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ENERGY SCENARIO IN WHEAT PRODUCTION AND POSSIBLE WAY TO CURTAIL ENERGY FOR TARAI CONDITION OF UTTARAKHAND, INDIA

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Abstract: The production and productivity are directly related with use in unit operation of agricultural production. The variation in yield of crop occurs in India due to wide variation in energy inputs, agro-climatic conditions and resources used. Keeping this in view, a study has been carried out to find the energy scenario of wheat crop and to optimize energy inputs for wheat production in Tarai region of Uttarakhand, India. The scenario shows, energy consumption was highest in tractor farm followed by mixed farm in wheat crop for Tarai region of Uttarakhand. In general, it was observed that fertilizer was the highest energy consuming source for wheat production. Threshing was highest energy consuming operation, which generally ranged from 31 to 36 per cent of total operational energy. The consumption of total energy ranged from 16308 to 20157 $MJ\cdot ha^{-1}$ for wheat crop in Tarai region. The yield and energy productivity of wheat crop can be improved by using optimum energy resource allocations obtained through optimization by 4150 to 6000 $kg\cdot ha^{-1}$ and 0.254 to 0.418 $MJ\cdot kg^{-1}$ respectively. Through use of optimization technique and recommended package of energy inputs the easily achievable yield in case of wheat is 6000 $kg\cdot ha^{-1}$ in Tarai region of Uttarakhand.

***Key words**: energy scenario, energy inputs, optimization, energy productivity*

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INTRODUCTION

Advance technology has created an energy intensive life style. Modern agriculture is no exception to it. India has become self sufficient in food production by adopting improved technologies in agriculture. The present level of production is an outcome of use of high yielding varieties of seeds, chemicals, fertilizers, pesticides, improved irrigation facilities, more area under irrigation, more area under crop, higher level of mechanization, better marketing facilities, well defined credit policies and support price of food grains. In our country (India) wheat production was 68.76 million tons in 2000-01. It has reached 94.88 million tons in 2011-12. The production and productivity is directly related with energy availability. This availability of power in Punjab is 3.5 $kW \cdot ha^{-1}$, which is highest in the country while average power availability in agriculture for whole country is 1.5 $kW \cdot ha^{-1}$. To obtain still more production and productivity, higher energy inputs and better management of food production is required. Energy is an essential input for economic development and improving the quality of life.

The development of conventional as well as non-conventional forms of energy is necessary for meeting the growing demand of energy needs of society. The power generation in India has increased from 1400 MW in 1947 to 2.00 Lakhs MW at the end of 2010-11, which is comprised of power from hydroelectric, thermal, wind and nuclear power stations. The power availability for production agriculture in India is 1.5 $kW \cdot ha^{-1}$ and lies higher its requirement in Punjab which is about 3.5 $kW \cdot ha^{-1}$. In comparison of above Japan is the highest energy consuming country, where the energy input to agriculture production is 14.0 $kW \cdot ha^{-1}$. The optimization of energy inputs in agricultural production by some researchers have shown that all kind of energies are interrelated to each other in crop production.

Ozkan and Firsby (1981) [4] used linear programming technique for optimizing power level and matching implements on multi cropped farm growing corn, soybean, wheat and alfalfa. The authors found that the initial conditions of the farm could be revised to increase net energy return by 30 per cent. Mishra *et al.* (1989) [2] studied the energy requirements for growing wheat after harvesting of paddy with different machinery management systems being used in Nainital district. Energy inflow ranged 15.3 to 17.4 $GJ \cdot ha^{-1}$ and outflow of 77.0 to 106.5 $GJ \cdot ha^{-1}$. Gupta *et al.* (1992) [1] conducted the experiments at Pantnagar to find out energy use in maize-wheat rotation using different tillage treatments. Maximum yield of 4683 $kg \cdot ha^{-1}$ (output energy 70531 $MJ \cdot ha^{-1}$) of wheat was found with tillage treatment of one pass of harrow plough + two pass of harrow and two pass of wooden leveler. The output-input energy ratio for grain was 3.6 and by-product 8.2.

