Agro-Economic Research

Strategies to Bridge Yield Gap of Major Crops in Bundelkhand Region of India

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Abstract

The study analyses the yield gap in major crops of viz.; rice, wheat, gram and soybean of Bundelkhand Region of India. The study reveals that the yield gap III between potential yield and average farm yield was found more in cultivation of rice (11.73 q/acre), followed by wheat (6.7 q/acre), soybean (3.89 q/acre) and gram (3.49 q/acre). The yield gap II was found to be more than yield gap I in cultivation of rice, wheat, gram and soybean which denotes that the recommended technologies for cultivation of these crops have reached the farmers field but farmers could not adopt these technologies due to several socio-economic constraints. It is also observed that factors like use of high yielding varieties (HYVs) seed, improved method of sowing (rice), source of seed (rice and wheat), seed rate (soybean and gram), use of DAP (soybean and wheat), application of urea (wheat), treatment with fungicide and bio-fertilizers in rice and gram (Rhizobium, azotobacter and Phosphate Solubilizing Bacteria), irrigation (wheat, soybean and gram)and soil testing (rice and wheat) were found to be positive and significant, while area under irrigation (rice), size of land holding (soybean and wheat) and seed rate (wheat) were found to be negative and significant. This indicates that with the increase in the factors which are positive and significant, the yield of crop will increase and vice-versa.

Keywords: *Yield gap, HYVs, Bundelkhand Region*

1. Introduction

Improving crop yield is essential to meet the increasing demand for food which is driven by the increasing population and income growth in the 21st century. Increasing agricultural productivity or yield is critical to economic growth and development. This can be achieved by using improved agricultural technologies and proper management techniques. Adoption of agricultural technologies differs from farmer to farmer, referring to both mental acceptance and also the use of new agricultural technologies. This can be achieved by using high yielding management practices (Yang *et al.*, 2008). Minimizing yield gaps in major crops by using optimal management practices may lead to improvements in production, while offering both environmental benefits and economic value.

The yield gaps are attributable to the inability of the farmers to apply critical inputs to the recommended level. The yield gap is the difference between the potential farm yield and the actual average farm yield. The yield gap between on–farm demonstrations and actual farm yield has failed to show appreciable reduction over the past two decades in India. (Basavaraja, 2000; Lobell *et al.*, 2009; Jha *et al.*, 2011; Mondal, 2011). Assessing the yield gaps in major field crops can help in understanding yield variability, yield potential, and the input use efficiency of major crops and may indicate appropriate strategies to bridge the yield gap for improving agricultural efficiencies and farm income (Fischer *et al.*, 2009; Van Ittersum *et al.*, 2013).

Prevailing farmers' practices were treated as control for comparison with recommended practices (Pushpa and Srivastava, 2014; Joshi *et al.*, 2014 and Soni *et al,.* 2014). Understanding the yield gap is very crucial as it can assist in crop yield predictions since yield potential shows the probable future productivity to be achieved.

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Also, information on the determinants of yield can be used in policy interventions for enhancing crop production. In order to meet the increasing demand of food due to increasing population and income, food production in India needs to be increased. The production of food grains in India increased considerably since 1960 due to increase in the arable area, large-scale cultivation of high yielding semi-dwarf varieties and increased application of irrigation, fertilizers and pesticides.

TABLE 1: AVERAGE YIELD OF MAJOR CROPS IN BUNDELKHAND REGION OF INDIA

(q/acre)

Particulars	Rice	Wheat	Gram	Soybean
Bundelkhand Region of Madhya Pradesh	4.1	8.5	4.2	3.1
Bundelkhand Region of Uttar Pradesh	6.46	10.92	-	-
Bundelkhand Region of India	10.4	13.8	4.6	4.3

Source: Directorate of Economics and Statistics, 2015-16

Agriculture is the foundation of Bundelkhand's economy. But the yield is affected by the poor water retention capacity of the soil, weather fluctuations and large amount of wasteland. Land use pattern across the districts of Bundelkhand region of Uttar Pradesh and Madhya Pradesh is not significantly different from the rest of Uttar Pradesh and Madhya Pradesh, respectively. Net sown area in all the Bundelkhand districts of Madhya Pradesh except Datia is considerably lower than in UP Bundelkhand. Around 7% of cultivable land in UP Bundelkhand and around 5% of cultivable land in MP Bundelkhand lies fallow year after year. In MP Bundelkhand as a whole, marginal holdings accounted for 40% of all holdings. The average yield of rice and wheat were found to be lower in Bundelkhand region of Madhya Pradesh as compared to Bundelkhand region of Uttar Pradesh and India, while average yield of gram and soybean were also found to be lower in Bundelkhand region of Madhya Pradesh as compared to Bundelkhand region of India (Table 1).

It seems that the farmers were not able to adopt the recommended package of practices for cultivation of crops due to several socio-economic, technological constraints, etc. resulting in low farm income. This is the main cause of farmers' dissatisfaction and they have no other option but to satisfy with the low level of income in the area.

