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Improving lentil (*Lens culinaris*) productivity and profitability through farmer participatory action research in India

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ABSTRACT

Application of technology for on-farm productivity enhancement is the major intervention besides meeting the other requirements like input supply, marketing, biotic and abiotic stresses. Further, to what extent farmers are involved in technology delivery process is another dimension of technology application. Farmers may be either the passive receiver of any technology of information, or they be be the active partners in planning, implementing and evaluating the interventions. In the first phase of the study, documentation and characterization of lentil based cropping systems, variety use pattern and existing yield level; comparison of lentil (*Lens culinaris* Medik.) and non-lentil based cropping systems, constraint analysis and identification of need based and situation specific potential solutions were done. In the second phase of the study, the suggested solutions were translated and prioritized into meaningful interventions in the form of lentil variety demonstration; assessment of different technological components like weed management, fertilizer management, irrigation management and disease management in integrated crop management (ICM) mode and implemented for two cropping seasons of 2010-11 to 2011-12. Action research was, therefore, conducted among 965 lentil growers (389 ha area) selected from 35 districts across four states of India during 2010-11 to 2011-12. Yield gap II (37.65 - 54.39%) was found more prominent than the research gap or yield gap I (15.0 - 22.5 %) in selected states. The states of Uttar Pradesh (716 kg/ha), Bihar (629 kg/ha), Madhya Pradesh (619 kg/ha) and West Bengal (604 kg/ha) showed higher yield gap in lentil. Distinct lentil based existing cropping system and very poor level of yields was observed (as low as 300 kg/ha in Madhya Pradesh to 932 kg/ha in some parts of Uttar Pradesh). Lentil based cropping systems (B: C ratio - 3.11-3.77) was economically efficient than non-lentil based cropping system (B:C ratio - 1.17 to 1.72). Assessment of improved lentil varieties and integrated crop management technologies resulted in higher gain both in yield (57.8%) and net return (87.8%), followed by improved variety (50.4% increase in yield and 82.2% higher net return) over the farmers' practices. Other technological components like weed management, fertilizer management, irrigation management and disease management contributed increase in yield (20-29%) and net returns (17-37%) over farmers' practices.

Key words: Constraints, Integrated crop management, Lentil based cropping systems, Technological impact, Yield gap

Cultivated lentil (*Lens culinaris* Medik.), an annual crop has been grown as an important food source for over 8 000 years. It comes in two varieties, i.e. macrosperma (with large seeds and little pigmentation) and microsperma (with small seeds pigmentation). The comparative economics of winter season crops were worked out taking net returns into consideration. It was observed that the cultivation of lentil is more profitable than other crops under rain-fed conditions (Yadav *et al*. 2007).

The important lentil-growing countries of the world are India, Canada, Turkey, Bangladesh, Iran, China, Nepal and Syria (Ahlawat 2012). The total cultivated area in the world is around 4.9 million hectares producing 4.8 million tonnes with an average production of 1 095 kg/ha (FAOSTAT 2013). Due to the mismatch between supply and demand of pulses, prices of pulse grains in India have increased exorbitantly during the recent years (Reddy *et al*. 2013). To meet the demand for pulses, country has been importing a large quantity of pulses since last few years (IIPR 2011). The import of pulse crops increased from 0.38 mt in 1993 to 3.3 mt in 2011-12 (about nine fold increases) and lentil is one among them. During the post-WTO regime, the export potential of lentil has increased as India is the largest producer of pulses in the world. It implicates the need for wider dissemination of low-cost and sustainable lentil production technologies among the farmers of the potential states of country to meet the growing domestic as well as global

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demand. This paper examines the detailed accounts of lentil production in Indian states, their yield gap, lentil based cropping systems, constraints analysis, impact and assessment of usable interventions in integrated crop management mode and the related issues.

