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Economic impact assessment of soybean rust (*Phakopsora pachyrhizi*) resistance breeding in India: An ex-ante analysis

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ABSTRACT

Soybean rust (*Phakopsora pachyrhizi* Syd.) is one of the most prevalent soybean diseases particularly in Krishna basin area of Karnataka and Maharashtra, which can cause losses from 10-100%. The research conducted to estimate benefits from adoption of rust resistant soybean varieties in rust prone districts of Karnataka and Maharashtra using primary data collected from adopter and non-adopter farmers for the crop year 2017–18. Rust resistant varieties require less chemical pesticides and reduce yield loss. The study estimated potential economic benefits in terms of economic surplus for rust resistant varieties. In normal conditions, total benefits from the adoption of rust resistant soybean varieties using the economic surplus model was estimated at ₹ 198.8 crores per annum at a discount rate of 5% and ₹ 99.3 crores at 8% discount rate, respectively. Adoption of rust resistant varieties performed well over other varieties in reducing yield loss and cost of cultivation. The popularization of these varieties in rust prone areas to cope up with this biotic stress is needed.

Keywords: Economic benefits, Impact assessment, *Phakopsora pachyrhizi*, Resistant varieties, Soybean rust

Rust caused by *Phakopsora pachyrhizi* Syd. is the most important and widespread soybean disease in Asia and a potential threat to soybean production. The rapid spread of *P. pachyrhizi* and potential for severe yield losses makes this as the most destructive foliar disease of soybean. Soybean rust was first noticed in India at Pantnagar during September 1970 (Thapliyal 1971). The disease appeared suddenly in epiphytotic form during *kharif* 1994 and 1995 and caused substantial yield losses, up to 80%, particularly in Krishna basin region of Karnataka and Maharashtra (Anahosur *et al.* 1995, Patil and Basavraja 1997). Maximum disease severity was noticed in Belgaum district followed by Dharwad of Karnataka (Dadke 1996). Disease was widespread in severe form on soybean in northern Karnataka and parts of Maharashtra during *kharif* 1996, 1997 and 1998 (Hundekar 1999). Hegde (2001) reported that during 1999 and 2000 average maximum disease severity was noticed in Belgaum (47.16%) followed by Dharwad and Haveri districts. It can cause losses from 10 to 100% (Sarbhoy and Pal 1997) depending upon locality, season and cultivar. The soybean rust has been known to drastically reduce yields in Asia up to 80% (Sharma and Mehta 1996).

Soybean cultivation in rust affected areas was totally dependent on timely spray of fungicides for management of rust. Although, cultivation of resistant varieties is the effective and economical method to combat the plant disease. The most popular soybean variety in these states was JS 335 (released in 1994) is highly susceptible to rust. Rust resistant soybean varieties like DSb 21 (2700 kg/ha, released in 2012), KDS 344, KDS 726 (2441 kg/ha), DSb 23 (2440 kg/ha), KS 103 (2730 kg/ha) and KDS 753 have been developed using two exotic germplasm lines, viz. EC 241780 and EC 241778 (Patil *et al.* 2004, Basavaraja *et al.* 2009). The variety DSb 21 has become more popular in the rust prone areas of Karnataka and Maharashtra. Looking at the importance of the disease and research efforts to minimize the yield losses, the paper aims to assess the economic benefits of the rust resistant varieties developed and popularized in rust prone areas of Karnataka and Maharashtra.

MATERIALS AND METHODS

The adoption of disease resistant varieties not only saves yield losses on the occurrence of the disease, but also reduces the cost of cultivation through savings on labour and pesticide costs. On an average, 2-3 sprays of chemicals are

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required to minimize the effect of rust. Since management practices differ with the capability and knowledge of farmers, all the losses due to rust occurrence cannot be minimized. Thus, rust resistant varieties have helped in minimizing yield loss irrespective of the capability and disease management knowledge of farmers. The area affected by rust is about 4-5 lakh ha mainly in Krishna basin region (Maharashtra and Karnataka). Rust resistant varieties developed by the soybean R&D system presently cover only ~10% of the frequent rust prone area and is expected to increase to nearly 40% of the soybean area in the region by 2025.

