042	279306	206474	139169	1.5	0.9
Intensive cropping	122224	144362	444986	472274	322762	327912	2.6	2.3
Chemical check	122371	171197	392226	452274	269854	281077	2.2	1.6
SE (m±)	606	2846	29959	19565	29403	16953	0.2	0.1
LSD (P = 0.05)	1801	8457	89016	58133	87365	50373	0.7	0.3

*Based on crop rotation, maize-garlic/peas in the first year and soybean-sarson in the second year i.e. In kharif, maize/soybean and in rabi garlic/peas/sarson alternatively

It was found that more direct energy per hectare is consumed in organic farming. We evaluated not only the energy consumption per unit of the land, but also that per unit of output, because the main goal of agriculture is to ensure enough food for society. The results indicate that the mean energy required in the mulch treatment was higher than in

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the other treatments, especially than the non-mulched treatments. So, we can say that energy-use efficiency per unit of output is strongly influenced by the method of weed management. Hoeing is also found to be an interesting alternative from the energetic point of view, provided that weed density should be low. RSSB + hoeing treatment was the most energy efficient treatment in maize based cropping system. The lowest returns were recorded in treatments with mulch (T_4) and SSB + mulch (T_5).

Conclusion

The results highlighted the role of agricultural choices in introducing raised stale seedbed and intercropping along with chemical check as an effective weed suppression tool. Given that organic farming therefore depends on human manpower, there is a need to seek long-term sustainability, not only from the environmental point of view, but also from the economic perspective. The inclusion of 'human energy' aspect in this study presented an optimistic view of the increased labor requirements associated with organic production systems as it would create jobs in addition to encouraging more added value through on-farm processing of products and direct sales. A higher system productivity of treatments with growing of more crops in a year was mainly attributable to have higher B:C ratio. Therefore, we should focus on adopting weed management practices that would not only increase system's productivity but will also foster an economic sustainability in the long term.

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