MATERIALS AND METHODS

Study was conducted in three phases of analysis and planning, design and implementation and impact assessment. In the first phase of the study, secondary data available from official records, published papers and reports on area, production and yield of lentil across the various states of India was procured and analyzed for two cropping seasons of 2009-10 and 2010-11. According to the relative percent share of these indicators apropos National status, first four states namely Uttar Pradesh, Madhya Pradesh, Bihar and West Bengal were identified for the study for which yield gap analysis was done. From these states, total of 10,14, 9 and 2 districts sharing 48, 48, 27 and 64%, respectively, of the state's acreage under lentil were selected. Further, districts were purposively sampled on the criteria of growing lentil as the sole or mixed crop for the last three years before the project initiation. Thus, total of 965 lentil growers constituted the sample for the study. These farmers were interacted individually and in group using semi-structured interview schedule or checklist and triangulated with other participatory tools in partnership with the experts from the *Krishi Vigyan Kendras* (KVKs) of the respective districts. This interaction was done for documentation and characterization of lentil based cropping systems, variety use pattern and existing yield level; comparison of lentil and non-lentil based cropping systems, constraint analysis and identification of need based and situation specific potential solutions. In the second phase of the study, the suggested solutions were translated and prioritized into meaningful interventions in the form of lentil variety demonstration; assessment of different technological components like weed management, fertilizer management, irrigation management and disease management in integrated crop management (ICM) mode and implemented for two cropping seasons of 2010-11 to 2011-12. These interventions were supported with capacity building modules like on- and off-campus trainings, field visits, farmers-scientist meets, exposure visits, etc. Thus, total of 973 acres (389 ha) area was covered under these interventions in such a way that each participating farmer could share minimum of one (1) acre of land for these interventions. Finally, the impact of the interventions were assessed on the parameters of yield advantages, net return/ha, increase in net returns, incremental cost of the interventions and B:C ratio. Yield advantages from the treatments were assessed over local check as well as state and national average. Net return was computed by subtracting the total operational costs from the gross return calculated at the price of lentil what farmers were getting at the time of investigation. Simple statistics like mean, percentage, standard deviation (SD) and coefficient of variation (CV) were applied to draw meaningful conclusions.

RESULTS AND DISCUSSION

Economic indicators and yield gap analysis

The reported data on area, production and yield of lentil across the major states like Uttar Pradesh (UP), Bihar, Madhya Pradesh (MP), West Bengal (WB), Rajasthan and Asom for the production years 2010-11 and 2009-10 are shown in Table 1. Data show that, during both the years, Uttar Pradesh and Madhya Pradesh were the leading states in terms of total area, i.e. 0.59 mha and 0.54 mha and total production (0.41 and 0.28 mt, respectively). This reflected the higher yield of lentil in Uttar Pradesh (695 kg/ha) than in Madhya Pradesh (305 kg/ha) during both the years. Uttar Pradesh was also found to have highest share of area (36.88%) and total production (43.62%) of lentil over national status. Other states like Asom and Rajasthan shared very less in terms of area, total production and yield level (Table 1).

Further, considering area as the major yardstick for future improvement possibilities in lentil, only four states namely Uttar Pradesh (0.59 mha), Madhya Pradesh (0.59 mha), Bihar (0.24 mha) and West Bengal (0.06 mha) were

Table 1 Status of area, production and yield of lentil across the major states of India

State	2011-12					2009-10				
	Area (mha)	% to all-India	Production (mt)	% to all-India	Yield (kg/ha)	Area (mha)	% to all-India	Production (mt)	% to all-India	Yield (kg/ha)
Uttar Pradesh	0.59	36.88	0.41	43.62	695	0.59	39.86	0.48	46.60	814
Bihar	0.24	15.00	0.21	22.34	875	0.17	11.49	0.15	14.56	882
Madhya Pradesh	0.59	36.88	0.18	19.15	305	0.54	36.49	0.28	27.18	519
West Bengal	0.06	3.75	0.05	5.32	833	0.05	3.38	0.05	4.85	1000
Rajasthan	0.04	2.50	0.04	4.26	1000	0.03	2.03	0.02	1.94	667
Asom	0.02	1.25	0.01	1.06	500	0.02	1.35	0.01	0.97	500
Others	0.06	3.75	0.04	4.26	@	0.08	5.41	0.04	3.88	@
All India	1.60	100.0	0.94	100.0	591	1.48	100.0	1.03	100.0	697

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation, 2012.