1.1 Objectives of the study

Keeping aforesaid facts in mind, the present study was undertaken in Bundelkhand region of India with the following specific objectives:

a) To analyze yield gap of major crops grown by the cultivators across size of holdings.

b) To determine factors affecting productivity of major crops.

c) To identify various socio-economic and technological constraints in adoption of recommended package of practices in crop cultivation.

d) To suggests policy implication to narrow down yield gap of major crops.

2. Data source and methodology

All the major crops having more than 10 percent share in gross cropped area were selected for the study. Therefore, wheat (36%), rice (18%), soybean (14%) and gram (6%) were considered for analysis of yield gap in Bundelkhand region of India. Wheat was found to be a major crop grown in both the regions, while rice was found to be grown in UP Bundelkhand, and soybean and gram were grown in MP Bundelkhand as major crops other

that wheat. Gram occupied only 6 percent of gross cropped area in Bundelkhand region of India, however, it was considered for the analysis because it was found to be major pulse crop grown in more that 10 percent of gross cropped area in Bundelkhand region of Madhya Pradesh. All the districts of Bundelkhand region of India have been taken into consideration for the study.

TABLE 2: HIGH & LOW YIELD GAP DISTRICTS OF MAJOR CROPS IN BUNDELKHAND REGION OF MADHYA PRADESH (TE 2016-17)

(in q/ha)

Districts	Wheat	Gram	Soybean
Sagar	21.93	10.4	4.82
Damoh	20.15	10.7	13.14
Panna	17.48	11.55	4.22
Tikamgarh	19.16	9.77	6.04
Chattarpur	18.33	8.58	10.24
Datia	29.66	11.57	8.01
Madhya Pradesh	**31.15**	**11.15**	**7.53**
Percentage difference to Madhya Pradesh			
Sagar	-29.60	-6.73	-35.99
Damoh	-35.31	-4.04	74.50
Panna	-43.88	3.59	-43.96
Tikamgarh	-38.49	-12.38	-19.79
Chattarpur	-41.16	-23.05	35.99
Datia	-4.78	3.77	6.37

TABLE 3: HIGH & LOW YIELD GAP DISTRICTS OF MAJOR CROPS IN BUNDELKHAND REGION OF UTTAR PRADESH (TE 2016-17)

(in q/ha)

Districts	Rice	Wheat
Jhansi	17.07	26.33
Lalitpur	4.59	27.80
Jalaun	12.64	36.24
Hamirpur	19.58	31.30
Mahoba	19.58	17.91
Banda	19.71	22.88
Chitrakut	18.80	26.40
Uttar Pradesh	**26.18**	**36.55**
Percentage difference to Uttar Pradesh		
Jhansi	-34.80	-27.96
Lalitpur	-82.47	-23.94
Jalaun	-51.72	-0.85
Hamirpur	-25.21	-14.36
Mahoba	-25.21	-51.00
Banda	-24.71	-37.40
Chitrakut	-28.19	-27.77

High and low yield gap districts were selected for each of the chosen crop. Hence, Panna (-43.96%) and Tikamgarh (-19.79%) districts were selected for soybean, while Panna (-43.88%) and Datia (-4.78%) districts were selected for wheat, and Chhatarpur (-23.05%) and Damoh (-4.04%) districts were selected for gram in Bundelkhand region of Madhya Pradesh. While Lalitpur (-82.47%) and Banda (-24.71%) districts were selected for rice, Mahoba (-51%) and Jalaun (-0.85%) districts were selected for wheat for the study in Bundelkhand region of Uttar Pradesh (Table 2 & 3).

A block in each selected district was chosen on the basis of the highest area under the selected crop. A list of all the villages in the each selected block was prepared and 3 villages having maximum area under cultivation of crop were selected for the study. A list of all the cultivators growing the selected crop was further prepared and classified into small (<2 ha), medium (2-5 ha) and large (>5 ha) categories and 10 farmers in each category were selected randomly for the study. A total of 60 farmers, 30 from high and 30 from low yield gap districts were selected for each chosen crop. Thus, 180 farmers were selected in Bundelkhand region of Madhya Pradesh and 120 farmers were selected in Bundelkhand region of Uttar Pradesh. In total, 300 respondents were selected in the area under study from Bundelkhand region of India.

The secondary data for the study were collected from the office of District Statistics and respective Deputy Director Agriculture of selected districts; Department of Farmers Welfare and Agricultural Development, Govt. of Madhya Pradesh and Uttar Pradesh. The primary data were collected from the selected respondents through pre-tested interview schedule for the agricultural year 2019-20.

The interview schedule collected information on the topics essential for the study *viz.*, general information, land utilization pattern, sources of irrigation, cropping pattern, machinery used, soil testing status, sources of information and yield of different crops with constraints faced by the cultivators in adoption of Recommended Packages of Practices (RPP).

