Potato J (2023) 50 (2): 189-195

EVALUATION OF POTATO BASED CROPPING SEQUENCE THROUGH ON-FARM DEMONSTRATIONS IN BUXAR, BIHAR

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ABSTRACT: With changing climate, diversification can be an alternative option for farmers to fight climate change related problems. Rice-wheat being the major cropping system followed in Indo-Gangetic plains need to be diversified with other crops to get higher productivity and additional income. Potato is an important cash crop for farmers of eastern plains during rabi season. In this context, current study was conducted in Buxar district of Bihar to evaluate the inclusion of potato in the existing sequence and find the yield gap at farmers' fields using on-farm demonstrations. Data was recorded through timely observation and was analyzed using descriptive statistics. The yield gap in potato in study area was found to be 26.4 per cent which can be bridged by using high yielding variety like *Kufri Mohan* and following the recommended package of practices. The economic analysis showed that farmers can earn nearly 40 percent more net return by adopting new varieties and scientific cultivation practices. Among five crop sequences evaluated at farmers' field, rice-potato-moong gave highest system productivity of 234 quintal per hectare as well as maximum net returns. Thus, it is advocated to include potato in the current cropping system which will boost productivity and income of farmers by manifold.

KEYWORDS: Cropping sequence, Bihar, demonstration, economics, system productivity

INTRODUCTION

India is an agricultural country with smallholders dominating the overall landholding in this sector. Out of the total holdings, 89.4 per cent are in marginal and small farm categories having less than 2.0 ha land (PIB, 2023). Almost 55 per cent of the total workforce is employed in agricultural and allied sectors which have a share of 17.1 per cent in country's Gross Value Added (GVA) for the year 2017-18 at current prices (DAC & FW, 2019). The average monthly income per household in India stands at Rs 10218/-. Jharkhand (Rs 4895), Odisha (Rs 5112), West Bengal (Rs 6762) and Bihar (Rs 7542) are among the poorest states in terms of agricultural income/household (MoSPI, 2021). Changing climate and global warming are harsh realities faced by farming communities worldwide. Agriculture being the most climate vulnerable sectors of Indian economy is likely to experience significant yield reduction in major crops. Due to climate change, irrigated wheat and maize yields may decline by 5-10 per cent by 2050 (ICAR Vision 2050). Rice yields will go down by 15-17 per cent in Punjab and Haryana and by 6-18 per cent in all other regions (CRIDA, 2013). Similarly, changing climate will also affect potato production in India. As per study, climate change may likely to benefit potato in Punjab, Haryana and western and central Uttar Pradesh by 3.46 to 7.11% increase in production, but in West Bengal and southern plateau region, potato production may likely to decline by 4 - 16% by 2030 (Reddy *et al*., 2019). There is a need to enhance the productivity and profitability of farmers and reduce their vulnerability due to climate change by introducing innovative agricultural technologies.

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Rice-wheat cropping system is the most popular system followed across the eastern Indo-Gangetic plains area. Bihar is the third most populous state of India located in eastern region with a total population of 10.4 crore and area of 93.6 lakh hectares. Around 74 percent of the workforce in Bihar depends on the agricultural and allied sectors for their livelihood contributing almost 20 percent of the state's GSDP (Hoda *et al*, 2017). The small and marginal farmers have limited access to technology, inputs, credit, capital and markets. In Bihar, they frequently face problems of floods, drought, erratic rainfall etc. More than 90 per cent of farmers in Bihar are from small and marginal category and they grow paddy during *kharif* season and wheat during *rabi* season. These farmers cultivate wheat and rice using old varieties and traditional production practices. Potato is the most important vegetable crop of India. It is very nutritious food and has higher yield per unit area and time as compared to food grains like rice and wheat. Production of this crop is very effective means of converting plant, land, water and labour into a palatable and nutritious food (Sahadevan, 2007). India is the second largest potato producer in the world after China and both these countries together contribute nearly one third of total world potato production (Scott and Suarez, 2012). During the year 2020-21, India recorded a total of 56.17 million t of potato production from 2.20 million ha area with an average yield of 25.5 t/ha. Uttar Pradesh ranked first in terms of potato production followed by West Bengal, Bihar, Gujarat and Madhya Pradesh (Agricultural Statistics at a Glance, 2022). Bihar contributes around 15 per cent of total potato production. During the year 2020-21, Bihar recorded 90.41 lakh tonnes of potato production from an area of 3.27 lakh ha. As per forecast, India will require nearly 125 million t of potato from an enhanced area of 3.62 million ha with an average yield of 34.5 t/ha during the year 2050 (CPRI, 2015).