Table 2 Yield gap analysis of lentil in the selected Indian states

States	Research station large- seed (kg/ha)	Research-station small-seed (kg/ha)	Yield gap-between large-seeded and small-seeded (Research station) (kg/ha and %)	Demon. trial yield (kg/ha)	State yield (kg/ha)	Yield gap I (between research station and demon. yield) (kg/ha and %)	Yield gap II (between on-farm demon. yield and state yield) (kg/ha and %)
Madhya Pradesh	1 600	1 400	200 (10.66%)	1 138	519	262 (18.71%)	619 (54.39%)
Uttar Pradesh	1 800	1 600	200 (12.55%)	1 530	814	270 (15.00%)	716 (46.79%)
West Bengal	1 750	1 950	200 (11.42%)	1 604	1000	346 (17.74%)	604 (37.65%)
Bihar	1 800	1 950	150 (8.33%)	1 511	882	439 (22.51%)	629 (41.62%)

Data source: AICRP on MULLaRP (2012).

taken for further analysis of yield gap, cropping system, possibilities of improvement under *kharif/rabi*-fallow situation, planning and implementing the on-farm integrated crop management interventions, and their impact on productivity and profitability. As analyzed by Tikko *et al.* (2005), Uttar Pradesh, Madhya Pradesh and Bihar among themselves command 84-90% of total lentil area in India since the last 20 years, with 86-90% of production. Uttar Pradesh and Bihar, which mostly grow small seeded types, have yield levels of around 800 kg/ha, while in Madhya Pradesh which grows mostly bold seeded types, yield levels hover around at 450 to 480 kg/ha only. As an immediate short-term strategy, priority steps must be taken to enhance the productivity in these states.

As the selected states have the preferences for both large seeded and small seeded lentil varieties, the yield gap analysis was done for the types as applicable to the respective states. Results shown in Table 2 show that the research station yield gap between the large seeded and small seeded lentil varieties was similar (200 kg/ha) for Madhya Pradesh, Uttar Pradesh and West Bengal; the percentage gap, however, was more in UP (12.55%), followed by WB (11.42%) and MP (10.66%). This confirmed the varietal preferences according to the consumer preferences and marketing for either small seeded or large seeded lentil as per the case in the states. Findings further showed that the yield gap I (i.e. the difference between research station and demonstration yield) was highest in Bihar (439 kg/ha; 22.51%) followed by West Bengal (346 kg/ha; 17.74%), Uttar Pradesh (270 kg/ha; 15%) and Madhya Pradesh (262 kg/ha; 18.71%). However, these gaps may not be considered alarming which support the fact that improved lentil varieties developed at the research stations are almost matching with the production situations prevailing at the farmers' fields. The yield gap II (between on-farm demonstration yield and state yield), however, was computed to be very high in all the four states (Table 2). Findings show that yield gap II was as high as 746 kg/ha (46.79%) in Uttar Pradesh followed by 629 kg/ha (41.62%) in Bihar, 619 kg/ha (54.39 %) in Madhya Pradesh and 604 kg/ha (37.65%) in West Bengal. The findings indicate that the lentil farmers of the Uttar Pradesh, Madhya Pradesh and Bihar are harvesting only about 50% of the yield potential of the recommended and appropriate lentil varieties. This further gives the clue of poor seed delivery systems in these states.