Analysis of data was done with descriptive statistical tools *i.e.*, mean, percentage, etc. A multivariate regression analysis was done to identify determinants of yield.

$$Y = a+b_1X_1+b_2X_2+b_3X_3+b_4X_4+b_5X_5+b_6X_6+b_7X_7+b_8X_8+b_9X_9+b_{10}X_{10}+b_{11}X_{11}+b_{12}X_{12}+E$$

where,

Y = Productivity of i^{th} crop (kg/acre)
X_1 = Education (in numbers)
X_2 = Age in years
X_3= Source of seed (Purchase-1, Self-0)
X_4 = Soil test (Yes-1, No-0)
X_5 = Seed rate (Kg/acre)
X_6 = Seed treatment (Yes-1, No-0)
E= Error term
X_7= High Yielding Varieties (HYVs-1, Local-0)
X_8= Urea (kg/acre)
X_9= DAP (kg/acre)
X_{10}= No. of irrigation (acre)
X_{11}= Size of holding (acre)
X_{12}= Method of sowing (Line sowing=1 & Broadcasting=0)
b_1 to b_{12} = Regression coefficient of X_1, X_2, …….. X_{12}

3. Results and discussion

Yield gap, constraints in adoption of recommended technology and determinants of yield of major selected crop *i.e.*, rice, wheat, gram and soybean were analyzed for the study.

3.1 Rice

Rice was found to be a major Kharif crop grown in Bundelkhand region of Uttar Pradesh. The yield gap, constraints and adoption of recommended technology and determinants of yield of rice were analysed.

3.1.1 Yield gap analysis

A considerable yield gap (III) of 41.88 percent was found between potential farm yield (28 q/acre) and average farm yield (16.3 q/acre) on an average rice growers' farm in production of rice. Out of this total yield gap (yield gap-III), a gap of 24.15 percent (yield gap-I) and 23.33 percent (yield gap-II) was found between potential farm yield (28 q/acre) and highest farm yield (21.2 q/acre), and between the highest farm yield and average farm yield (16.3 q/acre), respectively (Table 4).

These findings were found to be similar for all size of farms with minor variation. However, yield gap I was found to be less in small farms (21.57%) as compared to medium (25.48%) and large (25.39%) farms. Yield gap II (23.33%) was found to be more than yield gap I (24.15%) which denotes that socio-economic constraints were found to be more important than transfer of recommended packages of practices of rice.

TABLE 4: YIELD GAP ANALYSIS OF RICE IN UTTAR PRADESH

(in q/acre)

Particulars	Small	Medium	Large	Overall
Potential yield	28.0	28.0	28.0	28.0
Average yield	16.4	15.8	16.7	16.3
Highest yield	22.0	20.9	20.9	21.2
Yield gap I	6.04 (21.57)	7.14 (25.48)	7.11 (25.39)	6.76 (24.15)
Yield gap II	5.61 (25.55)	5.1 (24.42)	4.19 (20.03)	4.97 (23.33)
Yield gap III	11.65 (41.61)	12.23 (43.68)	11.3 (40.34)	11.73 (41.88)

Note: Figure in parenthesis show percent yield gap

3.1.2 Constraints in adoption of recommended technology

The various constraints which were faced by the respondents in enhancing yield of rice are presented in Table 5.

TABLE 5: CONSTRAINTS IN ADOPTION OF RECOMMENDED PACKAGES OF RICE OF UTTAR PRADESH

(in percentage)

Particulars	Small	Medium	Large	Overall
Low germination of seed	35.86	33.84	65.00	44.90
Un-availability of desired variety of seed	84.35	64.15	75.00	74.50
Lack of suitable machinery	95.46	100.00	100.00	98.49
Lack of knowledge about method of seed treatment	51.52	46.97	55.00	51.16
High cost of input	100.00	90.00	90.00	93.33
Lack of knowledge about proper dose of fertilizer	64.15	61.62	50.00	58.59
Unavailability of capital	76.27	55.06	60.00	63.77
Unavailability of electricity on time	21.21	19.19	15.00	18.47
Lack of labour during the peak operational period	49.50	30.30	55.00	44.93
Lack of proper knowledge of packages of practices	45.96	39.39	45.00	43.45

It is observed from the data that the yield gap was found due to various constraints faced by the respondents in cultivation of rice. Lack of suitable machinery for cultivation practices of crop (98.49%), high cost of input (93.33%), unavailability of desired variety of HYVs seed (74.50%), unavailability of capital for purchase of inputs (63.77%), lack of knowledge about proper dose of fertilizer application (58.59%) and lack of knowledge about method of seed treatment (51.16%) were found to be major constraints as reported by more than 50 percent of respondents in adoption of recommended package of farming system. Lack of labour during peak operational periods (44.93%), low germination of seed (44.90%), lack of proper knowledge of recommended packages of practices (43.45%) and unavailability of electricity in time for peak operations of cultivation of soybean (18.47%) were found to be minor constraints as reported by less than 50 percent of respondents.

3.1.3 Determinants of yield of rice

A multiple regression model was carried out with education (x_1), age (x_2), source of seed (x_3), adoption of soil test recommendation (x_4), seed rate (x_5), adoption of seed treatment technology (x_6), replacement of seed with HYVs (x_7), consumption of urea (x_8), consumption of DAP (x_9), area under irrigation (x_{10}), increase in size of holding (x_{11}) and method of sowing (X_{12}) as independent variables. A multiple regression model was carried out to find out the factors affecting productivity of rice.