Inclusion of potato in the prevalent cropping system can help in achieving this challenging task. Demonstration of high yielding potato varieties can increase the adoption rate of such varieties among farming communities. Keeping in mind the importance of potato in agricultural economy of Bihar, current study was undertaken to evaluate the demonstration of potato variety *Kufri Mohan* and potato based cropping sequence in Buxar district of Bihar.

MATERIALS AND METHODS

Selection of study area and sampling

The Climate Resilient Agriculture Program of Government of Bihar is being implemented by ICAR Research Complex for Eastern Region, Patna in two selected districts, *i.e* Buxar and Gaya. Potato was identified as one of the potential rabi crops for diversification of the existing cropping system in Buxar district alongwith chickpea, mustard etc. Therefore, Buxar district was selected purposively for this study. On farm demonstrations were conducted at farmers' fields in five selected villages of Buxar district of Bihar during rabi season for diversifying the existing rice-wheat cropping system and augmenting agricultural income. These villages namely Dalsagar, Balapur, Churamanpur, Harikishunpur and Ramobariya were selected in a cluster for the better impact of technology (Fig. 1). A total of 10 on farm demonstrations of high yielding new potato variety *Kufri Mohan* were carried out. *Kufri Mohan* is a variety having white-cream ovoid tubers with high yield (35-40 t/ha), moderate level of late blight resistance and good keeping quality. It was developed and released in 2016 for western

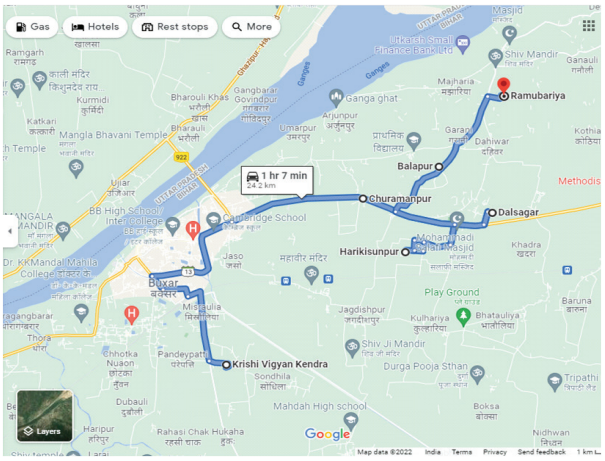

Fig.1. Map of Buxar showing cluster of selected villages

and eastern Indo-Gangetic plains by ICAR-Central Potato Research Institute, Shimla (Luthra *et al*., 2017).

Data collection and analysis

A participatory research design was used in this study. Farmers' Participatory Research (FPR) is an approach, which involves encouraging farmers to engage in experiments in their own fields so that they can learn, adopt new technologies and spread them to other farmers (Paris, 2023). Personal observation and survey method of data collection were employed for collection of primary data on variables like yield of potato, cost of cultivation, price etc. Secondary data were also collected from Government websites like Ministry of agriculture, Ministry of statistics and programme implementation, Press information bureau etc and published literature on area, production and yield of potato in India as well as Bihar. Technology interventions were made in the form of varietal demonstrations of the potato variety *Kufri Mohan*. Observations were recorded on yield, cost, price etc. The total yield gap (Yg) is the quantitative differences between a base-line yield (average farmers' yield) and either attainable (taken as experiment-based yield) or potential yield (Yp) over some specified spatial and temporal scale (Sadras *et al.*, 2015). In this study, the total yield gap comprised of yield gap I and yield gap II. Yield Gap I (YG-I) is the difference between the potential yield (Yp) and yield of demonstration plot (Yd).

$$YG\text{-}I = Yp - Yd$$

Yield Gap II (YG-II) is the difference between the demonstration plot yield (Yd) and the actual yield at farmers' field (Ya)

$$YG\text{-}II = Yd - Ya$$

Total yield gap was estimated using following formula:

$$\text{Total yield gap (TYG)} = Yp - Ya$$

Where, Yp is potential yield of variety and Ya is the actual yield at farmers' field.

Different cropping sequences including potato based sequence at farmers' fields were also evaluated in terms of system productivity and net returns. In this study, four cropping sequences i.e., Rice-Wheat-Moong, Rice-Potato-Moong, Rice-Lentil-Moong and Rice-Mustard- Moong were tried by providing quality seed of these crops and technical support. For estimating system productivity, rice equivalent yield of other crops was calculated by multiplying the yield of respective crops with its price and divided by price of rice. Collected data were tabulated and analyzed using descriptive statistics *viz.* mean, frequency, percentage etc. Inferences were drawn based on results and personal observations.

RESULTS AND DISCUSSION

Assessment of yield gap in potato

Kufri Mohan is a medium maturing, main season, high yielding table purpose potato variety suitable for cultivation in Indo-Gangetic plains. It has white creamy ovoid tubers with shallow eyes and white flesh. It has good keeping quality and moderate

dry matter (15-18%). The variety yielded 35-40 t/h (Luthra *et al.*, 2017). Potato in demonstration plot was grown using raised bed planting method with this high yielding variety *Kufri Mohan*. It was compared with the productivity of potato grown using traditional method using farmer's practice and shown in Table 1.