Lentil based cropping systems, variety use pattern, yield level and economics

Under the rainfed, partially irrigated production situation and *tarai* area as prevailing in MP and part of UP; *kharif* submerged condition of Bihar (*Tal* area) and the excessive residual moisture condition of *kharif* season in WB are some of the prominent situations where lentil is included as the important element of cropping system. Out of the total reported area of 0.59 mha in Uttar Pradesh, the selected 10 districts had 0.28 mha area under lentil. Rice - lentil, maize-lentil and *kharif* fallow-lentil are the main cropping systems wherein the prevailing lentil varieties are K 75, DPL 62 and other local and non-descript varieties with their obtained yield ranging between 318-932 kg/ha. Similarly, in Madhya Pradesh, soybean-lentil was found as the prominent lentil based cropping systems practices in an area of 0.28 mha of selected 14 districts. Jl-3 variety of lentil is most widely used variety in these areas and farmers are harvesting the average lentil yield ranging between 300 to 545 kg/ha. Bihar has another unique situation where lentil is grown in the situation where the rainwater slowly recedes and lentil is sown at various time in a season besides the other situation of rice-lentil and maize-lentil. For this study, 10 districts having 0.0064 mha area under lentil were involved. Under all such systems, old variety K 75 is more predominant which yields poor harvest ranging between 513 to 824 kg/ha. Lastly, in two districts namely Murshidabad and Nadia of West Bengal, lentil is sown in the area of 0.0038 mha using the non-descript lentil variety with good yields of 732 to 781 kg/ha. In this state, lentil is mostly grown as the para-crop in the residual moisture of paddy field.

For, better comprehension of economic significance of lentil based cropping system, the parameters like gross cost, gross returns, net returns and B:C ratio under lentil based and non-lentil based cropping systems were analyzed. The findings as presented in Table 4 show that except for paddy-lentil (B:C ratio 1.54) cropping system, other sequences like soybean lentil, moong-lentil and maize-lentil have higher and more remunerative economics (BC ratio: 2.23, 3.11 and 3.71, respectively) as compared to the non-lentil based cropping sequences like paddy-wheat (B:C ratio 1.17), jowar-wheat (1.36) and moong-wheat (1.72). The net return realized from maize-lentil and moong-lentil cropping sequences were as high as ₹ 27 and 28 th/ha in comparison to paddy-wheat

Table 3 Major lentil growing districts, prevailing cropping systems and productivity level of lentil in the selected states of India

States	District	Total area (ha)	Cropping systems	Existing varieties	Productivity (kg/ha)
Uttar Pradesh	Ballia , Chandauli, Bahraich, Jhansi, Chitrakoot, Hamirpur, Banda, Lalitpur, Jalaun and Sonbhadra (n=10)	283776 (48%)	Rice-Lentil, Maize-Lentil, Fallow-Lentil	DPL-62, K-75, Local	318 to 932
Madhya Pradesh	Chhatarpur, Jabalpur, Narsinghpur, Panna, Raisen, Rajgarh, Sagar, Satna, Seoni, Shajapur, Shivpuri, Rewa, Raisen and Sagar (n=14)	282700 (48%)	Soybean-Lentil	JL-3	300 to 545
Bihar	Aurangabad, Nalanda, Patna, Rohtas, Bhojpur, Nalanda Harnaut, Chandi, Rahui, Sarmera (n=9)	064529 (27%)	*Kharif* fallow-Lentil, Rice-Lentil, Maize-Lentil	K 75	513 to 824
West Bengal	Murshidabad and Nadia (n=2)	038442 (64%)	Para crop of lentil in paddy field	non-descript	732 to 781

Figures in parentheses indicate the percent share of state's total area under lentil.

Table 4 Comparative economics of prominent lentil-based vs non-lentil-based cropping systems in Indian sub-tropics

Crop rotation	Gross returns ('000 ₹/ha)	Cost ('000 ₹/ha)	Net returns ('000 ₹/ha)	B/C ratio
Lentil-based cropping system under rainfed or partial irrigation system				
Maize-lentil	36.6	10.7	25.9	3.42
Moong-lentil	43.0	13.2	29.8	3.25
Paddy-lentil	42.4	27.3	15.1	1.55
Soybean-lentil	37.4	16.8	26.4	2.23
Non-lentil-based cropping systems under irrigated system				
Paddy-wheat	45.8	37.9	07.9	1.21
Jowar-wheat	28.8	21.7	07.1	1.32
Moong-wheat	43.9	25.7	18.2	1.71

Table 5 Estimates of rice-fallow area for selected lentil growing states of India

