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Impact evaluation of seed replacement on pulse productivity in India

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ABSTRACT

Pulses are traditionally an essential part of the Indian diet and primary protein source for the poorer and the vegetarian population in the country. Pulse productivity has been stagnant in India due to the widespread use of low-quality farm-saved seeds and low seed replacement rates. The present study was carried out during 2019–20 to assess the drivers of seed replacement and its ex-post impact on yields of chickpea and pigeonpea in India. The study is based on the data on 1764 chickpea and 944 pigeonpea farmers from the nationally representative Situation Assessment Survey of Agricultural Households conducted during 2013. A probit model was used to study the drivers of seed replacement, and coarsened exact matching technique used to assess the impact on yields causally. We found that access to irrigation and institutional credit can increase seed replacement and result in increased chickpea productivity. Chickpea farmers in districts under the National Food Security Mission on pulses (NFSM-pulses) are more likely to be replacing seeds. In pigeonpea, access to irrigation alone is the key driver. Further, using coarsened exact matching estimation, we found that seed replacement is indeed beneficial for chickpea farmers and would lead to increased chickpea productivity in India.

Keywords: Chickpea, NFSM-pulses, Pigeonpea, Productivity, Seed replacement

Pulse production had been stagnant for several decades in India. It has only recently picked up momentum, jumping from 17.2 million tons (mt) in 2014-15 to 22.07 million tons in 2018-19. As of 2018, pulses contribute 7.74% to food grain production (GoI 2020). Historically, the green revolution spurred a growth in the adoption of new technology and irrigation, which expanded wheat and rice cultivation at the cost of other crops like pulses, coarse cereals, and oilseeds (Nagaraj *et al*. 2010, Pingali 2012, Smith *et al*. 2019). Low and stagnant yields in pulses have been attributed to the use of poor-quality seeds of local (traditional) cultivars (Reddy *et al.* 2007, Holmesheoran *et al.* 2012). The use of high-quality seeds can enhance productivity by as much as 25% (Ali and Gupta 2012). In this context, we study the current seed replacement scenario in chickpea (*Cicer arietinum*) and pigeonpea (*Cajanus cajan*) in major pulse-producing states of India. Chickpea and pigeonpea together account for over 60% of the total pulse production in India (GoI 2020).

Pulses have a seed renewal period of three to four years (Holmesheoran *et al.* 2012). The use of farm-saved seeds for more than this stipulated period leads to a decline in genetic purity and an increase in susceptibility to pests and diseases. High protein content already means that pulses are inherently susceptible to pests and diseases. Moreover, pulses are mainly cultivated in rainfed areas in the country, and frequent droughts often reverse the increased pulse production in recent years (Joshi *et al*. 2017). All the above factors make them a risky crop compared to cereals. Therefore, it is imperative to focus on replacing farm-saved seeds of modern cultivars that are both high-yielding and resistant to biotic and abiotic stresses (Dixon *et al.* 2006). Considering these facts, this paper assesses (i) drivers of seed replacement in chickpea and pigeonpea in India and (ii) the impact of seed replacement on productivity in chickpea and pigeonpea.

MATERIALS AND METHODS

Present study (2019–20) is based on the data from the nationally representative 'Situation Assessment Survey of Agricultural Households' conducted by the NSSO of the Government of India in 2013. The survey was conducted in 4529 villages in two visits. A total of 35200 households were interviewed in the first visit, which covered the agricultural period from July–December 2012. In the second visit, 34907 of these households were interviewed for the agricultural period from January to June 2013. Of the total sample, we analyze data from 1764 (5%) chickpea and 944 (2.7%) pigeonpea growing households, respectively.

The dataset contains information on the sources of seed used by farmers, such as farm-saved, farmer-to-farmer

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exchange, purchased and borrowed. Seed source data enables us to study the extent of seed replacement by farmers. When a farmer uses seeds procured from sources other than farm-saved seeds, we say that he/she is replacing seeds. In the data set, 50.40% of chickpea farmers and 53.60% of pigeonpea farmers had replaced seeds. Local traders were the primary source of replaced seeds for both chickpea (40.59%) and pigeonpea farmers (40.57%), followed by input dealers (5.78% and 9.11%, respectively), and cooperative, and government agencies (2.61% and 2.33%, respectively).

