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Agricultural Economics Research Review 2018, 31 (2), 281-289
DOI: 10.5958/0974-0279.2018.00045.9

Technology adoption, its impact and determinants: the case of soybean in Madhya Pradesh

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Abstract There has been a rapid growth in soybean production in India. Most of it came from area expansion and little from yield improvements. In this paper, we assess the adoption of improved soybean technologies, their effects on yield, and the factors determining their adoption. The findings show that adoption of improved technologies does improve crop yield and farm profit, but their adoption largely remains confined to economically well-off, better-informed, educated large farmers. This implies a need for strengthening linkages between research and extension systems for widespread adoption of improved technologies and cropping practices.

Keywords Soybean, Technology adoption, Constraints, Impacts

JEL classification D24, O33, Q16

1 Introduction

The production of soybean in India has grown rapidly since its introduction for commercial cultivation in the early 1970s (Birthal et al. 2010; Chand 2007). The growth occurred mainly due to area expansion (Sharma 2016). Growth in its yield has not been so impressive. The average yield of soybean is low, hovering around one ton per hectare. But, there exists a large gap between the potential and actual yield (Bhatnagar & Joshi 2004; Billore et al. 2009; Jha et al. 2011) on account of several biotic and abiotic constraints (Jha et al. 2011).

India's agricultural research system has developed several high-yielding cultivars and good agronomic practices for different production environments. These, however, are not being fully adopted by farmers probably due to a lack of information on these or their poor economic conditions or inefficiencies in technology delivery systems (Tomar & Sharma 2002; Gupta & Shrivastava 2002; Sharma, et al. 2006; Dupare, et al. 2011; Kumar, et al. 2012; Singh, et al. 2013). Several studies have examined farmers' technology adoption behaviour and its underlying factors (see, Feder & Umali 1993), but most of these have focused either on a single technology or one of the components of technology package. The technology adoption process, in general, is complex but it becomes more complicated in case of a packaged technology that contains several components complementing each other. Farmers, however, rarely adopt the full package, and it is often adopted sequentially. There are only a few studies that have investigated adoption of the package of technologies (Kim et al. 2004; Rahelizatovo & Gillespie 2004; Ramirez & Shultz 2000). A few studies in India have also investigated adoption of technology package (Dupare et al. 2011; and Singh et al. 2013), but these do not make any attempt to understand the factors underlying farmers' adoption decisions. With this background, in this paper we attempt to assess the level of adoption of package of soybean technologies, its effect on yield, and the factors influencing its adoption.

2 Data and method

The study is based on primary data collected from soybean farmers of Madhya Pradesh following a multi-

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stage sampling procedure. In the first stage, we ranked all the districts based on yield level (during 2010-12) and categorised these into high, medium and low productivity districts. Then, from each category, one district was randomly selected, i.e. Sehore, Ujjain, and Khandwa respectively representing high, medium and low productivity districts. In the second stage, we selected a cluster of three villages from each selected district, and finally a sample of 100 farm households was randomly drawn from each cluster of villages. The required information on various aspects of soybean production system including technology adoption, constraints to technology adoption, costs and returns, and socioeconomic characteristics was collected through personal interviews using a questionnaire schedule. The data pertain to 2015-16.

As the focus of this study is on understanding the technological change in soybean production system, we sought detailed information on different types of technologies and modern agronomic practices recommended by the agricultural research and extension systems. The extent to which the recommended package had been adopted by the farmers was ascertained by an adoption index constructed using score of 3, 2, 1 and 0 for full, over, partial adoption and no adoption, respectively, and assigning equal weights to each of these (Dupare 1995).

$$A_i = (S_o / S_{max}) \qquad \ldots(1)$$

where, A_i is the index of adoption, S_o is the total score obtained by a farmer, and S_{max} is the maximum attainable score. The index is a continuous variable, ranging from zero to one, and provides the intensity of adoption. Hence, to identify the factors influencing adoption we use Tobit model.

$$Y_i^* = \beta X_i + \mu_i \quad (i= 1,2,3,\ldots\ldots N) \qquad \ldots(2)$$

where, Y_i^* is the latent, unobserved dependent variable (i.e., intensity of adoption), X_i is a vector of the explanatory variables, β is a (k×1) vector of unknown parameters, and μ is the random error term with mean zero and constant variance σ^2. The observed component of the dependent variable is Y_i.