Singh and Singh (1996) [3] conducted survey in Meerut district of Northern India on energy requirement in production of wheat and maize crop. Fertilizer energy input was found to affect wheat and maize yield more than irrigation energy while irrigation energy input was most influencing on sugarcane. In general crops yield did not show any direct relation with tillage energy. The study on energy optimization in crop production is highly scanty using linear programming especially in Uttarakhand. Management for energy use in crop production is highly essential to prevent leakage.

MATERIAL AND METHODS

Study has been carried out to find the energy scenario of wheat crop and to optimize the energy inputs for wheat in Tarai region of Uttarakhand. The data were collected on prescribed proforma using multistage sampling technique by individual interviewing method including all categories of farmers. The selected villages were Phoolsungi and Khamariya in Tarai region of Uttarakhand. Under All India Coordinated Research Project "Energy Requirement in Agricultural Sector" energy data were collected from the selected villages of Tarai region of Uttarankhand in the years 1986-87, 1995-96, 1996-97 and 2000-2001. These survey years were termed as first, second, third and fourth round of survey respectively for wheat crop in Tarai region. The informations collected from the farmers were transformed into computer data sheet as per requirement of energy calculation, and results were obtained from energy FORTRAN-77 computer programmes. The analysis carried out in MS Excel and energy scenario was prepared for wheat crop. The statistical analysis was performed with SPSS 7.5 computer software programme using linear regression model. The outlier points were removed. After removal of outlier points the optimization of energy inputs was done using linear programming technique of What's Best 4.0 package with the simulated energy inputs data sets.

Table 1. Energy calculation

Yield =	$\sum_{i=1}^{n} Y_i X_i^*$	*Human energy =*	$\sum_{i=1}^{n} h_i X_i^*$
Animal energy =	$\sum_{i=1}^{n} an_i X_i^*$	*Diesel energy =*	$\sum_{i=1}^{n} d_i X_i^*$
Electrical energy =	$\sum_{i=1}^{n} e_i X_i^*$	*Seed energy =*	$\sum_{i=1}^{n} s_i X_i^*$
Fertilizer energy =	$\sum_{i=1}^{n} f_i X_i^*$	*Machine energy =*	$\sum_{i=1}^{n} m_i X_i^*$
Chemical energy =	$\sum_{i=1}^{n} c_i X_i^*$	*Total energy =*	$\sum_{i=1}^{n} t_i X_i^*$

where $t_i = h_i + an_i + d_i + e_i + f_i + s_i + m_i + c_i$

Total energy is the sum of the energy usage from different sources.

To maximizing the yield, data were analyzed with the help of linear programming (L.P).

$$Maximize\ yield = \sum_{i=1}^{n} Y_i X_i \qquad (1)$$

Where:

Y_i [kg·ha^{-1}] - yield level per activity,

X_i [ha^{-1}] - farm area per activity.

Subject to constraints the upper limit of energy sources used by the farmers. When no explicit lower bounds are specified, LP assumes lower bounds are zero.

RESULTS AND DISCUSSION

Changing scenario of energy use pattern in wheat cultivation

The data collected from selected villages of Tarai region for four rounds of survey were analyzed and compared for wheat crop with the first round of survey. Source wise, operation wise, use of different implements/equipments and significance of different sources on wheat production is discussed for mixed and tractor farms and animal farms is not discussed as these were not available.