Probit model: The probit model is used to find out the drivers of seed replacement in chickpea and pigeonpea. The specification of the probit model is as follows;

$$\underline{Y}^{*}_{it} = \underline{\beta}_i X_{it} + \underline{u}_{it} \quad (1)$$

where, $\underline{\beta}_i$ = Regression parameter vector; X_{it}= Explanatory variables; $\underline{u}_{it}$ = Random error with N (0, σ^2); $\underline{Y^*}_{it}$ = Unobserved latent variable.

Coarsened exact matching: To study the impact of seed replacement on yield, we wanted to compare yields of farmers who replace seeds to yields of farmers who do not replace seeds. If we consider seed replacement as the treatment variable, treated individuals (those who replace seed) may differ from control individuals (those who do not replace seed) based on observable and unobservable factors that may bias estimates from a simple linear regression. Nonparametric coarsened exact matching (CEM) is used in this study to control the confounding influence of observable pre-treatment control variables and obtain unbiased coefficient estimates. CEM dominates commonly used existing matching methods like propensity score matching to reduce imbalance, model dependence, estimation error, bias, and mean square error (Iacus *et al*. 2009, 2011a, 2011b).

Treated farmers were matched with similar control farmers based on the values of nine confounding covariates: access to irrigation, farm size, age, sex, education, agricultural training, access to government advisory services, awareness about MSP, and access to crop insurance. The average treatment effect of seed replacement on yield is then calculated using the CEM probability weights for matched individuals in a regression framework. Similarly, Datta (2015) has used CEM to analyse the impact of a watershed development program on agricultural productivity, income, and livelihood in India. Anuja *et al.* (2020) employed CEM to assess the impact of crop diversification towards high-value crops on economic welfare of agricultural households in eastern India.

The indicators of interest for which changes are estimated due to treatment on the matched sub-sample of treated and control units are;

Δ Yield (kg/ha) in chickpea and pigeonpea = (Yield from the use of replaced seeds) − (Yield from farm saved seeds)

The estimates for the causal effects on indicators can be defined as:

$$SAAT = \frac{1}{m_T} \sum_{i \varepsilon T^m} TE_i \quad (2)$$

where SAAT = sample average treatment for the treated; m_T = number of matched treated units; T^m = subset of matched treated units; TE_i = difference between the yield from the use of replaced seeds and that of farm saved seeds.

RESULTS AND DISCUSSION

Status of seed replacement in chickpea and pigeonpea: Chickpea production in the country has increased from 7.33 mt in 2014–15 to 9.93 mt in 2018–19 while pigeonpea production has increased from 2.81 mt in 2014–15 to 3.31 mt in 2018–19 (GoI 2020). Data (Fig 1) shows that in 2013, the percentage share of farmers replacing seeds of chickpea is highest in the states of Gujarat (86%) and Andhra Pradesh (75%). Whereas in the states of Chhattisgarh (32%) and Madhya Pradesh (41%), a higher proportion of farmers still use farm-saved seeds. In pigeonpea, the percentage share of farmers replacing seeds is highest in Andhra Pradesh (83.54%), followed by Telangana (67.39%). It is the least in Madhya Pradesh (37.85%) and Karnataka (38.78%).

Drivers of seed replacement: We use a probit regression model to study the drivers of seed replacement in chickpea and pigeonpea (Table 1). The dependent variable denotes the probability that a farmer replaces seed. It takes the value 1 if a farmer replaces seed and takes the value 0 if the farmers uses own/farm-saved seed.

Seed replacement in chickpea and pigeonpea is positively associated with access to irrigation. This effect is more pronounced in chickpea compared to pigeonpea. Farm size is negatively associated with seed replacement in chickpea, while for pigeonpea, it has no significant influence. We find no significant effect of social status on seed replacement, implying that farmers belonging to different social groups are likely to have similar opportunities in accessing seeds. Household factors, such as age and gender, are also not significant. There is a positive association between monthly per capita consumption expenditure and seed replacement in chickpea, implying that farmers with higher incomes are more likely to replace seeds. This relationship is not significant in the case of pigeonpea. Moreover, farmers with access to credit are more likely to replace seeds in chickpea. Similar evidence on the importance of credit in adopting improved groundnut cultivars has been reported by Kassie *et al.* (2011). However, in pigeonpea, availability of credit is not a significant driver of seed replacement.

