Himachal Journal of Agricultural Research 51(1): 73-77 (2025)

Effect of tillage and crop management practices on phenology, productivity and energetics of potato under north-western Himalayan conditions

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Manuscript received: 26.03.2025; Accepted: 06.04.2025

Abstract

The experiment comprising of three tillage practices *viz.* conventional tillage (CT), minimum tillage (MT) with furrow and minimum tillage flat-bed (MTF) as main-plots and three crop management practices (CMPs) *viz.*, organic farming (OF), natural farming (NF), and natural farming + FYM as sub-plots was conducted under a split plot design with three replications during *rabi* seasons of 2022-23 and 2023-24 at Palampur. Among tillage practices, CT and MT with furrow were more promising for most of the traits than MTF. CT gave significantly higher tuber and haulm yields along with energy output, net returns of energy, energy efficiency, energy intensity and energy productivity over the years. NF + FYM recorded maximum plant emergence, tuber yield, haulm yield, energy output, net returns of energy and energy intensity, whereas energy efficiency and energy productivity had high values under NF without FYM.

Key words: *Solanum tuberosum* L., Tillage, Energetics, Organic farming, Natural farming

Potato (*Solanum tuberosum* L.) is traditionally grown during the summer and winter seasons in the hilly tract of Himachal Pradesh under rainfed and irrigated situations. The climatic conditions in many parts of the state offer excellent opportunity for producing both disease-free quality seed and table potato. Recent studies have shown that potato tubers can be predisposed to harvesting damage if certain soil conditions exist during the growing period. To meet the growing food demand of burgeoning population, the only possible approach is left to go for more productivity and profitability with limited resources. Tillage at different planting and growth stages of potatoes is a requirement and necessary for preparing a seedbed and for weed control. It has considerable influence on soil physical properties like pore space, structure, bulk density, water content and colour therefore, tillage practices have the greatest effect on seed germination, seedling emergence and stand establishment. Over the last few years' demand for healthier food and changing government policies on environmental security and safety for productive and sustainable agricultural ecosystems have promoted a rapid expansion of organic cultivation in the country (Patra *et al*. 2016). There has been growing public concern about negative impacts of chemical fertilizers and pesticides on environment and quality of produce (Parmar *et al*. 2007). Imbalance use of fertilizers not only reduces soil organic matter but adversely affects the human health especially in hilly regions, where majority of farming community in the rural areas drinks flowing water. This situation warrants opting to organic and natural farming practices for sustaining productivity of potato (Sarkar *et al*. 2011). Energy is also one of the most important factors of crop and production systems performance (Singh *et al*. 2008). Agriculture itself is energy user and energy supplier in the form of bio-energy. Energetics is a mean to quantify and determine relationship between output and input energy to augment crop productivity and energy use efficiency. The net return of energy in a production practices can be quantified for the sound planning of

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sustainable production practices (Chaudhary 2016). By using optimal level of energy input, yield of crop can be increased upto 30%. The energy was invested in farm machines, animal/human labour, seeds, fertilizers, water management, herbicides, fungicides, insecticides and various organic and inorganic inputs. Keeping these points in view, an investigation was undertaken to study the effect of tillage and production practices (organic and natural farming) on phenology parameters, yield and energetics of potato in Palampur condition.

Materials and Methods

The experiment was conducted at Model Organic Farm, Department of Organic Agriculture and Natural Farming of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur during *rabi* season of 2022-23 and 2023-24. The experimental farm is located at 32°14′ N latitude and 76°45′ E longitude perched in the lap of majestic snow clad Dhauladhar range of North-Western Himalayas at an elevation of 1290 m above mean sea level. The field was located in the Palampur valley of Kangra district under mid hills sub humid agro-climatic zone of Himachal Pradesh, India. The soil was sandy loam with pH 5.49, moderately fertile, being high in organic carbon (9.2 g/kg), low in available nitrogen (263.4 kg/ha), high in available phosphorus (26.3 kg/ha) and medium in available potassium (244.7 kg/ha). 464.3 and 323.4 mm rainfall were received during *rabi* 2022-23 and 2023-24, respectively. The experiment consisting of three tillage, *viz.* conventional tillage (with furrow); minimum tillage with furrow and minimum tillage flat-bed in the main plot treatments with three crop management practices (CMPs) *viz.* organic farming {Vermicompost @10 t/ha + biofertilizer (*Azospirillium* + PSB) + Vermiwash 250 l/ha}, natural farming {*Beejamrit* + *Jeevamrit* (500 l/ha) + *Ghanjeevamrit* (500 kg/ha) + Mulching (5-10 t/ha)}and natural farming {*Beejamrit* + *Jeevamrit* (500 l/ha) + *Ghanjeevamrit* (500 kg/ha) + Mulching (5-10 t/ha)}+ FYM (10 t/ha) were conducted under split plot design, having three replications. The recommended package of practices was used to serve as a basic guide especially for organic inputs, natural inputs and other cultural practices in planting of potato "*Kufri Jyoti"* variety under tillage and production practices in the present study. With a view to avoid the mixing of soil among different treatments, individual plots were thoroughly prepared by power tiller and manual labour. *Setaria* grass was used as the mulching material.

