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Productivity, Profitability, Nutrient Uptake and Energetics of Wheat (*Triticum aestivum* L.) Cultivars as Influenced by Varying Cultivation Methods and Fertility Levels

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ABSTRACT

A field experiment consisting of 2 methods of cultivation *viz.* system of wheat intensification and conventional method; 2 fertility levels (80:40:20 kg N:P_2O_5:K_2O ha^{-1} and 120:60:40 kg N:P_2O_5:K_2O ha^{-1}) and 5 wheat cultivars (K 9107, Birsa Gehu 3, HUW 468, HUW 234 and K 0307) was conducted at the University Research Farm of Birsa Agricultural University, Kanke, Ranchi, Jharkhand, India during winter (*rabi*) season of 2009–10 and 2010-11 to find out their effect on growth attributes, yield attributes, yield, economics, nutrient uptake and energetics of wheat. The experiment was laid out in factorial randomized block design of 2 X 2 X 5 with 20 treatment combinations and 3 replication. System of wheat intensification exhibited significantly higher growth and yield attributes *viz.* tillers number m^{-2}, leaf area index, dry matter accumulation, spikes number m^{-2}, filled grains spike^{-1}, spike length, spike weight and 1000 grain weight which led to significantly higher grain yield, straw yield, net return, benefit: cost ratio and NPK uptake. Significant enhancement in gross energy output, net energy return, energy use efficiency, energy productivity and minimum energy input and specific energy was recorded with system of wheat intensification than conventional method. Higher fertility level of 120 kg N + 60 kg P_2O_5 + 40 kg K_2O ha^{-1} significantly increased the growth attributes, yield attributes, grain yield, straw yield, net return, benefit: cost ratio, NPK uptake, energy output, net energy return and energy use efficiency over lower fertility level i.e. 80:40:20 kg N: P_2O_5: K_2O ha^{-1}. Among cultivars, K 9107 being comparable to HUW 234 led to significantly higher growth and yield attributes and finally the grain yield, straw yield, net return, benefit: cost ratio, NPK uptake, energy output, net energy return, energy use efficiency and energy productivity than K 0307, HUW 468 and Birsa Gehu 3.

Keywords

Economics, energetics, net returns, nutrient uptake, productivity

Introduction

Agricultural production being an interactive effect of soil-water- fertilizer-climate continuum, a wise scientific management of this complex system is crucial for enhancing crop productivity on a sustained manner without giving any detrimental effect on the environmental ecology. The irrigated ecosystem sharing major part of the wheat area is now threatened by issues like resource degradation, declining productivity, escalating input cost and diminishing return. However, our country need further higher production to feed the ever increasing population at a rate of 1.8 per cent annually which warrants increased productivity of wheat to meet the targeted requirement of around 109.0 million tonnes by the year 2025 AD. This can be achieved only through changes in management practices to exploit the soil-water-fertilizer-climate continuum effectively. System of wheat intensification which is an extrapolation of SRI system of rice involving adoption of set of agronomic practices, has the potential for improvement in yield and factor productivity by changing some of the plant, soil, water and nutrient management practices. Almost all the wheat cultivars respond positively to system of wheat intensification resulting in higher yield than conventional method. However, there exists wide scale variability among wheat genotypes in response to SWI cultivation as top yielders in conventional method are not always superior under SWI. Hence, there was a need to evaluate wheat cultivars for their suitability under system wheat of intensification. Therefore, it is high time to strengthen the research programme on such management technology like system of wheat intensification not only to maximize production but also to make it sustainable. Keeping all these points in view, the present investigation was planned to study the effect of different methods of crop establishment at varied fertility levels on wheat cultivars in order to identify suitable wheat genotype and appropriate fertility level separately for existing method of cultivation and system of wheat intensification (SWI) grown in medium land soil of Jharkhand.