Source wise energy use pattern in wheat cultivation for tractor farms with four rounds of survey results is presented in Tab 2. It is evident from this table that tractor farms were present in each round of survey in the study area. The tractor farms decreased from 83 to 78 in numbers within time span of 1986 to 2000 year because of combining of the some tractor farms. Whereas mixed farms decreased from 4 in first round to 2 in fourth round in the same period. These farms have been changed to tractor farms with pace of time. Table 1 show that the total energy use in tractor farms for wheat production has decreased by 2.26%, 0.10% and 19.09% in second, third and fourth round with respect to first round of survey, respectively. The overall use of human energy has decreased by 34.73% in fourth round with respect to first round of survey whereas it has decreased by 35.74% and 3% in second and third round of survey with respect to first round. It is due to increased use of matching implements with power source. The use of diesel energy has decreased by 9.43%, 8.97% and 31.73% in second, third and fourth round of survey respectively due to above cited reason. The use of electric energy has increased by 13.56%, 23.23% and decreased by 38.41% in second, third and fourth round of survey with respect to first round of survey respectively due to availability of electric supply in the area. Use of seed energy has decreased by 5.79%, 5.21% and 12.38% in second, third and fourth round with respect to first round of survey respectively due to use of efficient and certified seeds. Fertilizer energy use has increased by 3.65% and 10.72% in second and third round with respect to first round of survey to increase the yield of wheat crop whereas it was more or less constant in third round. The chemical energy has decreased by 79.85%, 79.04% and 82.35% in second, third and fourth round with respect to first round of survey respectively due to use of disease resistant high yielding varieties. Use of machinery energy has increased by 19.96% in second round with respect to first round of survey whereas it has decreased by 1.85% and 11.61% in third and fourth round of survey due to use of improved implements. The use of canal energy has increased by 40.05%, 18.86% and decreased by 11.50% in second, third and fourth round respectively with respect to first round of survey depending upon the availability of water in canal and requirement. Canal is the cheapest source of water for irrigation purpose. The use of direct energy has decreased by 5.64%, 1.24% and 33.54% in second, third and fourth round of survey with respect to first round respectively. Indirect energy has decreased by 11.32% in fourth round of survey with respect to first round. The energy productivity has increased by 15.86%, 17.60% and 64.68 in second, third and fourth round with respect to first round of survey due to increase use of fertilizer and better quality seeds in wheat cultivation

Table 2. Source wise energy use pattern in wheat cultivation on irrigated tractor farm in Tarai region of Uttarakhand ($MJ·ha^{-1}$)

Source	I Round	II Round	III Round	IV Round	%Change in II round w.r.t. 1st round	%Change in III round w.r.t. 1st round	%Change in IV round w.r.t. 1st round
Human	399	257	387	253	-35.74	-3.00	-36.69
Diesel	5029	4555	4578	3434	-9.43	-8.97	-31.73
Electric	1619	1839	1995	997	13.56	23.23	-38.41
Seeds	1746	1645	1655	1530	-5.79	-5.21	-12.38
Fertilizer	7963	8254	8817	7975	3.65	10.72	0.15
Chemical	1255	253	263	221	-79.85	-79.04	-82.35
Machinery	522	626	512	461	19.96	-1.85	-11.61
Canal	1624	2274	1930	1437	40.05	18.86	-11.50
Total($MJ·ha^{-1}$)	20157	19702	20138	16308	-2.26	-0.10	-19.09
Direct	7048	6650	6961	4684	-5.64	-1.24	-33.54
Indirect	13110	13052	13177	11625	-0.44	0.52	-11.32
Renewable	2146	1902	2043	1783	-11.36	-4.80	-16.91
Nonrenewable	18012	17801	18096	14526	1.17	0.46	-19.35
Commercial	19758	19446	19751	16056	-1.58	-0.04	-18.74
Noncommercial	399	257	387	253	-35.74	-3.00	-36.69
Energy productivity	0.155	0.179	0.182	0.254	15.86	17.60	64.68
Yield ($kg·ha^{-1}$)	3115	3527	3660	4150	13.25	17.49	33.23