The data were recorded on phenology parameter i.e. plant emergence at 60 DAP as per the formula (Anonymous 1996). The tuber and haulm yields obtained from each plot were recorded in kilogram and then converted to tonnes per hectare. The energy input and output for human, machinery, farmyard manure, vermicompost, tuber seed and haulm for different treatments calculated by adding the energy requirement of inputs (Mittal *et al*. 1985).

$$\text{Plant emergence at 60 DAP \%} = \frac{\text{Number of tuber emergence per row}}{\text{Number of tuber planted per row}} \times 100$$

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

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

$$\text{Energy productivity kg/MJ} = \text{Biological yield kg/ha / Energy input (MJ/ha)}$$

$$\text{Energy intensity MJ/} = \text{Energy output MJ/ha / Cost of cultivation (/ha)}$$

The data were subjected to statistically analysis following Gomez and Gomez (1984) and the critical differences (CD) were assessed at $\leq$0.05.

Results and discussions

Crop phenology is the study of the periodic plant life cycle, which shows the length of survival of a crop in an environment. Days taken to emergence of plant, plant emergence at 60 DAP and physiological maturity remained unaffected by different tillage and production practices during both the years (Table 1). However, numerically, minimum days of tuber emergence and days taken to physiological maturity were recorded under MT (flatbed) followed by CT during both the years. It may be attributed due to the combination of improved soil structure, moisture retention, and stable environmental conditions under minimum tillage that contributes to quicker plant emergence (Saini and Poonia 2018). Similarly, Kaur *et al*. (2022) found higher values of growth parameters under conventional tillage + mulch (CT+M) as compared to other tillage practices whereas, CT had maximum emergence of plant at 60 DAP in 2022-23 and 2023-24 due to break up soil crusts, which can otherwise inhibit tuber emergence (Jat *et al*. 2008). Among organic and natural farming practices, NF +

Table 1. Effect of tillage and crop management practices on days taken to plant emergence, plant emergence at 60 DAP, days taken to maturity, tuber and haulm yield

Treatment	Days taken to plant emergence		Plant emergence at 60 DAP (%)		Days taken to maturity		Tuber yield (t/ha)		Haulm yield (t/ha)	
	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24
Tillage practices										
CT (with furrow)	32.7	33.2	90.34	89.00	146.1	147.4	14.56	13.84	0.802	0.775
MT (with furrow)	33.6	33.8	86.97	86.30	147.0	148.1	12.88	12.37	0.718	0.691
MT (flat bed)	31.1	32.1	84.95	82.93	144.9	145.8	11.42	11.09	0.625	0.617
SEm±	0.66	0.35	1.63	1.76	0.46	0.56	0.34	0.40	0.02	0.02
LSD (*P*=0.05)	NS	NS	NS	NS	NS	NS	1.35	1.55	0.06	0.08
Crop management practices										
Organic farming	32.6	33.1	87.65	86.30	146.1	147.1	12.89	12.30	0.718	0.693
Natural farming (NF)	32.9	33.6	85.62	84.28	146.6	147.6	12.27	11.90	0.688	0.664
NF + FYM	31.9	32.4	89.00	87.65	145.3	146.7	13.71	13.09	0.740	0.725
SEm±	0.43	0.36	0.91	0.91	0.36	0.25	0.20	0.13	0.01	0.01
LSD (*P*=0.05)	NS	NS	NS	NS	NS	NS	0.63	0.41	0.03	0.02

FYM: Farmyard manure DAP: Days after planting

FYM had the minimum days taken to plant emergence and maturity and maximum plant emergence at 60 DAP. It might be due to improvement in soil health, nutrient availability, water retention, and microbial activity that further contributes to quicker emergence and faster maturity of plants (Sundararajan and Pati 2016).