Economic surplus estimation: The most often used method to estimate the economic benefits of agricultural technologies is based on the principle of economic surplus (Alston *et al.* 1998). In this study also, the economic surplus model is used to calculate the potential benefits derived from the adoption of rust resistant soybean varieties. The economic surplus model consists of a set of supply and demand equations that model the market as a system (Alston *et al.* 1998). Both primary as well as secondary data were used for estimating economic surplus from rust resistant varieties. Primary data were collected through pre-structured survey schedule from selected adopters and non-adopters of the rust resistant variety of soybean from Karnataka and Maharashtra states for the crop year 2017–18.

Small open economy is assumed in this case as the country imports close to 70% of edible oil requirement, contributes less than 10% of the global soybean production and is not in a position to influence the global trade. Any widespread fluctuation in the oil price in the domestic economy is addressed through imports. Based on this, it is presumed that analysis using open economy framework would be ideal. In the present study, the surplus of rust resistant soybean varieties (DSb 21, DSb 23, KDS 344, KDS 726, etc.) was estimated. These varieties have been developed and released by soybean research system, i.e. Indian Institute of Soybean Research, Indore and AICRP on Soybean, and are reported to be yield enhancing and have an additional advantage of being rust resistant. The economic surplus model was used to measure the total economic surplus obtained from the adoption of selected varieties in the selected region. The basic information needed for the model is as given below.

The calculation of the economic surplus needs an estimate of demand and supply elasticity for the crops. The Food and Agricultural Policy Research Institute (FAPRI) has reported the supply elasticity to be 0.36 for soybean and demand elasticity of -0.30 for India, was used for the study. The value of the proportionate change in yield due to adoption of rust resistant variety over susceptible variety has been worked out from the farmers' survey. The probability of research success was taken as one because the technology already adopted completely and is available in the field. The adoption rate was estimated from the year-wise breeder/ certified seed production of the varieties in Karnataka and Maharashtra. The price of soybean in the international market is taken as US$ 493.8 per q (Pink sheet, World Bank)

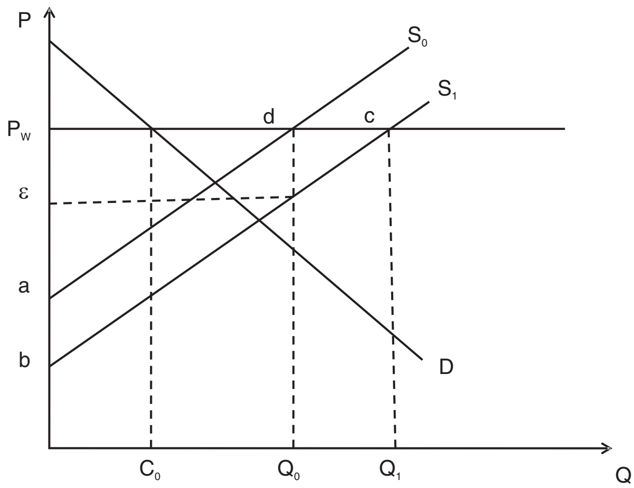

Fig 1 Economic surplus due to yield improvement in a small open economy framework.

for TE 2014-15 (average exchange rate of ₹ 57.7 per US$ for the period). The area and production of the soybean in rust prone area/districts of Karnataka and Maharashtra for TE 2014-15 was considered.

Yield-increasing benefits: There are number of variants of the economic surplus approach depending on the economic structure of region/country (Alston *et al.* 1998). We have estimated economic surplus in small open economy framework in this study. The changes in economic surplus due to yield improvement have been illustrated in Fig 1. Adoption of a yield-increasing variety shifts soybean supply curve downwards, from S_0 to S_1; and the demand curve for soybean and its products is assumed to remain unchanged at C_0. The price of soybean is determined by the world market at P_0 and will not change due to increase in domestic production. Consumer surplus, thus, remains constant, and the entire benefits from adoption of the improved variety accrue to the producers. In this figure, the producer surplus increases equal to the area *abcd*.