TABLE 6: FACTORS AFFECTING PRODUCTIVITY OF RICE

Particulars	Coefficients	SE	P-value
Education (X_1)	7.6058N	9.0856	0.4068
Age (X_2)	1.1152N	1.7190	0.5197
Source of seed (X_3)	135.2879*	53.8269	0.0154
Soil test (X_4)	81.4322**	36.2644	0.0295
Seed rate (kg) (X_5)	0.1279N	0.9016	0.8878
Seed treatment(X_6)	97.2556*	47.4362	0.0459
Use of HYV (X_7)	154.2798**	55.2940	0.0076
Urea (kg) (X_8)	1.7541	0.8949	0.0559
DAP (kg) (X_9)	2.4834	1.3782	0.0780
Irrigated land (X_{10})	-16.9956*	7.3105	0.0245
Size of holding (X_{11})	13.3519**	4.2454	0.0029
Method of sowing (X_{12})	249.6084**	92.6053	0.0097
R^2 (coefficient of multiple determinates)	**0.942**		

Note: * & ** significant at 5 (P<0.05) & 1 (P<0.01) percent, respectively

It is clear from the data presented in table that the response of rice in terms of productivity to use of HYV seeds over local varieties, optimum size of holdings and improved method of sowing over conventional method was positive and highly significant. The use of purchased seed over owned seed and seed treatment before sowing had positive and significant impact on productivity, while area under irrigation had negative and significant impact. This indicates that with the use of HYVs over local varieties; raising of crops in optimum size of holdings and use of improved method of sowing over conventional method; use of purchased seed over own farm seed; soil test based balanced application of fertilizers; proper seed treatment and optimum irrigation led to enhancing the productivity of rice in the area under study (Table 6).

The coefficient of multiple regression model was found to be good fit as it explained that 94.20 percent (R^2 0.942) of productivity of rice is

determined by these known independent variables and only 5.80 percent was the contribution of unknown variables which were not taken into consideration in this regression model.

3.2 Wheat

Yield gap, constraints in adoption of recommended technology and determinants of yield of wheat were analysed for the study.

3.2.1 Yield gap analysis

A considerable yield gap (III) of 29.48 percent (6.7 q/acre) between potential yield (23 q/acre) and average yield (16.22 q/acre) was found on an average wheat growers' farm in Bundelkhand region of India. Out of this total yield gap (yield gap III), a gap of 12.13 percent (yield gap I) was found between potential farm yield (23 q/acre) and highest farm yield (20.21 q/acre) while a gap of 19.74 percent (yield gap II) was found between highest (20.21 q/acre) and average farm yield (16.22 q/acre) in Bundelkhand region of India (Table 7).

TABLE 7: YIELD GAP ANALYSIS OF WHEAT IN BUNDELKHAND REGION OF INDIA

(in q/acre)

Particulars	Small	Medium	Large	Overall
Potential yield	23	23	23	23
Average yield	16.15	15.97	16.54	16.22
Highest yield	19.36	20.88	20.34	20.21
Yield gap I	3.39 (15.83)	2.89 (9.22)	2.52 (11.57)	2.93 (12.13)
Yield gap II	3.81 (16.58)	3.88 (23.52)	3.61 (18.68)	3.77 (19.74)
Yield gap III	7.2 (29.78)	6.77 (30.57)	6.13 (28.09)	6.7 (29.48)

Note: Figure in parenthesis show percent yield gap

The yield gap in cultivation of wheat was found to be 6.7 q/acre (29.48%) with potential yield of 23 q/acre in the area under study. Yield gap II (19.74 %) was found to be more than yield gap I (12.13%) which denotes the non-adoption of technology in cultivation of wheat due to socio-economic constraints.

3.2.2 Constraints in adoption of recommended technology

The various constraints across size of holdings which were faced by the respondents in cultivation of wheat are presented in Table 8. The major constraints which was reported were; high cost of input (82%), lack of knowledge about method of seed treatment (70%), unavailability of desired variety of seed (69%), lack of knowledge about proper doses of fertilizers (62%), lack of labour during peak operational periods (53%), unavailability of capital (42%), lack of suitable machinery (38%), unavailability of electricity on time (38%) and lack of proper knowledge of packages of practices (30%).

TABLE 8: CONSTRAINTS IN ADOPTION OF RECOMMENDED PACKAGES OF WHEAT ON BUNDELKHAND REGION OF INDIA

(in percentage)

Constraints	Small	Medium	Large	Overall
Low germination of seed	48	40	53	47
Unavailability of desired variety of seed	75	73	60	69
Lack of suitable machinery	43	48	25	38
Lack of knowledge about method of seed treatment	73	75	63	70
High cost of input	90	83	73	82
Lack of knowledge about proper dose of fertilizer	60	63	63	62
Unavailability of capital	60	43	38	47

Constraints	Small	Medium	Large	Overall
Unavailability of electricity on time	50	35	28	38
Lack of labour during the peak operational periods	43	58	58	53
Lack of proper knowledge of packages of practices	28	28	35	30

3.2.3 Determinants of yield

The response of wheat in terms of productivity to the use of purchased seeds over own farm seed, soil test based application of fertilizers, balanced application of urea and area under irrigation were found to be positive and highly significant. While the use of HYV seeds and application of DAP were found to be positive and significant, the higher seed rate and size of land holdings were found to be negative and highly significant, and age of respondents was found to be negative and significant. This indicates that use of higher seed rate, large size of holdings and higher age were found to be responsible for decrease in yield of wheat in area under study (Table 9).