The results revealed that there was a significant difference in potato yield at on-farm demonstration plots and under farmers' practice. The yield level of *Kufri Mohan* realized on demonstration plots was 28.16 t/ ha which was nearly 7 t/ha lesser than the potential yield. Thus, an yield gap of 19.5% was observed between potential yield at demonstration yield. The actual average yield under farmers' practice was even lesser at 25.8 t/ha. It is inferred that yield gap II which is the difference between the demonstration plot yield (*Yp*) and actual yield (*Ya*) was found to be only 8.5 per cent. Therefore, total yield gap (TYG) observed at Buxar was found to be 26.37% per cent at overall level. The findings of this study underscore the substantial impact of on-farm demonstration plots on potato yield compared to traditional farmers' practices. Higher yield of potato at demonstration plot could be attributed to improved potato variety used in demonstration plots and the fact that production technologies are on scientific lines and carried out under the supervision of scientists while farmers do traditional farming.

Table 1: Yield gap in potato at sampled farms in Buxar, Bihar

Sl. No.	Particulars	Actual yield/ yield gap (t/ha)	Percentage yield gap
1.	Potential yield* (*Yp*)	35.00	-
2.	On farm demonstration yield** (*Yd*)	28.16	-
3.	Actual yield under Farmers practice (*Ya*)	25.77	-
4.	Yield gap I (*Yp-Yd*)	6.84	19.54
5.	Yield gap II (*Yd-Ya*)	2.39	8.5
6.	Total yield gap (*Yp-Ya*)	9.23	26.37

Note: *Taken as lower level of potential yield of *Kufri Mohan* (35-40 t/ha)
**Yield of *Kufri Mohan* in demonstration plot at Buxar

Comparison of Economics of potato cultivation under demonstration and farmers' practice

The yield level and value of output per hectare for the demonstration plots and under farmers' practice is presented in Table 2. The gross return was estimated for both conditions by multiplying yield with average price of potato tubers *i.e* Rs 12000/- per ton. Thus, overall value of output per hectare came to Rs 337920/ha in demonstration plot, which was nearly 10% higher than under farmers' practice. The net return for demonstration plot was Rs 222320/ha which was significantly higher (41.56%) than farmer's practice mainly due to higher cost of potato cultivation under farmers'

Table 2: Comparative economics of potato under demo plot and farmers' practice

Sl. No.	Economic Parameters	Farmers' practice	Demonstration plots	Absolute change
1.	Average yield (tonnes/ha)	25.77	28.16	2.39
2.	Average price (Rs/t)	12000	12000	0.00
3.	Gross returns (Rs/ha)	309240	337920	28680
4.	Cost of cultivation (Rs/ha)	152200	115600	-36600
5.	Net returns (Rs/ha)	157040	222320	65280
6.	Cost of production (Rs/t)	5906	4105	-1801
7.	Input output ratio	1: 2.03	1: 2.92	-

practice. The substantial cost reduction in potato cultivation in demonstration plots, attributed to mechanization, contributed to this economic disparity. Cost of potato production was estimated to be nearly Rs 4.0/kg in demonstration plots which was Rs 2.0/kg lower than Farmers' practice. The overall input output ratio was found to be 1:2.9 in demo plot while it was only 1:2 in farmers' practice. Thus, farmers can earn Rs 3 after investing Rs 1 in potato cultivation for variety *Kufri Mohan*.

Evaluation of cropping sequences at farmers' field

Rice-wheat-fallow is the traditional cropping system followed by farmers in Buxar district. Interventions under the climate resilient agricultural programme included study of various crop sequences and identification of most suitable cropping sequences at farmers' field. Rice was common crop in *kharif* and moong was common in summer season. Different *rabi* crops like wheat, potato, lentil and mustard were used in the sequences and data were recorded regarding grain yield.

It can be observed from Table 3 that potato based cropping sequence, i.e., Rice-Potato-Moong had the highest system productivity of 234.3 q/ha among all the five cropping sequences. It was followed by Rice-Wheat-Moong and Rice-Lentil-Moong having nearly equal system productivity of around 140 q/ha. Very high system productivity in potato based sequences is mainly because of higher yield of potato per unit area and time. Therefore, if farmers can diversify existing system with potato in rabi, they can get more productivity.