The operation wise energy use in wheat cultivation for tractor farms with four rounds of survey results is presented in Tab. 3. It is evident from this table that the total energy used in different operations has increased by 13.18% and 5.32% in second and third round whereas it has decreased by 9.73% in fourth round with respect to first round of survey as presented in Tab. 3. The use of tillage energy has decreased by 9.68%, 13.55% and 43.90% in second, third and fourth round of survey with respect to first round due to increase in use of matching implements with power source. Sowing energy was more or less constant in second and third round whereas it has decreased by 16.76% in fourth round survey with respect to first round. The use of irrigation energy has increased by 10.98%, 8.81% and decreased by 25.86% in second, third and fourth round with respect to first round of survey due to demand of water by high yielding varieties of wheat and efficient use of water. Spraying energy has increased by 5.04%, 254.24% and 147.49% in second, third and fourth round with respect to first round of survey due to increase use of herbicide. Weeding energy was more or less constant in last three rounds of survey. The use of harvesting energy has increased by 128.36%, 34.02% and 67.42% in second, third and fourth round with respect to first round of survey whereas threshing energy has also increased by 18.62%, 7.51% and 32.0% in the same period with respect to first round of survey due to increase in production of wheat crop. Transportation energy has increased by 152.95%, 34.62% and 172.24% in second, third and fourth round of survey with respect to first round of survey which is obvious due to increase in transportation of main product and by product.

Table 3. Operation wise energy use pattern in wheat cultivation on irrigated tractor farm in Tarai region of Uttarakhand ($MJ.ha^{-1}$)

Operations	I Round	II Round	III Round	IV Round	%Change in II round w.r.t. Ist round	%Change in III round w.r.t. Ist round	%Change in IV round w.r.t. Ist round
Tillage	2944	2659	2545	1651	-9.68	-13.55	-43.90
Sowing	393	396	396	327	0.74	0.69	-16.76
B.M	0	0	117	24	0.00	0.00	0.00
Irrigation	2007	2228	2184	1488	10.98	8.81	-25.86
Weeding	0	114	193	111	0.00	0.00	0.00
F.A.	16	13	21	10	-19.44	38.32	-34.59
Spray	5	6	19	13	5.04	254.24	147.49
Harvesting	384	876	514	642	128.36	34.02	67.42
Threshing	1849	2194	1988	2441	18.62	7.51	32.00
Transportation	82	208	111	224	152.95	34.62	172.24
Total ($MJ \cdot ha^{-1}$)	7680	8692	8088	6932	13.18	5.32	-9.73

The regression coefficients for different sources of energy impacts were determined The seed energy has been found significant at 1% level of significant (*LOS*) and machinery energy at 5% *LOS* in first round of survey. The canal, chemical, diesel, fertilizer, human and machinery energy have been found significant at 1% *LOS* in second round of survey. The diesel, electrical and fertilizer energy have been found significant at 1% *LOS* in third round of survey whereas human energy is significant at 5% *LOS* in third round of survey. The chemical and seed energies have been found significant at 5% *LOS* in fourth round of survey whereas fertilizer energy and human energy is significant at 1% and 10% *LOS* in fourth round of survey respectively.

Energy use pattern for mixed and tractor farms in Tarai region of Uttarakhand for wheat cultivation at last round of survey

A comparison has been made to represent the overall energy use pattern in mixed and tractor farms for fourth round of survey in Tarai region of Uttarakhand. Animal farms are not included because no farm in this category was available. It is clear that out of total energy consumption in wheat cultivation the most energy consuming source was fertilizer (48.89 to 58.11%), followed by diesel (9.03% to 21.06%), seed (9.38% to 10.40%), canal (8.81% to 8.91%), animal (0% to 6.30%), electric (0% to 6.11%), human (1.55% to 3.95%), machinery (1.89% to 12.83%) and chemical energy (1.36% to 1.42%). The yield of wheat was higher in tractor farms (4182 $kg \cdot ha^{-1}$) followed by mixed farms (3872 $kg \cdot ha^{-1}$).

Comparison of operation wise energy use in mixed and tractor farms for wheat cultivation in fourth round of survey for Tarai region shows that threshing energy has consumed the highest share (31.97% to 35.22%) out of total operational energy followed by tillage energy (23.82% to 25.1%), irrigation energy (21.47% to 26.57%), harvesting energy (8.59% to 9.26%), sowing energy (4.42% to 4.72%), transportation energy (2.57% to 3.23%), weeding energy (0 to 1.6%), bund making energy (0.35% to 0.41%), spraying energy (0.19 to 0.21%) and fertilizer application energy (0.14% to 0.16%) respectively.