Materials and Methods

A field experiment was conducted at the University Research Farm of Birsa Agricultural University, Kanke, Ranchi during winter (*rabi*) season of 2009–10 and 2010-11. The soil was sandy loam (sand, silt and clay contents of 53.7, 30.2 and 13.8% respectively), having *p*H 5.6, organic carbon 3.7 g kg^{-1} of soil and available NPK were 253.4, 12.2, 155.0 kg ha^{-1}, respectively. The treatment consisting of two cultivation methods (System of wheat intensification and conventional method), two fertility levels (80:40:20 kg N: P_2O_5: K_2O ha^{-1} and 120:60:40 kg N: P_2O_5: K_2O ha^{-1}) and five wheat cultivars (K 9107, Birsa Gehu 3, HUW 468, HUW 234 and K 0307) in randomized block design replicated thrice. System of wheat intensification involves seed treatment with 60^0C hot water (20 litre per 10 kg seed) for ½ hour, removal of infertile and damaged seeds, seed soaking with mixture of cow urine, vermicompost and jaggery @ 4 litre, 5 kg and 4 kg per 10 kg of wheat seed respectively for 8 hours and left overnight in moist jute bag to break the dormancy of seeds.

Single seed was sown at row to row and plant to plant spacing of 20 X 20 cm, use of 5 tonnes of FYM ha^{-1}, irrigation was done at 15, 25, 35, 65, 85 and 105 days after sowing, $^1/_3$ of nitrogen and full dose of phosphorus and 50 per cent potash was applied at sowing and rest 2/3 of nitrogen was applied in two split after 2 days of 1^{st} and 3^{rd} irrigation. 50 per cent of the potash was applied at panicle initiation. Weeding by using mechanical weeder was done at 3-4 days after 1^{st}, 2^{nd} and 3^{rd} irrigation after fertilizer top dressing. In conventional method seeds of particular cultivar were sown in regular rows of 20 cm with seed rate of 125 kg ha^{-1}. Full dose of P_2O_5 and K_2O along with $^1/_3$ of the nitrogen was applied as basal application as per treatment. The remaining $^2/_3$ of nitrogen was top dressed in two equal splits at 20 and 40 days after sowing. Altogether six irrigation were applied at 20 days interval throughout the crop growth period. Two hand weeding were done at 20 and 40 days after sowing. Need-based plant protection measures were adopted. The plants from net plot area were harvested, threshed and cleaned. After complete sun drying the grain weight of each net plot was recorded and converted to kg ha^{-1}. After threshing, the cleaned grain yield was deducted from the bundle weight for obtaining straw yield of each net plot area and converted to kg ha^{-1}. The nutrient uptake was estimated by multiplying the nutrient concentration with the grain and straw yield. The data were subjected to statistical analysis as prescribed by Gomez and Gomez (1984) and significant effects were presented. The economics were computed on the basis of prevailing market rates of produce and agro-inputs. The net return was calculated by subtracting total cost of cultivation from gross return. The benefit: cost ratio was calculated by dividing the net return by the cost of cultivation.

Energy input was calculated from the recorded data for each item of operations and expressed in MJ ha^{-1} for each treatment using standard values suggested by Paneshar and Bhatnagar (1994). The net energy output was calculated by subtracting energy input from gross energy output.

It is expressed in MJ ha^{-1}. Energy use efficiency is energy produced by per unit energy consumed. It was calculated by using the following formula.

$$\text{Energy use efficiency} = \frac{\text{Energy output}}{\text{Energy input}}$$

Specific energy is the amount of energy required to produce one tonne of grain. It was calculated by using the following formula.

$$\text{Specific energy (MJ } t^{-1}) = \frac{\text{Energy input (MJ } ha^{-1})}{\text{Grain yield of crop (t } ha^{-1})}$$

Results and Discussion

Growth attributes

System of wheat intensification had significantly higher tiller numbers, leaf area index, dry matter accumulation (Table 1) than conventional method of cultivation, as under wider spacing under system of wheat intensification each individual plant effectively utilized the more available resources which resulted in enhanced tiller production, leaf area index and dry matter accumulation as compared to conventional method. The method of cultivation failed to cause significant variation in plant height. However, conventional method of cultivation had higher plant height than SWI method as dense plant population in conventional method favour the vertical growth of plant in search of light while, greater spacing provided in system of wheat intensification leading to lesser competition between the plants thus favouring horizontal spread to utilize the available space resulting in shorter plant than conventional method

Increasing fertility level increased the growth attributes and maximum plant height, tillers number, leaf area index and dry matter accumulation were observed with 120 kg N ha^{-1}, 60 kg P_2O_5 ha^{-1} and 40 kg K_2O ha^{-1} as compared to lower rate of application. As such, higher fertility level increased the supplying capacity of the soil which in turn resulted in a better growth rate eventually leading to higher plant height, tillers number, leaf area index and dry matter accumulation.