Awareness of MSP is positively associated with seed replacement in chickpea. It implies that policy interventions that make farmers aware of price support and improve access could facilitate faster seed replacement in chickpea. The presence of other chickpea farmers in a farmer's neighbourhood is negatively associated with seed replacement. This implies that the use of farm-saved seeds is more prominent than seed replacement in areas where chickpea cultivation is more concentrated. In contrast to this, a higher number of other neighbouring pigeonpea farmers is positively associated with seed replacement in pigeonpea. Farmers who replace seeds in other crops are

Table 1 Drivers of seed replacement in chickpea and pigeonpea (Probit model)

Dependent variable: Seed replacement (1=yes; 0=otherwise)	Chickpea		Pigeonpea	
	Probit model	Marginal effects	Probit model	Marginal effects
Access to irrigation (1=yes, 0=otherwise)	0.1632**	0.0599**	0.1730*	0.0657*
	(0.0670)	(0.0245)	(0.0997)	(0.0377)
Farm size (ha)	-0.0349**	-0.0128**	-0.0158	-0.0060
	(0.0157)	(0.0057)	(0.0232)	(0.0088)
Social group- Other backward castes (1=yes; 0=otherwise)	0.0577	0.0212	0.0081	0.0031
	(0.0777)	(0.0285)	(0.1031)	(0.0392)
Social group- General (1=yes; 0=otherwise)	0.0923	0.0338	0.0678	0.0257
	(0.0903)	(0.0331)	(0.1176)	(0.0447)
Age of household head (years)	-0.0021	-0.0008	-0.0010	-0.0004
	(0.0024)	(0.0009)	(0.0033)	(0.0012)
Sex of household head (1=male; 0=otherwise)	0.0169	0.0062	0.0189	0.0072
	(0.1486)	(0.0545)	(0.2020)	(0.0768)
Education of household head (1=literate; 0=otherwise)	-0.0663	-0.0243	0.0152	0.0058
	(0.0699)	(0.0256)	(0.0921)	(0.0350)
Agricultural training (1=undergone; 0=otherwise)	0.1191	0.0437	-0.3842	-0.1460
	(0.1803)	(0.0661)	(0.2354)	(0.0891)
Access to credit (1=borrowed; 0=otherwise)	0.2998***	0.1100***	0.1369	0.0520
	(0.0664)	(0.0239)	(0.0884)	(0.0334)
Log of monthly per capita consumption expenditure	0.1300**	0.0477**	-0.0362	-0.0138
	(0.0643)	(0.0235)	(0.0881)	(0.0335)
Crop loss experienced (1=yes; 0=otherwise)	0.0383	0.0141	0.0212	0.0081
	(0.0627)	(0.0230)	(0.0861)	(0.0327)
Awareness about MSP (1=yes; 0=otherwise)	0.1205	0.0442	0.1223	0.0465
	(0.0984)	(0.0360)	(0.1472)	(0.0559)
Access to crop insurance (1=yes; 0=otherwise)	-0.0570	-0.0209	0.0777	0.0295
	(0.1099)	(0.0403)	(0.1860)	(0.0707)
Total number of cultivators of the crop	-0.0008	-0.0003	0.0065***	0.0025***
	(0.0019)	(0.0007)	(0.0025)	(0.0009)
Whether seed replaced in other crops (1=yes; 0=otherwise)	0.8482***	0.3111***	0.5668***	0.2154***
	(0.0801)	(0.0264)	(0.1047)	(0.0378)
Whether the district is under NFSM (1=yes; 0=otherwise)	0.2134***	0.0783***	0.0220	0.0084
	(0.0720)	(0.0262)	(0.0973)	(0.0370)
Visit	-0.0854	-0.0313	-0.0688	-0.0262
	(0.0889)	(0.0326)	(0.0957)	(0.0363)
Constant	-1.8060***		-0.2457	
	(0.5643)		(0.7666)	
Observations	1,763		944	