TABLE 9: FACTORS AFFECTING PRODUCTIVITY OF WHEAT IN BUNDELKHAND REGION OF INDIA

Particulars	Coefficients	SE	P-value
Education (X_1)	20.824	30.063	0.490
Age in years (X_2)	-2.357*	1.006	0.021
Source of seed (X_3) (Purchase-1, Self-0)	148.733**	33.668	0.000
Soil test (X_4) (Yes-1, No-0)	101.797**	28.722	0.001
Seed rate (kg) (X_5)	-10.801**	3.418	0.002
Seed treatment(X_6) (Yes-1, No-0)	-17.161	33.374	0.608
Use of HYV's seed (X_7) (HYVs-1, Local-0)	75.805*	34.215	0.029
Urea (kg) (X_8)	1.640**	0.580	0.006
DAP (kg) (X_9)	1.561*	0.880	0.079
Area under irrigation (X_{10})	44.273**	8.727	0.000
Size of holding (X_{11})	-41.817**	7.919	0.000
R^2 (Coefficient of multiple determinates)	**0.835**		

Note: * & ** significant at 5 (P<0.05) & 1 (P<0.01) percent, respectively

This indicates that if all things remain constant and with the present level of technological adoption of soil test based application of fertilizers, balanced use of fertilizer (urea & DAP), use of proper seed rate, use of purchased seeds over own farm seeds, use of HYV's seed over local varieties and proper irrigation facilities and optimum size of holdings would help increase yield of wheat in the area under study.

The multiple regression model was found to be good fit as it explained 83.50 percent (R^2 0.835) of productivity of wheat determined by these known independent variables and only 16.50 percent was the contribution of unknown variables which were not taken into consideration in this regression model.

3.3 Gram

Gram is a major Rabi crop grown in Bundelkhand region of Madhya Pradesh. Yield gap, constraints in adoption of recommended technology and determinants of yield of gram were analysed for the study.

3.3.1 Yield Gap Analysis

A yield gap (III) of 43.59 percent between potential farm yield (8 q/acre) and average farm yield (4.51 q/acre) was found on an average gram grower's farm. Out of this total yield gap (yield gap III), a gap of 18.76 percent (yield gap I) and 30.49 percent (yield gap II) was found between potential (8 q/acre) and highest farm yield (6.5 q/acre), and between highest farm yield and average farm yield (4.51 q/acre), respectively (Table 10).

TABLE 10: YIELD GAP ANALYSIS OF GRAM

(in q/acre)

Particulars	Small	Medium	Large	Overall
Potential yield	8	8	8	8
Average yield	4.56	4.27	4.71	4.51
Highest yield	6.82	6.13	6.54	6.5
Yield gap I	1.18 (14.75)	1.87 (23.38)	1.46 (18.25)	1.5 (18.79)
Yield gap II	2.26 (33.14)	1.86 (30.34)	1.83 (27.98)	1.98 (30.49)
Yield gap III	3.44 (43.00)	3.73 (46.63)	3.29 (41.13)	3.49 (43.59)

Note: Figure in parenthesis show percent yield gap

The findings were found to be similar at overall level with minor variation across various size of holdings. However, yield gap I was found to be less in small farms (14.75%) as compared to large (18.25%) and medium (23.38%) farms. Yield gap II was found to be more than yield gap I which denotes the non-adoption of recommended packages of practices of gram due to socio-economic constraints.

3.3.2 Constraints in adoption of recommended technology

The various constraints which were found to be faced by the respondents in enhancing the yield of gram are presented in Table 11. Unavailability of desired variety of HYVs seed (86.67%), lack of knowledge about method of seed treatment (70%), lack of knowledge about proper dose of fertilizer application (63.33%) and unavailability of capital for purchase of inputs (61.67%) were found to be major constraints as reported by more than 50 percent of respondents.

TABLE 11: CONSTRAINTS IN ADOPTION OF RECOMMENDED PACKAGES OF GRAM

(in percentage)

Particulars	Small	Medium	Large	Overall
Low germination of seed	20.00	35.00	55.00	36.67
Unavailability of desired variety of seed	95.00	95.00	70.00	86.67
Lack of suitable machinery	20.00	30.00	45.00	31.67
Lack of knowledge about method of seed treatment	80.00	60.00	70.00	70.00

Particulars	Small	Medium	Large	Overall
High cost of input	60.00	70.00	55.00	61.67
Lack of knowledge about proper dose of fertilizer	70.00	60.00	60.00	63.33
Unavailability of capital	25.00	35.00	40.00	33.33
Unavailability of electricity on time	20.00	5.00	15.00	13.33
Lack of labour during the peak operational period	25.00	25.00	15.00	21.67
Lack of proper knowledge of packages of practices	55.00	35.00	40.00	43.33

Lack of proper knowledge of Recommended Package of Practice (RPP) (43.33%), low germination of seed (36.67%), unavailability of capital (33.33%), lack of suitable machinery for sowing, intercultural operations and harvesting of crop (31.67%), lack of labour during the peak operational periods (21.67%), unavailability of electricity on time for peak operations of cultivation of gram (13.33%) were found to be minor constraints as reported by less than 50 percent of respondents. These constraints were found to be similar across different categories of farmers with minor variance. However, constraints reported by small farmers were found to be more as compared to medium farmers in cultivation of gram.