Optimization of energy inputs in production of wheat crop

In the prevalent crop production system there exists a scope of improvement in terms of net energy return and energy efficiency. There is a possibility that an increase up to a certain limit in crop production inputs would cause an increase in crop output also. The farmers may not always be able to use more inputs because of their high prices. To bring forth better results from the existing energy use patterns, it is thus suggested that optimization of existing energy inputs be done with the simulated data sets. In view of this energy data sets have been optimized using linear programming technique by maximization of objective function i.e. yield of wheat crop under the given set of energy input (s) constraints. The optimization has been done for wheat crop in Tarai region of Uttarakhand. The models are formulated assuming linear crop production function and constraints so that liner programming could be used to obtain the optimal solution. The optimal allocation would, thus indicate the utilization of energy input resources on the farm for a particular crop with saving of energy resources wherever possible. The optimization has been done only for present actual farm practice with simulated energy input data. The average energy use in tractor farms for wheat cultivation in Tarai region of study area is presented in Tab. 4. The average yield of wheat crop has been found 4150 kg.ha-1 in study area under actual farm cultivation. The sources used in wheat cultivation are human, diesel, electric, seeds, fertilizer, chemical, machinery and canal. The fertilizer energy and diesel energy are main energy consuming sources in wheat cultivation. The share of human, diesel, electric, seeds, fertilizer, chemical, machinery and canal energy input is 1.55%, 21.06, 6.11, 9.38, 48.90, 1.36, 2.82 and 8.81 percent respectively. The average energy productivity has been found 0.254 $kg{\cdot}MJ^{-1}$. Use of electricity is only in irrigation and threshing of wheat crop.

Table 4. Source wise average energy use pattern ($MJ{\cdot}ha^{-1}$) in wheat cultivation under actual farm practices for irrigated tractor farm in Tarai region of Uttarakhand

Yield ($kg{\cdot}ha^{-1}$)	*HUM*	*ANI*	*DSL*	*ELE*	*SEEDS*	*FYM*	*FER*	*CHE*	*MACH*	*CAN*	*TE*	*E.PROD*
4150	*253*	*0*	*3434*	*997*	*1530*	*0*	*7975*	*221*	*461*	*1437*	*16308*	*0.254*

The Tab. 5 represents optimum energy resource allocation with maximum yield under actual farm practice i.e. existing farm practice. The yield of wheat has increased by 30.98% from 4150 to 5436 $kg{\cdot}ha^{-1}$ due to use of optimum energy resource allocation in actual farm practice. The consumption of energy inputs would save 44.27% human, 22.95% diesel, 29.39% seeds, 33.03% chemical and 1.30 % machinery energy as compared to existing farm practice used in wheat cultivation whereas the energy input consumption of seed and fertilizer energy input has exceeded by 6.86% and 2.01% respectively. The more seed energy is required to increase the population of plants in the field while fertilizer energy use is more for increasing the yield of wheat. Thus the total energy used in optimized wheat cultivation has decreased by 14.99% from 16308 to 13864 MJ·ha^{-1}. The energy productivity has increased by 54.33% from 0.254 to 0.392 kg·MJ^{-1} on using optimized energy resource allocation. Thus the energy efficiency can be improved by using quality seeds, better fertilizer combinations, better seed bed preparation, tool combination and use of matching implements with the tractor.

Table 5. Maximum yield and optimum energy resource consumption (MJ.ha^{-1}) under existing farm practices for irrigated tractor farm in Tarai region of Uttarakhand

Yield (kg·ha^{-1})	HUM	ANI	DSL	ELE	SEEDS	FYM	FER	CHE	MACH	CAN	TE	E.PROD
5436	141	0	2646	704	1635	0	8135	148	455	0	13864	0.392

The Tab. 6 shows optimum energy resource allocation with maximum potential yield in wheat cultivation. This set of energy input has been obtained by optimizing the energy inputs with simulated data sets. The yield of wheat crop has increased by 44.58% from 4150 to 6000 kg·ha-1 as compared to actual farm practice average yield. For achieving the potential yield in tractor farms, farm operations would require 24.51% more human energy, 18.14 less diesel energy, 11.74% less electric energy, 9.22% more seed energy, 0.82% more fertilizer energy, 34.39% more chemical energy and 23.43% less machinery energy. The use of canal energy is nil because it does not supply water throughout the year timely. The optimized resource allocation with the simulated data sets can improve the energy productivity by 64.57% from 0.254 to 0.418 kg·MJ^{-1} in tractor farm.