Among cultivars, K 9107 produced significantly higher plant height and number of tillers m^{-2} than HUW 234, K 0307, HUW 468 and Birsa Gehu 3 as the cultivar differ in their ability to produce tillers and plant height due to differences in genetic constitution. The leaf area index of wheat cultivar K-9107 was also recorded significantly higher than other cultivar as the cultivar with higher number of tillers putting forth more leaves resulting in higher leaf area index. Among the cultivars, K 9107 and HUW 234 due to higher tiller number and leaf area index, led to higher dry matter accumulation than Birsa Gehu 3, HUW 468 and K 0307. Bhardwaj *et al.,* (2010) also reported significant variation in plant height, tillers number, leaf area index and dry matter accumulation among the different cultivar tested.

Yield attributes

System of wheat intensification significantly improve the yield attributes viz. spikes number m^{-2}, spike length, filled grains per spike, spike weight and 1000 grain weight (Table 3) over conventional method of cultivation. This may be attributed to adequate availability and supply of resources under system of wheat intensification and their translocation along with other nutrients to the sink.

The changes in the management could form more photosynthetic organ, strengthen photosynthetic ability, produce higher dry matter and provide sufficient nutrient to sink continually making the seed more plump, increased 1000-grain weight, seed setting percentage and filled grains per panicle (Lu *et al.,* 2005) under system of wheat intensification.

Significant improvement in yield attributes i.e. spikes m^{-2}, spike length, filled grains per spike, spike weight and 1000 grain weight was recorded with application of 120+60+40 kg $N+P_2O_5+K_2O$ ha^{-1} over 80+40+20 kg $N+P_2O_5+K_2O$ ha^{-1}. In plant well supplied with N, P_2O_5 and K_2O, senescence of flag leaf is delayed and increases the CO_2 assimilation rate resulting in more supply of photosynthates which led to higher number of effective tillers and grains per spike while, lower supply of nitrogen and potassium also induced the synthesis of absicisic acid (ABA) leading to smaller grains responsible for lower thousand grain weight (Kausik *et al.,* 2016).

Among cultivars, K 9107 was found significantly superior to other cultivars but remained at par with HUW-234 in respect of number of spikes m^{-2}, grains per spike and 1000-grain weight. This might be due to better vegetative growth which favoured effective translocation of photosynathate resulting in higher yield attributes.

Grain and straw yield

System of rice intensification had pronounced effect on grain and straw yield (Table 3) as system of wheat intensification recorded the maximum and significantly higher grain and straw yield of wheat which was 10.53% and 6.35%, respectively higher over conventional system of wheat cultivation. The higher yield under system of wheat intensification was due to adequate supply of resources which contributed towards higher dry matter accumulation and better partitioning of photosynthate resulting in higher yield traits and ultimately the yield. Better vegetative growth which contributed towards higher dry matter accumulation resulting in significantly higher straw yield under system of wheat intensification. The physical productivity and biomass production rate were also significantly higher under system of wheat intensification than conventional method of wheat production system. However, the cultivation methods *viz.* system of wheat intensification and conventional method failed to cause significant variation in harvest index.

Wheat receiving higher fertility levels of 120 kg N ha^{-1}, 60 kg P_2O_5 ha^{-1} and 40 kg K_2O ha^{-1} gave significantly higher grain and straw yield than 80:40:20 kg N:P_2O_5:K_2O ha^{-1} fertility level. Application of higher fertility levels *i.e.* 120 kg N ha^{-1}, 60 kg P_2O_5 ha^{-1} and 40 kg K_2O ha^{-1} enhanced the grain and straw yield by was also recorded on grain yield and straw yield by 21.5% and 13.49%, respectively in comparison of 80:40:20 kg N:P_2O_5:K_2O ha^{-1} fertility level (Table 3).

The higher value of grain yield of wheat at higher fertility level may be owing to greater availability of nutrient in soil, improvement of soil environment resulting in higher root proliferation leading to better absorption of moisture and nutrient and ultimately resulting in higher grain and straw yield (Kumari *et al.,* 2013). Significant enhancement in harvest index, physical productivity and biomass production rate was also recorded with application of higher fertility level of 120:60:40 kg N: P_2O_5: K_2O ha^{-1} over 80:40:20 kg N: P_2O_5: K_2O ha^{-1} fertility level.