Note: Standard errors are in parentheses, *** P<0.01, ** P<0.05, * P<0.1.
Source: Authors' calculation using NSS 70th round Situation Assessment Survey of Agricultural Households 2013 data.

also more likely to replace chickpea and pigeonpea seeds. There is a significant positive association between NFSM-pulses and seed replacement in chickpea, suggesting the importance of such policy interventions. NFSM-pulses was launched in 2007-08 in 468 districts of 16 states to enhance pulses productivity through interventions like frontline demonstrations and distribution of seeds of high yielding varieties. However, this mission had no significant influence on seed replacement in pigeonpea.

Neither education of household head nor agricultural training had a significant influence on seed replacement in both crops. This shows that information per se is not the

Table 2 Impact of seed replacement on chickpea and pigeonpea yield (using CEM)

Dependent variable: Yield (kg/ha)	Chickpea	Pigeonpea
Treatment: Seed replacement (1=yes; 0=no)	117.36*** (34.048)	4.226 (55.279)
Constant	816.446*** (204.683)	843.239 (159.135)
Number of observations	1441	638
R squared	0.077	0.182
District Fixed Effects	Yes	Yes

Source: Authors' calculation using NSS 70th round Situation Assessment Survey of Agricultural Households, 2013 data. Note: Standard errors in parentheses. *** represents significance at 1% level.

primary limiting factor in seed replacement (Shiferaw *et al.* 2008). Education may be unimportant when preferences for older cultivars or farm-saved seeds are difficult to change, and when educated farmers are aware of transaction costs associated with adoption (Krishna *et al*. 2016). It possibly reflects risk aversion due to quality and technology mistrust (Bezu *et al.* 2014, Verkaart *et al.* 2017).

Impact of seed replacement on yield: Data (Table 2) reports the average treatment effects from CEM estimation for chickpea and pigeonpea. It was found that seed replacement in chickpea significantly increases yield by 117.36 kg/ha. However, seed replacement in pigeonpea does not significantly affect yield.

What might explain the absence of an impact of seed replacement on pigeonpea yields? One possible explanation could be that pigeonpea is a riskier crop than chickpea owing to biological and genetic differences. It is more likely to suffer from pests, diseases, and crop failure due to lower soil moisture than chickpea (Saxena *et al.* 2018). If seed replacement is not accompanied by the adoption of correct crop management practices, it may not increase yields. A second possibility is that even when pigeonpea farmers replace seeds, they may not be adopting newer varieties that have higher yields.

In this paper, we analyzed the determinants of seed replacement and its impact on yield of chickpea and pigeonpea in India. We used a probit model to study the determinants of seed replacement and a coarsened exact matching method to estimate the productivity gains from seed replacement, eliminating selection bias on observable differences between farmers who use replaced seeds and those who use farm-saved seeds. Our results shows that most of the farmers in the major pulse-producing states like Madhya Pradesh, are using farm-saved seeds, which results in lower than desired pulse production in India. Access to irrigation can positively influence seed replacement in chickpea and pigeonpea. Access to credit and a higher consumption expenditure are also associated with an increased likelihood of farmers replacing seeds of chickpea. Moreover, household factors such as age and gender, and socio-cultural factors such as caste do not play a role in the decision to replace seeds. Seed replacement in chickpea is higher in the districts covered under the NFSM-pulses program, whose aim was to strengthen the pulse seed system using quality seeds. We found that seed replacement is indeed beneficial for chickpea farmers and would lead to increased chickpea productivity in India.

The results have several policy implications. Seed replacement is low in major pulse producing states like Madhya Pradesh, highlighting the need to strengthen the seed supply system in pulses. Irrigation coverage also needs to expand, especially for pigeonpea cultivation, where irrigation is a leading driver of seed replacement. The impact of NFSM-pulses suggests that this scheme can be extended to cover more area for increasing seed replacement and thereby increasing productivity. Access to institutional credit plays a role in farmers' likelihood of replacing chickpea seeds. Enhancing local availability of high-quality seeds at reasonable prices could significantly accelerate seed replacement.

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