The probability of adoption is defined as:

$$Y_i = f(x) = \begin{cases} 0 & if\ Y^* \leq 0 \\ Y^* & if\ 0 < Y^* < 1 \\ 1 & if\ Y^* \geq 1 \end{cases} \quad (i= 1\ldots\ldots\ldots\ldots, N) \qquad \ldots(3)$$

Adoption occurs when Y_i falls within $0<Y^*<1$ and $Y^* \geq 0$; and non-adoption occurs when $Y^* \leq 0$.

The Tobit regression that we estimate is:

$$A_i = \beta_0 + \beta_1\ Age + \beta_2\ Edu + \beta_3\ P_{SoyArea} + \beta_4\ Inc_{PP} + \beta_5\ Family\_Size + \beta_6\ Ext\_Contact + \beta_7\ Farm\_Size + \varepsilon \qquad \ldots(4)$$

The details of the explanatory variables are given in table 1.

Further, to understand the intensity of constraints faced in adoption, respondents were asked to rank the constraints as highly important, important and less important, and these were subjected to a Principal Component Analysis (PCA) that summarizes the information contained in a number of correlated variables into a smaller set of uncorrelated dimensions called principal components (PC) with minimal loss of information. The decision on which of the PC to retain depends on the variation in the original variables accounted for by each PC, and whether the PC can be meaningfully interpreted.

3 Results and discussion

3.1 Level of adoption

Table 3 presents component wise adoption of the package of practices. A majority of the farmers (>50%) followed recommended practices such as deep summer ploughing once in three year, use of improved soybean variety, seed treatment with fungicide, timely sowing (upon receiving 10 cm rainfall), maintaining proper row to row distance, use of herbicides for weed control, manual weeding and timely harvesting. The adoption of practices such as germination test, seed inoculation with bio-inoculants like Rhizobium (*Bradyrhizobium japonicum*) and PSB (phosphate solubilizing bacteria), intercropping, application of zinc, disease management and soil moisture conservation was not encouraging.

It is interesting to note that a large proportion of farmers was also over-adopting certain practices like deep summer ploughing, farm yard manure, seed rate, fertilizers and insecticides. Farmers use higher seed rate because of they have their own stock of seed from the previous harvest, but they are not sure of seed viability and less interested in germination tests. They perceive that high plant population suppresses weed growth. Appropriate distance between rows is known

Table 1. Hypothesized determinants of soybean production technology adoption in India

Variable	Unit	%	Mean	Rationale
Age	Years		43 (10.85)	Older farmers are more experienced; hence, more experienced and more likely to adopt the package of production technologies.
Edu	Years of schooling		7.18 (3.92)	Educated farmers have better access to information and are less risk averse; hence they are likely to adopt the package of production technologies.
P_Soy_Area	% area under soybean		95.41 (11.45)	Farmers allocating more area to soybean are more likely to adopt the package of production technologies.
Family_Size	Number of family members		6.58 (2.82)	More number of members in family assures availability of labour and therefore the ability to adhere to the package of production technology.
Inc_PP	Income in Rupees per capita/ year		27944.3 (30187)	Higher family income provides access to technologies.
Ext_Contact	Extension contact:			Extension contacts increases information access and provides readiness to adopt the technology.
	Yes=1,	54		
	0 otherwise	46		
Loan	1=Yes,	47.5		Crop loan alleviates liquidity constraint on purchase of inputs.
	0=No	52.5		
Farm_Size	1=Small,	25.5		Larger farmers are likely to adopt the package of production technology to realize scale economies.
	2=Semi-Medium	32	4.17 ha	
	3= Medium	33		
	4=Large	9.5		

Figures in parentheses are standard deviations.