Among wheat cultivars, K 9107 produced maximum and significantly higher grain and straw yield than K 0307, HUW 468 and Birsa Gehu 3 but remained at par with HUW 234. The significant variation in grain and straw yield among the cultivars was also reflected in terms of physical productivity and biomass production rate as wheat cultivar K 9107 being comparable to HUW 234 but, the former proved its significant superiority over other cultivars in respect of physical productivity and biomass production rate.

The wheat cultivars failed to express significant variation in harvest index and remained at par among themselves. The grain and straw yield of crop is closely related to the vegetative and reproductive growth which proved instrumental in improving the growth and yield attributes among cultivars and ultimately led to variation in grain and straw yield of cultivars.

Economics

Economic advantage is key factor for viability of any technology and will not be accepted to farming community until it is not economically viable. The net return and benefit: cost ratio was higher with system of wheat intensification due to higher yields than conventional method of cultivation while, cost of cultivation is comparatively lower under system of wheat intensification due to reduction in cost of seed, weeding, irrigation, chemicals and labour requirement. Higher gross return and lower cost of cultivation led to significantly higher net return and benefit: cost ratio under system of wheat intensification (Table 3).

The wheat crop fertilized with higher fertility level of 120 kg N ha^{-1}, 60 kg P_2O_5 ha^{-1} and 40 kg K_2O ha^{-1} gave significantly more net returns and benefit: cost ratio than lower fertility level i.e. 80:40:20 kg N: P_2O_5: K_2O ha^{-1}.

This might be due the higher yield obtained at higher fertility levels in spite of higher input cost under higher fertility level. This result is in conformity with the findings of Pandey *et al.,* (2004). Among wheat cultivars, K 9107 recorded highest net return and benefit cost ratio followed by HUW 234, K 0307, HUW 468 and Birsa Gehu 3 in decreasing order. The higher grain yield of cultivar was responsible for higher net return and benefit: cost ratio. Significant variation in net return and benefit: cost ratio among different wheat cultivars has also been reported by Jat and Singhi (2004)

Table.1 Effect of cultivation method and fertility level on growth and yield attributes of wheat cultivars (Pooled data of 2 years)

Treatments	Growth attributes				Yield attributes					
	Plant height (cm)	Total Tillers (No.)	Leaf area index at 80 DAS	Dry matter accumulation (g m^{-2})	Spikes number m^{-2}	Spike length (cm)	Filled grains $spike^{-1}$ (No)	Unfilled grains $spike^{-1}$ (No)	Spike weight (g)	1000 grain weight (g)
Method of cultivation										
SWI	94.59	449.17	3.58	1094.98	400.71	10.04	50.63	3.01	2.44	39.64
Conventional	97.15	405.48	3.41	979.21	372.74	9.52	45.39	3.89	2.10	39.36
Sem±	1.78	7.56	0.05	16.66	5.85	0.07	0.52	0.06	0.03	0.08
CD (P=0.05)	NS	21.63	0.16	44.02	16.31	0.20	1.52	0.17	0.08	0.22
Fertility levels (kg $N-P_2O_5-K_2O$ ha^{-1})										
80-40-20	92.45	402.54	3.27	930.33	355.18	9.51	45.73	3.93	2.12	39.32
120-60-40	99.29	452.11	3.72	1143.86	418.26	10.04	50.29	2.97	2.43	39.68
Sem±	1.78	7.56	0.05	16.66	5.85	0.07	0.52	0.06	0.03	0.08
CD (P=0.05)	5.03	21.63	0.16	44.02	16.31	0.20	1.52	0.17	0.08	0.22
Cultivars										
K 9107	104.06	470.64	3.65	1143.28	420.60	10.58	50.85	2.13	2.39	42.84
Birsa Gahu-3	87.37	403.23	3.25	925.64	361.05	9.22	43.86	4.43	2.18	36.31
HUW 468	91.74	416.43	3.48	971.52	372.44	9.47	47.55	3.97	2.22	37.32
HUW 234	98.43	424.50	3.57	1089.43	395.32	10.04	49.37	3.37	2.36	42.55
K 0307	97.74	421.84	3.52	1055.60	384.22	9.57	48.41	3.36	2.21	38.47
Sem±	2.81	11.96	0.08	24.83	9.08	0.10	0.83	0.10	0.04	0.12
CD (P=0.05)	7.95	34.19	0.25	69.60	25.79	0.31	2.40	0.27	0.13	0.35