The data on tuber and haulm yield of potato revealed that CT produced maximum tuber and haulm yields, which was 27.5 and 11.7% higher in 2022-23, and 24.7 and 12.2% higher in 2023-24 over MT (flatbed), respectively (Table 1). It might be due to more number of tubers, better soil structure, minimum soil compaction, enhancing nutrient availability and uptake brought on by tillage (Djaman *et al*. 2022). Among the production practices, NF + FYM increased tuber and haulm yields and produced maximum tuber and haulm yields during both the years due to consistent nutrient supply, improves of soil health, enhancing of pest and disease resistance, and steady supply of nutrients through FYM, all of which contribute to higher potato tuber and haulm yields compared to organic farming systems (Verma et al. 2024). Similarly, Nasratullah *et al*. (2021) found higher yield with the application of *Ghanjeevamrit* + *Jeevamri*t + mulching over control and rest of the treatments.

Energetic is a mean to measure and ascertain the relationship between input and output energy to increase crop productivity and energy use efficiency. The energy output, net return of energy, energy efficiency, energy intensity and energy productivity obtained under various tillage and production practices are presented in Table 2. During both the years, tillage and production practices significantly affected the energy output, net return of energy, energy efficiency, energy intensity and energy productivity. CT had higher aforementioned energy parameters followed by MT (with furrow) during both the years. The variation in energy indices across the tillage methods can be attributed to differences in yield potential, crop management and environmental conditions over the two years. The highest energy output associated with CT could be likely due to cumulative improvement in soil health, enhanced moisture conservation and weed suppression from residue cover (Ghosh *et al*. 2022). The production practices gave significant variation in the energy indices (Table 2). Among them, significantly higher energy output (45815 and 43894 MJ/ha), net returns of energy (28056 and 26136 MJ/ha) and energy intensity (0.275 and 0.264 MJ/[1]) were obtained under application of NF + FYM during 2022-23 and 2023-24, respectively followed by organic farming practices. This indicated that the combination

Table 2. Effect of tillage and crop management practices on energetics

Treatment	Energy output (MJ/ha)		Net returns of energy (MJ/ha)		Energy efficiency		Energy intensity (MJ/[1])		Energy productivity (kg/MJ)	
	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24
Tillage practices										
CT (with furrow)	48781	46471	30849	28538	2.75	2.62	0.278	0.265	0.87	0.82
MT (with furrow)	43260	41526	25923	24189	2.52	2.42	0.252	0.242	0.79	0.76
MT (flat bed)	38252	37234	21271	20254	2.28	2.26	0.226	0.220	0.72	0.69
SEm±	1115.3	1301.2	1115.3	1301.2	0.07	0.07	0.007	0.008	0.02	0.02
LSD (*P*=0.05)	4378.6	5108.5	4378.6	5108.5	0.26	0.26	0.026	0.030	0.08	0.09
Crop management practices										
Organic farming	43259	41363	23464	21568	2.18	2.12	0.217	0.208	0.69	0.66
Natural farming (NF)	41218	39974	26523	25278	2.80	2.72	0.263	0.255	0.88	0.85
NF + FYM	45815	43894	28056	26136	2.58	2.47	0.275	0.264	0.81	0.78
SEm±	660.0	434.4	660.0	434.4	0.04	0.04	0.004	0.003	0.01	0.01
LSD (*P*=0.05)	2033.9	1338.7	2033.9	1338.7	0.13	0.11	0.013	0.008	0.04	0.03

FYM: Farmyard manure

of natural inputs with application of FYM promoted better crop growth, resulting in higher tuber yields, consequently, higher energy output, net energy and energy intensity (Kumar *et al*. 2015). Mujahed et al. (2021) also found higher energy output under organic farming practices which had higher main and by product over natural farming practices. Whereas, higher energy efficiency (2.80 and 2.72) and energy productivity (0.88 and 0.85 kg/MJ) were recorded under NF without FYM application due to presence of natural components, low input energy requirements and low yield. The energy efficient use of available resources resulted in better returns per unit of input energy. These are in line to the findings of Singh et al. (2013) and Kumar *et al*. (2015). The higher energy efficiency of a crop was mainly attributed to higher energy production with the use of relatively lesser energy utilization under a particular sowing method (Jain *et al*. 2007).

Conclusions

Conventional tillage with furrow planting system was the best tillage practices among tillage practices in terms of plant emergence (%), tuber yield, haulm yield, energy output, net returns of energy, energy efficiency, energy intensity and energy productivity. Whereas, minimum tillage with furrow planting system had better effect on days taken to emergence and days taken to maturity. Natural farming practices + FYM was proved to be the best treatment in terms of phenology parameters, productivity and energy efficient as compared to organic farming practices.

Conflict of interest: The authors declare no conflict of interest in relation to this review article.

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