Table 2. Technology adoption index and impact on soybean yield and economics

Particulars	Adoption index			
	High (A_i> 50%)	Medium (>40 A_i<50 %)	Low (< 40%)	All
% farmers	19	47	34	100
% soybean area of sample farmers	26	40	35	100
Average yield (kg/ha)	1196	1086	808	1018
Minimum yield (kg/ha)	872	500	200	200
Maximum yield (kg/ha)	2000	1700	1333	2000
Operational cost (Rs/ha)	16855.0	17479.6	15636.0	16680.9
Gross returns (Rs/ha)	38336.9	33241.0	25044.6	31710.4
Net returns over operational cost (Rs/ha)	21481.9	15761.4	9408.6	15029.5

Source: Field survey

to improve yields of crops and helps minimize infestation of pests and diseases. The viability of *Rhizobium and* PSB cultures is an important consideration in their adoption decisions.

Table 2 shows the adoption index and the distribution of farmers by the level of index. The adoption index ranges between 30.4% to 66.1%. For majority of the farmers the index lies in the range of 40-50% (44%),

Table 3. Adoption of improved soybean package of practices by selected farmers

(% farmers)

Package of practices	Full adoption	Over adoption	Partial adoption	No adoption
Deep summer ploughing once in 3 years	67	24	0	9
Two cross harrowing/ cultivator	7	6	46	42
Apply FYM @ 10 t/ha	15	16	27	43
Use improved soybean variety	84	0	0	16
Use recommended seed rate	49	51	0	0
Germination test	9	-	-	91
Seed treatment with fungicide	51	-	-	49
Seed treatment with Rhizobium/ PSB culture	45	-	-	55
Timely sowing	73	-	-	27
Use of intercrop	5	0	4	91
Maintain row to row distance	51	10	38	0
Plant to plant spacing	37	38	25	0
Herbicide use	57	13	26	5
Manual weed management/ inter-culture operation	59	-	-	41
Application of recommended dose of NPK	28	19	53	1
Application of recommended dose of Zinc	1	0	1	99
Application of recommended dose of Sulphur	15	14	23	49
Insect management	20	15	26	39
Disease management	7	7	12	73
Soil moisture conservation	7	-	-	93
Timely harvesting (at 95% of pods change colour)	92	-	-	8

Source: Field survey.

we term such farmers as medium adopters. Those who have index level below 40% are categorised as low adopters, and they constitute 38% of the total sample. Only 18% of the farmers fall in the category of high adopters (Ai>50%). Dupare et al. (2011) and Singh, et al. (2013) have also reported similar results.

3.2 Effect on yield and profit

The results show a clear positive association between intensity of technology adoption and yield; high adopters of technology achieved an average yield of 1196 kg/ha, almost 1.5 times of that realized by low adopters (Table 2). Higher yield ensures higher returns (Table 2). Although for high adopters, the adoption of recommended package of practices marginally raises the cost of cultivation (8%) over the low adopters, the net returns are higher by 128%. These findings imply that marginal returns from adoption of recommended package of practices are significantly higher than the marginal cost of its adoption, and there is a considerable scope to improve farm income through strengthening linkages between research and extension systems.

3.3 Factors influencing adoption

As to understand the relative importance of different factors in the adoption of technology, we regress technology adoption index on a set of variables, such as age and education of the household-head, proportion of area allocated to soybean, family size, income per capita, contact with extension worker, access to institutional credit availed and farm size. Except the area under soybean and credit all the other variable are significant (table 4). Age of the household-head has a negative and significant effect on intensity of adoption, indicating that older farmers are more risk-averse in their decision to adopt recommended technologies. Education level, on the other hand, has positive and significant effect, implying that educated farmers are more likely to adopt improved technology package. Farm size, contrary to our expectations, has

Table 4. Estimated parameters of tobit model

Parameter	Parameter estimate	t value	Pr > |t|
Intercept	3.13148*	11.26	<.0001
Ln_Age	-0.11006**	-2.35	0.0189
Education	0.00938*	3.20	0.0014
P_Soy_Area	-0.00105	-1.14	0.2532
Fam_Size	0.09901*	3.59	0.0003
Ln_Income PP	0.09572*	5.45	<.0001
Ext_Contact	0.08874*	4.02	<.0001
Loan	0.01304	0.62	0.5381
Farm_Size	-0.04868*	-3.12	0.0018
_Sigma	0.1444042*	20.00	<.0001
Log likelihood	103.743		

* and ** denotes significance at 1% and 5% level, respectively.

a negative and significant effect on adoption. However, the larger the family size, more is the level of adoption. It appears that the recommended package of technologies and practices is labour-intensive and for large farmers labour is a binding constraint on its adoption. Farmers in contact with extension workers have significantly higher probability of adoption of the recommended production technologies.