In small open economy, the reference price is the world price. The total surplus would be having only one component, that is the producer surplus as the consumer surplus is equal to zero ($\Delta CS = 0$). Mathematically, the change in producer surplus in a small open economy can be represented by Equation (1):

$$\Delta PS_t = \Delta TS_t = P_0Q_0 \, (K_t - Z_t) \, (1+0.5 \, Z_t\eta) \qquad (1)$$

where, ΔPS_t is the change in producer surplus in the year t; ΔTS_t is the change in total surplus in the year t; P_w is the initial price; Q_0 is the initial level of production; Z_t is the reduction in price in the year t as a result of an increase in supply due to adoption of improved variety; η is the absolute value of demand elasticity and K_t is the proportionate supply shift in the year t due to adoption of improved variety. The value of K_t can be obtained as:

$$K_t = \{[E(Y)] / \varepsilon - [E(C)] / [1 + E(Y)]\} \, \rho A_t \, (1 - \delta_t) \qquad (2)$$

where, E(Y) is the change in yield per ha, E(C) is the change in variable cost per ha to achieve the yield change; ε is the supply elasticity; ρ is the success rate or probability of success in achieving the expected yield; A_t is the adoption rate in the year t and δ_t is the depreciation on improved variety that is reduction in expected yield in the year t.

RESULTS AND DISCUSSION

Farm-level impact of rust resistant soybean varieties: A comparison of yield and cost of cultivation of rust resistant and susceptible varieties grown on sample farms during the *kharif* 2017 is presented in Table 1. The rust resistant variety DSb 21 had a yield advantage of 30% over the popular soybean variety JS 335 in rust prone area. Also, its operational cost of cultivation was about 3% less, mainly due to lower pesticide spray requirement as compared to JS 335. Machine labour cost accounts for about 32-37% of the total variable cost, while human labour shared nearly 20–21%. Fertilizers and manure accounted for 13-14% of total variable cost and the plant protection chemicals about 6-10%. Labour component (human, animal and machine) together with seed and fertilizers accounted for over 70-75% of the total operational cost. Switching over to rust resistant variety reduces the cost of production of soybean to the tune of 25.3% on sample farms.

Aggregate benefits from adopting rust resistant soybean varieties: For calculating the economic surplus generated, the farm-level benefits of the rust resistant variety were scaled up to the level of rust prone districts of Karnataka and Maharashtra under certain assumptions (Table 2). Changes in yield and cost of production are the main components of this analysis. Price of soybean was taken as the average of the world soybean price for the years 2012 to 2014 (Pink Sheet, World Bank). The average price of soybean was US$ 493.8/t, which was equivalent to ₹ 28328/t at a mean exchange rate of ₹ 57.7 per one US $. Proportionate difference in yield of rust resistant variety (DSb 21) and popular soybean variety (JS 335) was taken from Table 1 and assumed to be same for all other rust resistant varieties over susceptible varieties. Data on area, production and yield of rust prone districts has been collected from the website of Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, GOI, New Delhi and average production from 2012 to 2014 was used for analysis.

The production of breeder and certified seed was collected from respective agencies, and based on that the current level of adoption has been worked out for rust prone districts of Karnataka and Maharashtra. Based on expert opinion, it was assumed that the rust resistant varieties may occupy 40% soybean area in rust prone districts by 2025. Further, we have assumed that their adoption rate will follow a sigmoid curve to reach the ceiling. No depreciation on yield of improved varieties is anticipated. We have used demand elasticity estimate of -0.30 and supply elasticity coefficient of 0.36 (FAPRI). We have applied a discount rate, *r*, of 5% and also 8% in the present study.

The total benefits from the adoption of rust resistant soybean varieties for the period 2014-15 to 2025-26 have been estimated as ₹ 2187.25 crores at a discount rate of 5% and ₹ 1092.61 crores at a discount rate of 8%. These translate into ₹ 198.8 crores and ₹ 99.3 crores per annum at the respective discount rates of 5% and 8% (Table 3). This implies that a widespread adoption of rust resistant soybean varieties can make significant contributions to farm income and its stabilization in rust prone districts of Karnataka and Maharashtra.