State	Kharif-rice area ('000 ha)	*Rabi*-fallow ('000 ha)		Rice-fallow area as % of *kharif* rice area	% of total rabi-fallow area
		Frolking *et. al.* (2006)	ICRISAT (2009)		
MP	5 596	1 957	4 382	78.3	37.6
Bihar	5 974	2 342	2 196	36.8	18.9
WB	4 617	2 052	1 719	37.2	14.8
UP	6 255	1 347	3 530	05.6	03.0

(6.7 th/ha) and jowar - wheat (7.7 th/ha). Therefore, considering the greater extent of profitability and possibility for lentils as *rabi* crop under unirrigated/rainfed or partially irrigated conditions, the extent of rice-fallows which can be put under lentil cultivation during the *rabi* season has been shown in Table 5. The data depict that there are vast fallow lands in the selected four states of Madhya Pradesh (4.382 mha), Bihar (2.196 mha), Uttar Pradesh (3.530 mha) and West Bengal (1.719 mha) which can be suitably utilized for lentil cultivation.

In further analysis, sample of 500 lentil growers were interviewed for identification of major bottlenecks in lentil cultivation and to seek suggested potential solutions. These suggestions were translated into usable location specific interventions. The findings are presented in Table 6. According to the designed and executed interventions, the obtained results are narrated in the subsequent paragraphs.

Effect of improved technology on productivity and profitability

Uttar Pradesh: Lentil is mainly grown in the crop rotation of rice-lentil and maize-lentil in the central and eastern part of Uttar Pradesh, whereas in the Bundelkhand region it is grown in fallow-lentil rotation. The state accounts about 40% of area and 45% of the total lentil production of the country with highest average productivity of 7.15 q/ha (Table 1).The demonstrations (381) conducted on lentil

Table 6 Rank order of the major constraints in lentil cultivations across the selected states and potential solutions suggested by the farmers

Major constraints	Rank	Suggested potential solutions	Rank
Use of old and local seeds of lentil	I	Making the wilt resistance and HYVs of lentil available to farmers	I
Application of suboptimal dose of chemical fertilizers	IV	Ensuring how and when to apply the optimum dose of chemical fertilizers	II
Heavy infestance of weed	III	Chemical management of weeds	III
Application of only pre-sowing irrigation or use of residual moisture only	IV	Irrigation scheduling and management	IV
Incidence of wilt and other diseases	II	Minimizing the market fluctuations	II

crop with improved varieties and technologies showed an yield advantage of about 33% over local check (Table 7), about 114% to state and 141.71% to national average. A net return of ₹ 34 403/ha was realized which was 46% higher to local check (Table 8). Lentil is one of the important crops of Bundelkhand region but also has shown good performance in central and eastern part of Uttar Pradesh in rice fallows. Wilt infestation is one area which needs regular monitoring and proper solution.

Bihar: Lentil is grown in an area of 1.62 lakh ha with production of 1.14 lakh tonnes and productivity of 7.04 q/ha in Bihar. The state contributes about 11% to the total area and 12% to total production of the country (Table 1). Lentil is grown mainly in rice-fallow (Table 3). The performance of lentil crop under demonstration was good in terms of average productivity (15.11 q/ha) and net returns (₹ 51 199/ha). In some of the districts, like Nalanda, the average productivity of 23.05 q/ha was achieved as compared to 10.89 q/ha of local check (Table 7). The demonstrations indicated average increase of 48% in yield and 145% in net returns (Table 8). The average yield in these demonstrations varied between 11.45 to 23.05 q/ha. Overall, the average productivity (15.11 q/ha) was 114.63%, higher to state and 138.70% to national average. There is tremendous scope to enhance the area and productivity of lentil in the state of Bihar, as area under pulses is quite low in the state.

West Bengal: Lentil is cultivated on an area of 0.57 lakh ha with production of 0.47 lakh tonnes and productivity of 9.11 q/ha (Table 1). It is normally grown in rice-lentil and maize-lentil cropping systems in the state (Table 3). An average productivity of 16.04 q/ha was obtained in demonstrations against 9.0 q/ha in local check (Table 7). The performance of two varieties, viz. WBL 58 and B 77 were alike in terms of yield. The enhancement in yield over local was 78.22% and it was 109% in respect to net returns (Table 8). Lentil holds the potential to be rolled out on larger area especially in rice-fallow in the state to fulfill the requirement of pulses.