3.3.3 Determinants of yield of gram

The crop response in terms of productivity in gram with respect to use of HYVs seeds over local variety, consumption of urea and seed rate was found to be positive and highly significant, while, area under irrigation and seed treatment were found to have positive and significant impact over increase in yield of gram.

Education, status of soil test, seed replacement (source of seed), size of land holding, balanced use of fertilizers (DAP) as per soil test value were found have positive but non-significant impact in enhancing productivity of gram while age was found to be negative and non-significant in enhancing productivity of gram. This indicates that if other things remain constant and with present level of technological adoption, use of HYVs seed, proper seed rate, seed replacement and increase in area under irrigation would enhance productivity of gram in the area under study. The fitted of multiple regression model was found to be good fit as it explained 83.90 percent (R^2 0.839) yield of gram was determined by these known independent variables and only 15.20 percent was the contribution of unknown variables which were not taken into consideration in this regression model.

TABLE 12: FACTORS AFFECTING PRODUCTIVITY OF GRAM

Particulars	Coefficients	SE	P-value
Education (X_1)	37.2378	17.6515	0.0401
Age in years (X_2)	-1.6908	1.5099	0.2684
Source of seed (X_3) (Purchase-1, Self-0)	49.2581	37.8205	0.1990
Soil test (X_4) (Yes-1, No-0)	42.1450	40.5646	0.3040
Seed rate (kg) (X_5)	31.1188**	10.5891	0.0051
Seed treatment(X_6) (Yes-1, No-0)	106.4320*	46.0713	0.0252
Use of HYV's seed(X_7) (HYVs-1, Local-0)	154.4361**	49.6182	0.0031
Urea (kg) (X_8)	35.4693**	10.5265	0.0015
DAP (kg) (X_9)	2.3281	3.3762	0.4938

Particulars	Coefficients	SE	P-value
Area under irrigation (X_{10})	63.8487*	28.0681	0.0274
Size of holding (X_{11})	1.5688	1.3714	0.2583
R^2 (Coefficient of Multiple Determinates)	**0.839**		

Note: * & ** significant at 5 (P<0.05) & 1 (P<0.01) percent, respectively

3.4 Soybean

Soybean is a major Kharif crop grown in Bundelkhand region of Madhya Pradesh. Yield gap, constraints in adoption of recommended technology and determinants of yield of soybean were analysed for the study.

3.4.1 Yield gap analysis

A yield gap (III) of 38.87 percent between potential yield (10 q/acre) and average farm yield (6.11 q/acre) was found on an average soybean growers' farm in production of soybean. Out of this total yield gap (yield gap III), a gap of 11.43 percent (yield gap I) and 30.85 percent (yield gap II) was found between potential (10 q/acre) and highest farm yield (8.86 q/acre), and between the highest and average farm yield (6.11 q/acre), respectively (Table 13). These findings were found to be similar for all size of farms with minor variation. However, yield gap I was found to be less in medium farms (7.50%) as compared to small (11.20%) and large (15.60%) farms. Yield gap II (30.85%) was found to be more than yield gap I (11.43%) which denotes that socio-economic constraints were found to be more important than transfer of recommended packages of practices of soybean.

TABLE 13: YIELD GAP ANALYSIS OF SOYBEAN

(q/acre)

Particulars	Small	Medium	Large	Overall
Potential yield	10	10	10	10
Average yield	6.32	5.91	6.11	6.11
Highest yield	8.88	9.25	8.44	8.86
Yield gap I	1.12 (11.20)	0.75 (7.50)	1.56 (15.6)	1.14 (11.43)
Yield gap II	2.56 (28.83)	3.34 (36.11)	2.33 (27.61)	2.74 (30.85)
Yield gap III	3.68 (36.8)	4.09 (40.90)	3.89 (38.90)	3.89 (38.87)

Figure in parenthesis show percent yield gap

3.4.2 Constraints in adoption of recommended technology

The various constraints which were faced by the respondents in enhancing yield of soybean are presented in Table 14.