3.4 Constraints to adoption

Farmers face several constraints in soybean production. The dimensionality of the constraints was reduced using principal component analysis and the results are presented on Table 5. Principal components that meet Kaiser's criterion (i.e., have Eigen values of one or more), explain about 70% of the total variance and can be meaningfully interpreted have been retained and discussed here. Of the total 11 components that explained 66.9% of the variance in farmers' scores were extracted from the covariance matrix. Constraints with an estimated factor loading of more than ±0.4 were considered to make contributions to the principal component.

The first component (PC1) explained about 24% variance in the farmers' score. The constraints, like non-availability of proper seed drill for sowing, local unavailability of preferred variety seed, timely non-availability of herbicide, timely unavailability of fertilizers, lack of equipments for pesticide application, timely availability of pesticides, non-availability of seed of pest/ disease resistant variety, lack of remunerative price of produce, non-availability of market intelligence and lack of training facilities on improved methods contribute significantly to the first principal component. Broadly, this component reflects the constraints related to farmers' lack of access to resources or inputs or services.

The second component has positive loadings on the constraints such as unable to purchase high yielding seeds in want of funds and high cost of seeds, high cost of pesticides, non-availability of labour for weeding and harvesting and poor germination due to low or excess rainfall. This component broadly reflects the problem related to the bio-physical and economic conditions of the production system, and explains 7.8% of the total variance.

The third principal component explains 6.3% of the total variance. This component has positive loadings on non-availability of crop loan in time and in required amount. Therefore, this component to a great extent represents the constraints related to farmers' access to credit.

The fourth principal component explains 5.4 % of the total variations in the constraints' score and denotes the variables related to high cost of inputs and farmers poor economic conditions. The fifth principal component has positive loadings on the constraints, such as unavailability of BBF/FIRBS machines, difficulties in use of BBF/FIRBS technology, improper rainfall at critical crop growth stages, moisture stress in late maturing varieties and lack of processing facility. This component broadly reveals constraints related to technologies/methods of moisture conservation and adaptation to climate change. This principal component explains 4.4% of the total variance. Likewise, the sixth principal component explains 4.2% of the total variance in the farmers' score on constraints that include non-availability of right type of fungicides for seed treatment, and lack of knowledge on warehousing.

These findings clearly show that poor adoption of the recommended technologies and crop management practices is due to farmers' poor access to information and institutional credit. Several other studies have also arrived at similar conclusions (Sharma et al.1996; Dalvi et al. 2004, Ahirwar et al. 2006; Raghuwansi & Sahu 2007; Dupare et al. 2010; 2011; 2013; Ahirwar et al. 2014).

Table 5. Estimated principal components for the constraints faced by farmers in soybean production