Madhya Pradesh: Lentil is next to chickpea, being grown on an area of 5.90 lakh ha with annual production of 1.80 lakh tonnes and productivity of 305 kg/ha in Madhya Pradesh (Table 1). It is generally grown as rainfed crop during *rabi* season after rice, maize, pearl millet or *kharif* fallow (Table 3). In Madhya Pradesh, 339 lentil demonstrations were conducted in 12 districts of Madhya Pradesh. 294.64 acre area was covered under demonstrations using improved varieties, viz. JL-1, JL-3 and DPL-62. Through demonstrations, 45.15% yield enhancement and 58% increase in net return was realized (Table 7). Comparative yield trends show that there is 123.58 and 79.78 % yield increase over the state and national average, respectively. A total of 278 demonstrations were conducted in 11 districts of MP using improved variety JL-3 covering 233.14 acre area. 46.64 % increase in yield and 61.05 % gain in net return was noticed. A total of 20 demonstrations were conducted in district Rewa using improved variety JL-1 which provided best result in the state with 44.58 % yield and 93.81 % net return.

Comparison of integrated crop management technologies (case study) with farmers' practices on lentil yield and profitability

Farmers' practices: It was computed that under farmers' practices, the total cost of cultivation was ₹ 8 530/ha including the variable cost of inputs, etc as ₹ 4 100/ha (48% of total cost). Most of the cultivation operations like ploughing, land preparation, sowing, etc were performed mechanically in MP and Bundelkhand of UP and *Tal* area of Bihar, whereas these were done manually in WB, part of Bihar and UP. The recommended seed rate (@ 30 kg/ha) was seldom practiced by most of the farmers who applied lesser seed rate. Most of the farmers either applied suboptimal doses of chemical fertilizers in all the districts or not applied at all. In general, farmers were found not spraying any insecticide and fungicide and many of them adopted manual weeding. Further, the operation like weeding, harvesting, carrying, storing, etc were found carried out by the family labour sometimes with the help of neighbouring farmers on labour exchange basis. Other operations like sowing, threshing and winnowing were done mechanically which was paid either in cash or with payment in kind. During

Table 7 Effect of improved varieties of lentil on yield (q/ha) across major lentil growing states (2010-2012)

States	Varieties demonstrated	Districts covered	Area (acre)	Yield (q/ha)		% increase
				Demo	Check	
Uttar Pradesh	NDL-1, DPL-62, K-75	Chandauli, Ballia, Jalaun, Jhansi,Sonbhadra, Bahraich, Chitrakoot, Hamirpur and Lalitpur,	359.50	15.30	11.51	32.93
Madhya Pradesh	JL-1, JL-3 and DPL-62	Chhatarpur, Jabalpur, Sagar Narsinghpur, Panna, Raisen, Rajgarh, Sagar, Satna, Seoni, Shajapur, Shivpuri, Rewa and Raisen	294.64	11.38	07.84	45.15
Bihar	Arun, Hul-57, K-75 (Malika), WBL-58 and B-77	Aurangabad, Nalanda, Patna, Rohtas, Bhojpur, Nalanda Harnaut, Chandi, Rahui, Sarmera	297.68	15.11	10.22	47.85
West Bengal	WBL-58, B-77	Murshidabad and Nadia	020.85	16.04	09.00	78.22
Total area covered and average yield (q/ha)			972.67 (389 ha)	14.50	9.64	50.41
SD (CV)				3.29 (22.76)	2.5 (25.93)	

Table 8 Effect of improved varieties of lentil on profitability (₹/ha) across major lentil growing states (2010-2012)