TABLE 14: CONSTRAINTS IN ADOPTION OF RECOMMENDED PACKAGES OF SOYBEAN

(in percentage)

Constraints	Small	Medium	Large	Overall
Low germination of seed	65.00	60.00	85.00	70.00
Unavailability of desired variety of seed	75.00	60.00	75.00	70.00
Lack of suitable machinery	45.00	45.00	35.00	41.67
Lack of knowledge about method of seed treatment	60.00	30.00	80.00	56.67
High cost of input	60.00	25.00	90.00	58.33
Lack of knowledge about proper dose of fertilizer	40.00	25.00	70.00	45.00
Unavailability of capital	30.00	25.00	40.00	31.67
Unavailability of electricity on time	35.00	10.00	30.00	25.00
Lack of labour during the peak operational periods	30.00	35.00	35.00	33.33
Lack of proper knowledge of packages of practices	25.00	20.00	40.00	28.33

Low germination of seed (70%), unavailability of desired variety of HYVs seed (70%), high cost of input (58.33%) and lack of knowledge about method of seed treatment (56.67%) were found to be major constraints as reported by more than 50 percent of respondents in adoption of recommended package of farming system. Lack of knowledge about proper dose of fertilizer application (45%), lack of suitable machinery for sowing, intercultural operations and harvesting (41.67%), lack of labour during the peak operational periods (33.33%), unavailability of capital for purchase of inputs (31.67%), lack of proper knowledge of recommended packages of practices (28.33%) and unavailability of electricity in time for peak operations of cultivation of soybean (25%) were found to be minor constraints as reported by less than 50 percent of respondents.

3.4.3 Determinants of yield

The crop response in terms of productivity in soybean with respect to application of DAP and area under irrigation were found to be positive and highly significant, while seed rate and use of HYVs seed over local variety were found to be positive and significant. The size of holdings was found to have negative and highly significant impact while education of respondents, replacement of HYVs seed, seed treatment and method of sowing had positive but non-significant impact on productivity. Age in years and consumption of urea were found to have negative and non-significant impact. The coefficient of multiple regression model was found to be a good fit as it explained 83.90 percent (R^2 0.839) of productivity of soybean was determined by these known independent variables and only 16.10 percent was the contribution of unknown variables, which were not taken into consideration in this regression model (Table 15).

TABLE 15: FACTORS AFFECTING PRODUCTIVITY OF SOYBEAN

Particulars	Coefficients	SE	P-value
Education (X_1)	11.0281	5.8421	0.0652
Age in years (X_2)	-1.2299	0.8275	0.1439
Source of seed (X_3) (Purchase-1, Self-0)	103.7147	58.7358	0.0839

Particulars	Coefficients	SE	P-value
Soil test (X_4) (Yes-1, No-0)	53.5092	95.6298	0.5784
Seed rate (kg) (X_5)	3.8736*	1.7874	0.0353
Seed treatment(X_6) (Yes-1, No-0)	29.8112	46.4124	0.5238
Use of HYV's seed(X_7) (HYVs-1, Local-0)	81.8860*	34.7229	0.0226
Urea (kg) (X_8)	-0.5941	5.1535	0.9087
DAP (kg) (X_9)	5.7391**	2.1198	0.0094
Area under irrigation (X_{10})	51.0759**	16.6743	0.0036
Size of holding (X_{11})	-32.4088**	11.6433	0.0077
Method of sowing (X_{12}) (Line sowing=1 & Broad-casting=0)	203.5692	107.5977	0.0647
R^2 (Coefficient of multiple determinates)	**0.839**		

* & ** significant at 5 (P<0.05) & 1 (P<0.01) percent, respectively

4. Conclusions

The following conclusions have been drawn from the above results:

4.1 Yield Gap Analysis

- A considerable yield gap (III) of 41.88 percent between potential yield (28 q/acre) and average farm yield (16.3 q/acre) was found on an average rice growers' farm in the production of rice. Out of this total yield gap (yield gap III), a gap of 24.15 percent (yield gap I) and 23.33 percent (yield gap II) was found between potential (28 q/acre) and highest farm yield (21.2 q/acre), and between the highest and average farm yield (16.3 q/acre), respectively.

- A yield gap (III) of 29.48 percent (6.7 q/acre) between potential yield (23 q/acre) and average yield (16.22 q/acre) was found on an average wheat growers' farm in Bundelkhand region of India. Out of this total yield gap (yield gap III), a gap of 12.13 percent (yield gap I) was found between potential (23 q/acre) and highest farm yield (20.21 q/acre) while a gap of 19.74 percent (yield gap II) was found between highest (20.21 q/acre) and average farm yield (16.22 q/acre).

- A yield gap (III) of 43.59 percent between potential yield (8 q/acre) and average farm yield (4.51 q/acre) was found on an average gram growers' farm. Out of this total yield gap (yield gap III), a gap of 18.76 percent (yield gap I) and 30.49 percent (yield gap II) was found between potential (8 q/acre) and highest farm yield (6.5 q/acre), and between highest and average farm yield (4.51 q/acre), respectively

- A yield gap (III) of 38.87 percent between potential yield (10 q/acre) and average farm yield (6.11 q/acre) was found on an average soybean growers' farm in production of soybean. Out of this total yield gap (yield gap III), a gap of 11.43 (yield gap I) and 30.85 percent (yield gap II) was found between potential (10 q/acre) and highest farm yield (8.86 q/acre), and between the highest and average farm yield (6.11 q/acre), respectively.