Table 6. Maximum potential yield and optimum energy resource allocation (MJ·ha^{-1}) for irrigated tractor farm in Tarai region of Uttarakhand

Yield (kg·ha^{-1})	HUM	ANI	DSL	ELE	SEEDS	FYM	FER	CHE	MACH	CAN	TE	E.PROD
6000	315	0	2811	880	1671	0	8041	297	353	0	14368	0.418

Table 7. Source wise/operation wise energy use pattern for different levels of productivity with improved cultivation practices in wheat crop cultivation for tractor farm in Tarai region of Uttarakhand

Yield (kg·ha^{-1})	E.PROD (kg·MJ^{-1})	Source wise direct energy consumption (MJ·ha^{-1})				Operation wise energy consumption (MJ·ha^{-1})					
		HUM	ANI	DSL	ELE	TIL	SOW	IRR	HAR	THR	TRP
6000	0.418	315	0	2811	880	0	686	2884	611	0	125
5500	0.414	189	0	2700	663	645	439	1935	713	0	169
5000	0.406	120	0	2357	743	1081	286	1282	756	0	196
4500	0.383	130	0	1977	833	1182	286	1159	740	0	208
4000	0.347	115	0	2138	171	1296	286	1103	788	0	240
3500	0.299	139	0	2556	1294	1630	390	1483	847	0	186
3169	0.213	315	0	3356	1073	1485	415	1279	499	1193	225

The different yield levels achievable with their energy productivity are presented in Tab. 7. The source wise direct energy consumption and main operation wise energy consumption for wheat cultivation are given as obtained by optimizing the energy inputs. It shows a trend that the energy productivity decreases (from 0.418 to 0.213 kg·MJ^{-1}) with decrease in yield levels (from 6000 to 3169 kg·ha^{-1}). It is due to need of more energy inputs with lower yield levels.

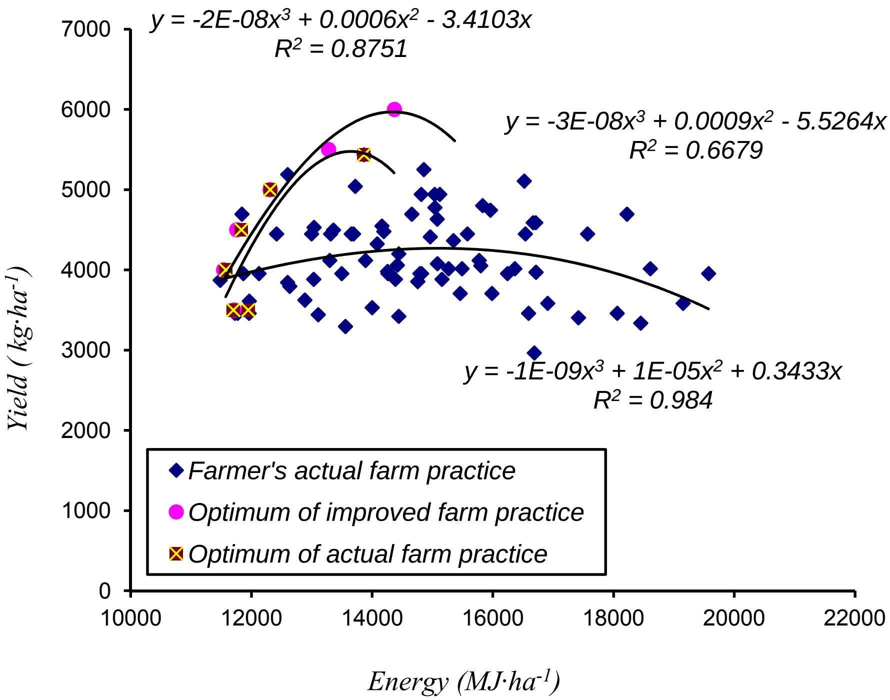

Figure 1. Optimum energy use patterns for different levels of wheat productivity for irrigated tractor farm in Tarai region of Uttarakhand