States	Varieties demonstrated	Districts covered	No. of Demo.	Net return (₹/ha)		% increase
				Demo	Local check	
Uttar Pradesh	NDL-1, DPL-62, K-75	Chandauli, Ballia, Sonbhadra, Bahraich, Chitrakoot, Hamirpur, Lalitpur, Jhansi, Jalaun	381	34403	24064	46.00
Madhya Pradesh	JL-1, JL-3 and DPL-62	Chhatarpur, Jabalpur, Narsinghpur, Panna, Raisen, Rajgarh, Sagar, Satna, Seoni, Shajapur, Shivpuri, Rewa, Raisen and Sagar	339	27240	17286	58.00
Bihar	Arun, Hul-57, K-75 (Malika), WBL-58 and B-77	Aurangabad, Nalanda, Patna, Rohtas, Bhojpur, Nalanda Harnaut, Chandi, Rahui, Sarmera	194	51199	22620	145.00
West Bengal	WBL-58, B-77	Murshidabad and Nadia	051	25545	12092	109.00
Total number of demonstrations conducted/Average			965	34641	19015	82.17

entire crop duration, water requirements were met through residual moisture without any additional irrigation other than *palewa* (pre-sowing irrigation). Most of the farmers found using their own home saved seed or seed procured from the neighbouring farmers. They rarely procured seed from the local market or Government institutions. Seed replacement rate, thus was very poor (less than 5%). It was also found that the availability of certified seeds at government seed outlet was always inadequate and untimely available. The varietal specification of the seed available at the private shop was not specified. The average yield obtained in the study area has been mentioned in Table 3 was 880 kg/ha. At the average selling price (₹ 17-19/kg), in the study areas , the gross revenue was ₹ 27 265/ha and net profit over total cost was ₹ 19 015/ha. The cost of production of lentil was about ₹ 738/q. The variability in farmers' yield was quite high (CV=25.93%) across the locations which may be attributed to variation in the residual moisture during crop growth, temperature, disease and pest attack and other biotic or abiotic factors..

Integrated Crop Management (ICM) Technologies (A case of Uttar Pradesh): The integrated crop management practices demonstrated included improved variety, weed management, fertilizer management, disease management, and irrigation management. All packages and cost benefit analysis were worked out for each on-farm demonstrations with recommended practices and the results are depicted in Table 8. In all the demonstrations, except for the package technology, all other recommended technologies were as per farmers' practice. Response to package technology was found higher towards increases in yield (57.8%) and net return (87.8%), followed by improved variety which contributed about 50.4% increase in yield and 82.2% higher net return over the farmers' practices (Table 9). Other technological components like weed management, fertilizer management, irrigation management and disease management contributed 24, 27, 20 and 29% yield increase and 17, 25, 27 and 37% increase in net returns, respectively, over farmers' practices. Overall, responses to all management practices individually and in package form were found economically viable as there was increase in net returns are in the range of 17 – 88% and yield gain ranging between 20-50%.

The technology assessment trials (989) on lentil were organized with coverage of 989.23 acres area in selected districts of four states. The average demonstration yield of 14.12 q/ha was attained which was 41.20% higher over farmers' practice and 123.06% higher over national average. The mean yield ranged between 6.95 q/ha to 11.82 q/ha across the states. The net economic gain of ₹ 28 246/ha was realized by the farmers. Lentil has shown great promise in rainfed as well as rice-fallows systems. The entire eastern Uttar Pradesh, Bihar, part of West Bengal and Bundelkhand region of Uttar Pradesh and Madhya Pradesh have tremendous scope of raising productivity and production of lentil to mitigate the scarcity of pulses at national level.

Table 9 Effect of different management practices over yield gain between integrated crop management (ICM; case of UP) as against farmers' practice in lentil cultivation

Management practices	Av. yield (kg/ha) from all sites			Incremental costs of improved package (₹/ha)	Net returns (₹/ha)		
	Farmers' practice	ICM components	Yield gain (%)		Farmers' practice	ICM components	Net returns gain (%)
Variety	964	1450	50.4	0810	19015	34641	82.2
Weed management	1090	1351	23.9	0640	10774	12649	17.4
Fertilizer management	1110	1411	27.1	0589	9489	11893	25.3
Irrigation management	1024	1227	19.8	0688	7988	10121	26.7
Disease management	0880	1138	29.3	0597	8415	11490	36.5
ICM Package	1040	1642	57.8	3784	19432	36500	87.8

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