4.2 Constraints analysis

- The yield gap was found due to various constraints faced by the respondents in cultivation of rice. Lack of suitable machinery for cultivation practices of crop (98.49%), high cost of input (93.33%), unavailability of desired variety of HYVs seed (74.50%), unavailability of capital for purchase of inputs (63.77%), lack

of knowledge about proper dose of fertilizer application (58.59%) and lack of knowledge about method of seed treatment (51.16%) were found to be major constraints as reported by more than 50 percent of respondents in adoption of recommended package of farming system.

- Various constraints were reportedly faced by the respondents in cultivation of wheat. The major constraint which was reported by about 80 to 90% of respondents was high cost of input, about 70% respondents reported unavailability of desired variety of seed, lack of knowledge about method of seed treatment and proper doses of fertilizers, while around 50 percent reported unavailability of capital and lack of labour during peak operational periods in adoption of recommended technology of wheat cultivation.

- Yield gap in gram was found due to various constraints like unavailability of desired variety of HYVs seed (86.67%), lack of knowledge about method of seed treatment (70%), lack of knowledge about proper dose of fertilizer application (63.33%) and unavailability of capital for purchase of inputs (61.67%) as reported by more than 50 percent of respondents.

- The yield gap in soybean was found due to various constraints like low germination of seed (70%), unavailability of desired variety of HYVs seed (70%), high cost of input (58.33%) and lack of knowledge about method of seed treatment (56.67%) as reported by more than 50 percent of respondents in adoption of recommended package of farming system.

4.3 Determinants yield

- A multiple regression model was used to find out determinants of yield of major crops. It was found to be good fit as it explained about 85 percent contribution of known independent variables like use of high yielding varieties (HYVs) seed, improved method of sowing (rice), source of seed (rice & wheat), seed rate (soybean & gram), use of DAP (soybean & wheat), application of urea (wheat), treatment with fungicide and bio-fertilizers in rice and gram (Rhizobium, azotobacter and Phosphate Solubilizing Bacteria), irrigation (wheat, soybean and gram), soil testing (rice and wheat) were found to be positive and significant, while area under irrigation (rice), size of land holding (soybean and wheat) and seed rate (wheat) were found to be negative and significant. This indicates that with the increase in the factors which are positive and significant, the yield of crop will increase and vice-versa.

5. Suggestions

From the above conclusions it is found that there is a yield gap of more than 30 percent between potential and average farm yield of major crops in Bundelkhand region of India. Therefore, following strategies may be formed to reduce the yield gap and enhance the income of the farmers.

- Need based training programme based on Recommended Package of Practice of cultivation of crops in the area may be organized for the field staff of the Farmer Welfare and Agriculture Development Department, Bundelkhand region of India followed by producers before the start of the season in the nearest KVK. The whole training must be designed keeping in the view the field staffs and producers of the area which will directly reflect into the productivity of crops.

- One or two demonstration should be conducted in villages keeping in view the complete transfer of technology with full package of practices along with component wise packages of practices of cultivation of crops in the field of key farmers. If there is a problem or incidence of insects or diseases, a field day should be organized in front of all the farmers of the village so that they understand all the package of practices of crop cultivation.

- Online portal of government on seed distribution needs to be created to show the

variety-wise and class-wise availability of seed with the facility of online purchase/booking, as majority of farmers reported unavailability of desired variety seed as major constraint in cultivation of crops.

- It was also found during the course of investigation that majority of farmers did not adopt need based Integrated Farming System (IFS) in a true sense. Hence, efforts should be made to introduce need based integrated farming system in the area and at least one Seed Producer Company, Producer Company, Custom Hiring Centre is required to be established in each and every gram panchayat/ Development Block of Bundelkhand region of India for fostering the all round growth of the region in true sense.

- It is observed that "Toll Free Number" of the Kisan Call Centre (1800-180-1551) was not reported by the respondents as the main source of information dissemination for the farmers in the area under study. Hence, strategies should be made in such a way that every farmer should able to use this particular number to solve his problem related to crop and animal husbandry.

- Technology adoption in agriculture is a long drawn process, which involves developing appropriate need-based technology, testing the new technology, taking it from lab-to-land, and optimum application of it for obtaining the desired benefit for its sustainability. Willingness to adopt the new technology by farmers is a crucial challenge, especially in view of the financial and knowledge constraints of farmers. Moreover, the new technology needs to be integrated with the extent systems and policies for wider acceptability.

- Digital technology requires uses of computers, internet, mobile technology, application tools, etc. It may not be easy for majority of farmers with their current level of education, exposure and remoteness of their locations. To certain extent, capacity building on the principle of seeing & believing (demonstration) needs to be adopted to motivate farmers to accept technological change in agriculture.

Thus, the yield gap of crops can only be narrowed down through enhancing productivity by batter management of available farm resources and proper allocation of funds for purchase of inputs. This needs strengthening of knowledge of producers through trainings, demonstrations, mass media approach through electronic means and information technologies. There is also a need of Public Private Partnership (PPP) for knowledge management, supply and procurement of produce at reasonable price, which works as a catalytic agent for increasing adoption of crop production technologies leading to break yield barriers in crop production.

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