Moreover, when income from these sequences are compared, rice-potato-moong tops with highest gross as well as net returns (Fig. 2). A farmer using this sequence can earn nearly Rs 3.5 lakhs per ha. If we compare it with traditional cropping system of rice-wheat-fallow having only Rs 55,000/ha net return, there is a huge boost in the income level of farmers. Therefore, it is advocated that we must include a third crop in summer for intensification of rice-wheat cropping system. Vegetables like potato can give very high returns if included in cropping system by farmers. Therefore, it is essential to acknowledge the volatility in potato prices, which may impact the consistency of such high returns. Careful consideration and strategic planning are therefore recommended when integrating potatoes or other crops into existing cropping systems.

CONCLUSION

Being the most important vegetable of India, potato can be utilized effectively for diversifying the existing rice-wheat cropping system. Demonstration of scientific technologies at farmers' fields is an important

Table 3: Yield, system productivity and net returns of different crop sequences

Sl. No.	Cropping sequences evaluated	Yield (q/ha)			System productivity in quintal per hectare (q/ha)	Gross return Rs/acre	Net return Rs/acre
		Kharif	*Rabi*	Summer			
1.	Rice-Wheat-fallow (Traditional)	39.875	32.075	-	71.55	128800	54840
2.	Rice-Wheat-Moong	49.55	43.25	12.8	140.275	273965	99060
3.	Rice-Potato- Moong	50.625	309.55	11.775	234.3	524892.5	354760
4.	Rice-Lentil- Moong	48.725	15.85	12.725	139.825	268630	193695
5.	Rice-Mustard- Moong	48.625	14.175	12.7	130.025	253647.5	180505

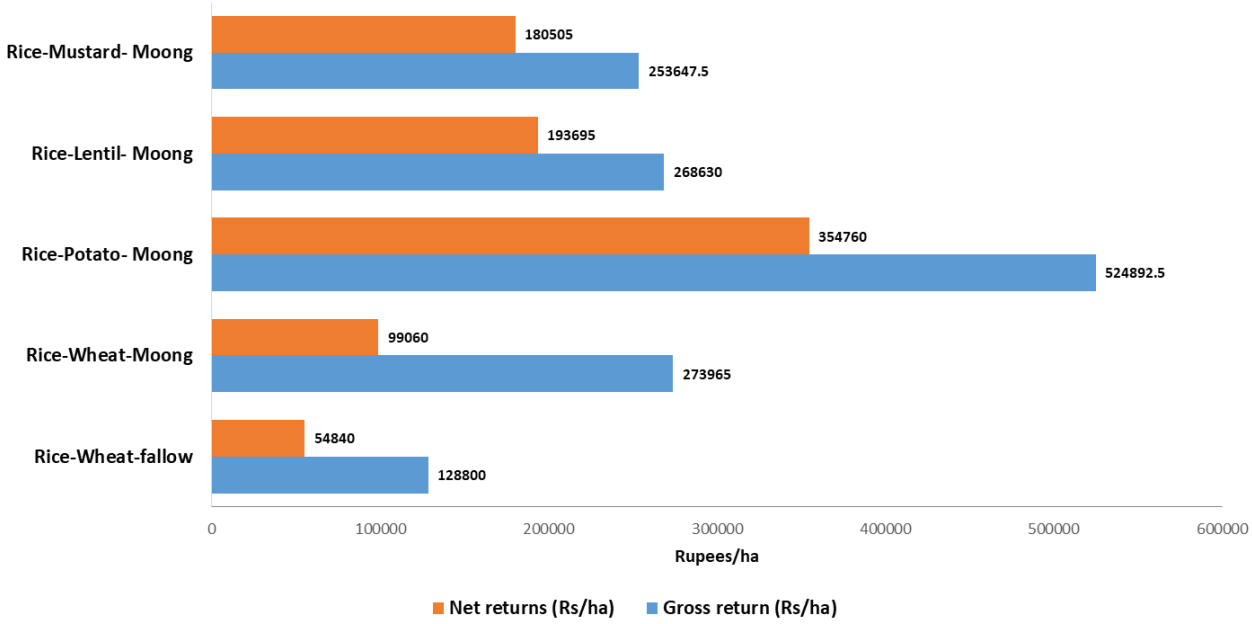

Fig. 2. Comparison of gross and net returns from various cropping sequences

method for adoption of these technologies by farmers. This study conducted in Buxar district of Bihar clearly showed that there exists a large gap in yield at farmers' field and potential yield of variety. Bridging this yield gap using suitable varieties of potato coupled with scientific management practices can enhance productivity of potato in the region. Moreover, farmers also get higher income by including potato in their existing cropping system. The present study has clearly shown the advantage of potato based cropping sequence over other sequences. Rice-wheat potato has been identified as most productive cropping sequence mainly due to higher yield of potato per unit area and time.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest

ACKNOWLEDGEMENT

This study was funded by Govt. of Bihar under its CRA programme.

ETHICAL STATEMENT

This article does not contain any studies with human participants or animals performed by any of the authors

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MS Received : December 27, 2023; Accepted : March 14, 2024