Table.2 Effect of cultivation method and fertility level on yield and economics of wheat cultivars (Pooled data of 2 years)

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest Index (%)	Physical productivity (kg $ha^{-1}day^{-1}$)	Biomass production rate (kg $ha^{-1}day^{-1}$)	Net Return (Rs ha^{-1})	Benefit :cost ratio
Method of cultivation							
SWI	4030	58.58	40.69	33.58	82.39	30145	1.41
Conventional	3646	55.08	39.81	30.38	76.28	23193	0.99
Sem±	60.3	83.6	0.52	0.48	0.88	732	0.03
CD (P=0.05)	165	258	NS	1.38	2.55	2088	0.09
Fertility levels (kg $N-P_2O_5-K_2O$ ha^{-1})							
80-40-20	34.65	53.24	39.43	28.87	73.24	22429	1.03
120-60-40	42.10	60.42	41.07	35.08	85.43	30909	1.36
Sem±	60.3	83.6	0.52	0.48	0.88	732	0.03
CD (P=0.05)	165	258	1.53	1.38	2.55	2088	0.09
Cultivars							
K 9107	42.17	60.20	41.25	35.14	85.30	31482	1.42
Birsa Gahu-3	34.52	52.27	39.78	28.77	72.32	21761	0.98
HUW 468	36.96	55.30	39.97	30.80	76.88	24871	1.11
HUW 234	39.86	59.22	40.18	33.21	82.57	28568	1.28
K 0307	38.36	57.16	40.08	31.97	79.60	26664	1.20
Sem±	93.4	141.2	0.83	0.82	1.40	1156	0.05
CD (P=0.05)	262	407	NS	2.18	4.02	3301	0.15

Table.3 Effect of cultivation method and fertility level on nutrient uptake of wheat cultivars (Pooled data of 2 years)

Treatments	Nutrient uptake (kg ha^{-1})					
	Nitrogen		Phosphorus		Potassium	
	Grain	Straw	Grain	Straw	Grain	Straw
Method of cultivation						
SWI	65.39	31.43	12.86	5.15	17.42	69.56
Conventional	60.24	29.77	11.95	4.88	15.27	66.09
Sem±	1.20	0.57	0.21	0.09	0.29	1.23
CD (P=0.05)	3.38	1.61	0.60	0.28	0.82	3.47
Fertility levels (kg $N-P_2O_5-K_2O$ ha^{-1})						
80-40-20	55.63	28.29	11.05	4.49	14.40	61.92
120-60-40	69.99	32.91	13.76	5.54	18.30	73.73
Sem±	1.20	0.57	0.21	0.09	0.29	1.23
CD (P=0.05)	3.38	1.61	0.60	0.28	0.82	3.47
Cultivars						
K 9107	70.47	31.35	13.36	5.22	17.45	70.37
Birsa Gahu-3	54.91	28.66	11.34	4.78	15.08	63.74
HUW 468	61.12	30.29	12.17	4.81	16.17	67.45
HUW 234	64.99	31.77	12.73	5.19	17.01	69.37
K 0307	62.57	30.93	12.42	5.10	16.03	68.21
Sem±	1.89	0.89	0.34	0.15	0.46	1.95
CD (P=0.05)	5.34	NS	0.96	NS	1.29	5.49

Table.4 Effect of cultivation method and fertility level on energetics of wheat cultivars (Pooled data of 2 years)