Constraints	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6	Factor7	Factor8	Factor9	Factor10	Factor11
Poor germination due to hard crust	0.247	**0.458**	**0.452**	-0.078	0.026	0.068	-0.301	-0.167	0.058	0.152	-0.002
Do not know recommended method of sowing	0.265	0.242	0.070	0.016	-0.149	0.144	0.037	-0.019	0.024	**0.773**	0.060
Non-availability of proper seed drill for sowing	**0.509**	0.311	0.243	0.102	0.107	0.237	-0.250	0.015	-0.027	0.346	0.016
Non availability of pure/ quality seed	0.250	0.086	0.212	0.036	0.065	**-0.426**	0.061	-0.074	0.154	**0.633**	0.112
Local unavailability of preferred variety seed	**0.784**	0.284	-0.092	0.185	0.061	-0.098	-0.046	-0.001	0.086	0.024	0.040
Unable to purchase HYV seed due to lack of money	0.320	**0.724**	-0.025	0.167	-0.269	0.082	-0.021	0.123	-0.045	0.102	-0.092
High cost of HYV seed	0.230	**0.753**	0.019	0.193	0.027	-0.226	0.101	-0.108	0.036	0.141	-0.040
Non availability of required fungicide for seed treatment	0.388	-0.026	0.079	-0.060	0.154	**0.723**	0.089	-0.071	-0.076	0.111	0.085
Lack of availability of rhizobium and PSB culture	0.179	0.289	-0.032	0.240	-0.104	0.334	-0.299	0.012	**-0.427**	0.070	0.234
Lack of knowledge about seed treatment/inoculation	0.005	-0.134	-0.196	0.010	0.087	-0.003	-0.041	**0.705**	0.035	-0.005	0.041
Poor quality of rhizobium and PSM culture	-0.055	0.042	0.304	0.310	0.258	0.393	**-0.429**	-0.089	0.173	-0.053	0.200
Timely non-availability of herbicide	**0.451**	0.073	0.178	0.010	0.174	0.372	0.086	-0.387	-0.324	-0.079	0.178
Lack of knowledge of herbicide application	-0.011	-0.107	0.165	-0.038	-0.133	-0.051	0.003	**0.667**	0.005	-0.109	0.175
High cost of herbicides	0.109	0.269	0.147	**0.521**	0.047	-0.009	-0.035	-0.299	0.209	-0.057	0.113
Lack of knowledge on recommended dose of fertilizers	-0.059	-0.162	-0.057	-0.091	0.013	0.045	0.026	0.105	-0.039	0.075	**0.839**
Timely unavailability of fertilizers	**0.683**	0.046	-0.037	0.300	0.020	0.138	0.192	-0.062	0.054	0.219	-0.218
Lack of money for purchase of fertilizers	**0.560**	0.120	0.251	**0.484**	-0.061	0.090	0.241	0.071	-0.094	0.045	0.005
High cost of fertilizers	0.052	0.179	0.252	**0.501**	0.211	-0.016	0.008	-0.148	0.236	-0.034	-0.008
Lack of knowledge about INM	0.234	-0.060	-0.289	0.010	0.190	0.143	0.194	0.351	-0.141	0.080	**0.511**
Lack of knowledge on pest/ disease management	-0.024	0.284	0.007	-0.002	0.391	0.121	0.108	**0.438**	-0.057	0.099	0.155
Lack of money for purchase of pesticides	**0.549**	0.272	0.249	**0.517**	-0.041	0.059	0.041	0.113	0.037	-0.220	-0.079
Lack of machinery for pesticide application	**0.551**	-0.188	0.374	0.080	-0.102	0.136	0.339	0.103	0.233	-0.166	0.091
Timely unavailability of pesticides	**0.584**	0.026	0.038	0.063	-0.096	0.135	0.010	-0.289	0.330	0.174	-0.031
High cost of pesticides	0.364	**0.489**	0.204	0.393	-0.019	-0.139	-0.153	-0.241	0.213	0.004	-0.119
Non-availability of seed of pest/ disease resistant variety	**0.409**	0.318	-0.178	0.352	0.033	0.085	-0.233	-0.299	-0.023	-0.051	-0.259
Lack of irrigation facilities at critical growth stages	**0.577**	**0.456**	0.234	0.000	0.004	0.190	0.361	-0.127	-0.050	-0.127	0.040
Un-willingness to irrigate crop under long dry spell	**0.678**	0.208	**0.409**	-0.085	-0.072	0.219	0.031	0.142	-0.022	0.150	0.006
Unavailability of BBF/FIRBS machines	-0.097	-0.021	0.203	-0.015	**0.597**	0.012	-0.199	-0.072	0.046	-0.089	0.091
Difficulties in use of BBF/FIRBS technology	-0.103	-0.151	-0.005	0.062	**0.664**	0.125	-0.162	-0.118	0.079	0.007	0.028
Non-availability of labour at weeding/ harvesting	0.039	**0.464**	0.036	0.254	-0.185	0.316	-0.007	-0.057	0.309	0.284	-0.052
High labour charges at weeding/ harvesting	0.147	0.331	0.020	0.053	-0.038	-0.114	-0.071	-0.059	**0.529**	0.025	-0.199
Non-availability of timely crop loan	-0.035	0.134	**0.715**	0.175	0.111	0.033	0.104	0.006	0.144	0.028	-0.009
High cost/difficulty in getting crop loan	0.055	0.080	**0.407**	0.224	0.254	0.022	0.233	0.116	**0.526**	-0.106	0.072
Unavailability of required amount of loan	0.191	-0.015	**0.648**	0.293	0.181	-0.106	0.038	-0.051	-0.052	0.166	-0.109
Long distance to credit agencies	0.097	0.047	**0.514**	0.088	0.013	**0.454**	0.213	-0.073	0.143	0.037	-0.344
Lack of knowledge about crop insurance scheme	-0.084	0.309	0.016	0.336	0.265	-0.382	0.143	0.104	-0.132	0.146	0.231

Contd...