Fig. 1 represents the total energy use models for farmer's actual farm practice, optimum of actual farm practice and optimum of improved farm practice. It is clear from the trend lines that the optimum of actual farm practice can save the energy in wheat cultivation with increase in yield of wheat crop. The trend line of optimum of improved farm practice further shows that energy used in wheat cultivation can save energy over the optimum actual farm practice with the increase in yield of wheat.

CONCLUSIONS

Thus keeping in view above study, the following conclusions may be drawn:

1. The seed energy and human energies are more or less constant in mixed farms and tractor farms but human energy in mixed farms ranged 430 to 990 MJ·ha^{-1}.

2. The use of total energy use in wheat cultivation has ranged from 16308 to 20157 $MJ \cdot ha^{-1}$ while diesel, electric and fertilizer energy consumption has ranged from 3434-5029, 997-1995 and 7963-8817 $MJ \cdot ha^{-1}$ respectively.
3. The total operational energy use in wheat cultivation has ranged from 6932 to 8692 $MJ \cdot ha^{-1}$ while tillage, irrigation and threshing energies have ranged from 1651-2944, 1488-2228 and 1849-2441 $MJ \cdot ha^{-1}$ respectively.
4. The yield of wheat crop can be increased by 44.58% from 4150 to 6000 $kg \cdot ha^{-1}$ with 11.89% less total energy input (from 16308 to 14368 $MJ \cdot ha^{-1}$) of optimum energy resource allocation with optimum of improved farm practice over actual farm practice in wheat cultivation of tractor farm.
5. The energy productivity of wheat crop can be improved by 64.57% from 0.254 to 0.418 $kg \cdot MJ^{-1}$ with the optimum of improved farm practice over actual farm practice in tractor farm.

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ENERGETSKI SCENARIO U PROIZVODNJI PŠENICE I MOGUĆNOST SMANJENJA POTROŠNJE ENERGIJE U USLOVIMA TARAI UTTARAKHANDA, INDIJA

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Sažetak: Proizvodnja i produktivnost su direktno povezani sa upotrebom u jediničnim operacijama poljoprivredne proizvodnje. Varijacije u prinosima u Indiji se pojavljuju zbog velikih variranja energetskih inputa, agro-klimatskih uslova i iskorišćenih resursa. Imajući ovo u vidu, izvedeno je istraživanje da bi se našao energetski scenario proizvodnje pšenice i optimizovali energetski inputi u proizvodnju pšenice u regionu Tarai u Uttarakhand, Indija. Scenario pokazuje da je potrošnja energije bila najveća na farmama sa traktorima, a zatim na mešovitim farmama u ovom regionu. Generalno, uočeno je da je đubrivo bilo najveći potrošač energije u ovoj proizvodnji. Vršidba je bila operacija sa najvećom potrošnjom energije, koja je generalno iznosila 31 do 36% od ukupne energije u svim operacijama. Ukupna potrošnja energije u ovom region iznosila je od 16308 do 20157 MJ·ha^{-1}. Prinos i energetska produktivnost pšenice mogu da se unaprede upotrebom energetskih resursa sa optimalnih lokacija, dobijenih optimizacijom za 4150 do 6000 kg·ha^{-1} i 0.254 do 0.418 MJ·kg^{-1}, redom. Upotrebom tehnike optimizacije i preporučenog paketa energetskih inputa lako je postići prinos pšenice od 6000 kg·ha^{-1} u Tarai regionu Uttarakhanda.

Ključne reči: *energetski scenario, energetski inputi, optimizacija, energetska produktivnost*

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