Treatments	Energy input- output relationship					
	Energy input ($MJ\ ha^{-1}$)	**Energy output ($MJ\ ha^{-1}$)**	**Net energy return ($MJ\ ha^{-1}$)**	**Energy use efficiency**	**Energy productivity ($g\ MJ^{-1}$)**	**Specific energy ($MJ\ t^{-1}$)**
Method of cultivation						
SWI	17431	59230	41799	3.40	230.72	4391
Conventional	19425	53585	34160	2.76	187.41	5395
Sem±	-	860	860	0.05	3.21	76.9
CD (P=0.05)	-	2455	2455	0.14	9.15	220
Fertility levels (kg $N-P_2O_5-K_2O\ ha^{-1}$)						
80-40-20	17033	50931	33898	3.01	204.62	5004
120-60-40	19824	61884	42061	3.14	213.51	4782
Sem±	-	860	860	0.05	3.21	76.9
CD (P=0.05)	-	2455	2455	0.14	NS	220
Cultivars						
K 9107	18428	61989	43560	3.39	230.53	4408
Birsa Gahu-3	18428	50743	32315	2.77	188.04	5434
HUW 468	18428	54329	35901	2.95	200.94	5060
HUW 234	18428	58584	40156	3.19	216.78	4698
K 0307	18428	56394	37965	3.08	209.05	4867
Sem±	-	1359	1359	0.08	5.07	121.1
CD (P=0.05)	-	3881	3881	0.21	14.47	347

Nutrient uptake

System of wheat intensification recorded higher uptake of nitrogen, phosphorus and potassium by grain and straw as compared to conventional method of cultivation which could be ascribed to better vegetative and reproductive growth thereby producing higher grain and straw yield under SWI method of cultivation.

The nitrogen, phosphorus and potassium uptake by grain and straw of wheat were higher when the crop was raised with higher fertility level of 120:60:40 kg N: P_2O_5: K_2O ha^{-1} (Table 4) compared to that raised with lower fertility level ie. 80:40:20 kg N: P_2O_5: K_2O ha^{-1}. Increase in uptake of N, P and K with higher nutrients doses was owing to increased availability of nutrients facilitating better root growth and as such better nutrient uptake (Singh *et al.*, 2011).

Among cultivars, K 9107 recorded the highest NPK uptake by grain and straw but failed to exhibit significant variation in nitrogen and phosphorus uptake by straw. The uptake of NPK in grain and straw followed the order K 9107 > HUW 234 > K 0307 > HUW 468 > Birsa Gehu 3 due to variation in grain yield among the cultivars. Since, uptake of a nutrient is a function of concentration of nutrient and yield per hectare. Significant variation in nitrogen, phosphorus and potassium uptake among different cultivars has also been reported by Kumar and Singh (2003).

Energetics

Energetics of wheat revealed that maximum gross energy output, net energy return, energy use efficiency, energy productivity and minimum energy input and specific energy was obtained with system of wheat intensification than the conventional method of cultivation (Table 4). The higher grain production and less input energy under system of wheat intensification resulted in achieving maximum energy use efficiency, energy productivity and minimum specific energy in comparison to conventional method. The reason for high energy output, energy use efficiency, energy productivity and minimum energy input and specific energy was due to the management practices under system of wheat intensification having lower requirement of labour, seed, weeding, irrigation and plant protection chemicals.

Among fertility level, higher fertility level of 120:60:40 kg N: P_2O_5: K_2O ha^{-1} gave significantly higher energy output, net energy return and energy use efficiency over lower fertility level ie. 80:40:20 kg N: P_2O_5: K_2O ha^{-1}. The input energy and energy productivity were also higher with fertility level of 120:60:40 kg N: P_2O_5: K_2O ha^{-1} but, it was par with 80:40:20 kg N: P_2O_5: K_2O ha^{-1} fertility level. The lower fertility level i.e. 80:40:20 kg N: P_2O_5: K_2O ha^{-1} had significantly higher specific energy than 120:60:40 kg N: P_2O_5: K_2O ha^{-1}.

Among cultivars, K 9107 being comparable to HUW 234 led to significantly higher energy output, net energy return, energy use efficiency and energy productivity than K 0307, HUW 468 and Birsa Gehu 3. However, the reverse trend was obtained in case of specific energy due to lower grain yield obtained with Birsa Gahu 3 having highest specific energy among all cultivars followed by HUW 468, K 0307, HUW 234 and K-9107.

Thus, it can be concluded that wheat variety K 9107 fertilized with 120 kg N ha^{-1}, 60 kg P_2O_5 ha^{-1} and 40 kg K_2O ha^{-1} under System of Wheat Intensification may prove as biologically efficient, resource conservative, highly profitable system under irrigated ecosystem of Chhotanagpur plateau region of Jharkhand.

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