Constraints	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6	Factor7	Factor8	Factor9	Factor10	Factor11
Long distance of market	-0.008	-0.122	0.188	-0.017	-0.155	0.097	**0.718**	-0.018	0.016	0.097	0.082
Lack of transport facilities/ high cost	0.364	0.070	-0.052	0.345	-0.179	0.247	**0.563**	-0.111	0.153	0.049	0.001
Dependency on middlemen for marketing	0.181	0.078	0.116	**0.704**	0.005	0.070	0.068	0.175	-0.076	0.120	-0.113
Lack of storage facilities	0.160	0.209	0.088	0.169	0.173	-0.065	**0.464**	0.214	-0.029	-0.180	0.393
Lack of knowledge about warehousing	0.286	-0.233	-0.094	0.277	-0.070	**0.562**	0.297	0.137	0.093	-0.066	0.134
Lack of remunerative price of produce	**0.823**	0.118	-0.067	-0.016	0.077	-0.060	-0.098	0.045	0.061	-0.096	0.072
Lack of processing facility nearby	0.151	0.063	0.200	0.091	**0.435**	-0.033	0.094	0.309	0.197	-0.316	0.152
Non-availability of market intelligence	**0.695**	0.151	-0.044	0.060	0.071	0.100	0.232	-0.033	0.064	0.309	-0.124
Improper rainfall at critical stages	0.194	0.062	0.193	-0.011	**0.452**	-0.117	0.274	0.326	-0.269	-0.177	-0.174
Moisture stress in late maturing varieties	0.229	0.221	-0.049	0.095	**0.589**	-0.172	0.050	0.335	0.230	0.108	-0.138
Non-availability of drought resistant varieties	0.291	0.000	0.119	0.041	0.206	0.136	-0.011	0.061	**0.724**	0.120	0.027
Lack of training facilities on improved methods	**0.659**	0.088	0.111	0.135	-0.174	0.166	-0.008	0.125	0.142	0.228	0.137
Poor germination due to low/ excess rains	0.128	**0.767**	0.138	0.094	0.191	-0.052	-0.074	-0.103	0.098	0.032	-0.064
Eigen values	11.038	3.596	2.869	2.461	2.039	1.933	1.737	1.494	1.284	1.185	1.067
Cumulative variation explained	24.0	31.9	38.1	43.5	47.9	52.1	55.9	59.2	62.0	64.5	66.9

Note: Factor loading >I0.4I are in bold.

4 Conclusions

The findings of this study clearly indicate that there exists significant yield gap in soybean mainly due to poor linkages between research and extension systems. Nonetheless, there is a considerable scope to enhance soybean yield and soybean farmers' income through adoption of recommended package of practices. On average, high adopters of improved production technology could realize 48% higher yield and 128% higher net returns over the low adopters. Tobit regressions indicated younger and educated farmers with sufficient family labour and access to extension services are more likely to adopt improved technologies. Interestingly, the package appears to be more suited to smaller farmers.

Farmers face a number of biotic and abiotic constraints in adoption of improved technologies. These include higher wages for activities such as weeding and harvesting, difficulties in the use of BBF/FIRBS technology, high cost of fertilizers and pesticides, high cost of accessing crop loan, and lack of knowledge about integrated nutrient and pest management practices.

Policy interventions required to boost soybean yield include; improving outreach and efficiency of extension services, strengthening of input supply and enhancing farmers' access to institutional credit.

Acknowledgement

Authors would like to thank chief editor and anonymous referees of the journal for providing valuable comments on the earlier version of the paper.

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Received: 22 September 2016; Accepted: 20 August 2018