Sensitivity analysis: These results are sensitive to changes in the assumptions and parameters, particularly those related to adoption of varieties and yield advantage. The adoption rate ceiling of 40% by 2025 and yield advantage of 30% from rust resistant varieties may be considered quite optimistic. Hence, we simulated benefits from rust resistant varieties by scaling down the rate of adoption by 10% and observed yield advantage by 20%, i.e. yield advantage to 26%. With the scenario of 10% reduction in rate of adoption, the total benefits from adoption of rust resistant soybean varieties declined to ₹ 179.9 crores per

Table 1 Change in cost structure in cultivation of rust resistant and other variety of soybean

Cost item	Unit	Adopters (DSb 21)	Non-adopters (JS 335)
Human labour	(₹/ha)	5745	6451
Animal labour	(₹/ha)	1350	795
Machine power used	(₹/ha)	10720	9619
Seed	(₹/ha)	3101	3625
Farm yard manure	(₹/ha)	1150	476
Fertilizers	(₹/ha)	2695	3721
Plant protection chemicals	(₹/ha)	1636	2973
Others	(₹/ha)	2886	2498
Total inputs cost	(₹/ha)	29282	30158
Yield	(Qt/ha)	27.4	21.0
Unit variable cost	(₹/ha)	1070	1433

Table 2 Parameters used in estimation of benefits from the adoption of rust resistant soybean varieties in rust prone districts of Karnataka and Maharashtra

Parameter	Value	Source
Elasticity of supply	0.36	FAPRI
Elasticity of demand	-0.30	FAPRI
Production quantity ('000 tonnes): TE 2014-15	1138.7	DES, MoA&FW, GOI
International market price (₹/q): TE 2014-15	2838.2	World Bank
Yield change (%)	30.0	Field survey
Per ha variable cost change (%)	-2.9	Field survey
Present adoption (%): 2017-18	10	Estimated from seed production data
Maximum adoption rate (%): 2025	40%	Expert opinion

Table 3 Benefits from adoption of rust resistant varieties in rust prone districts of Karnataka and Maharashtra for the period 2014-15 to 2025-26 and sensitivity analysis

Parameter	Unit	Value
NPV of net benefits	₹ crores/yr	198.8
NPV of net benefits	₹/ha/yr	2320
IRR	%	76
Sensitivity analysis		
	NPV (₹ Crores/yr)	*NPV (₹/ha)*
@ 8% discount rate	99.3	1159
10% decrease in adoption : 5% discount rate	179.9	2099
: 8% discount rate	90.0	1050
20% reduction in yield advantage : 5% discount rate	172.2	2010
: 8% discount rate	86.1	1004

annum at a discount rate of 5% and to ₹ 90 crores per annum at a discount rate of 8% (Table 3). In another scenario of 20% reduction in yield advantage, total benefits worked out to be ₹ 172.2 crores per annum and ₹ 86.1 crores per annum, respectively at 5 and 8% discount rate.

To sum up, we have estimated benefits from adoption of rust resistant soybean varieties in rust prone districts of Karnataka and Maharashtra using economic surplus model for small open economy. Selected farmers, adopting rust resistant variety and susceptible variety, were surveyed using pre-tested survey schedule in rust prone districts of Karnataka to work-out the change in yield and cost of production of soybean. The results of analysis revealed that total economic benefits from the adoption of rust resistant soybean varieties for the period 2014-15 to 2025-26 have been estimated as ₹ 2187.25 crores at a discount rate of 5% and ₹ 1092.61 crores at a discount rate of 8% or ₹ 198.8 crores and ₹ 99.3 crores per annum, respectively. The analysis provided an insight into the economic potential of breeding for biotic stress tolerant varieties. The increasing challenge of climatic change induced higher incidence of insect-pests is to be a greater focus for varietal development programme. Development and promotion of disease resistant varieties for disease prone areas has a potential to reduce yield loss and impart resilience to the system.

REFERENCES

Alston J M, Norton G W and Pardey P G. 1998. *Science under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting*. Cornell University Press, Ithaca, NY.

Anahosur K H, Rao V G and Patil P V. 1995. *Soybean Rust Survey Report 1995*, pp 1-14. University of Agricultural Sciences, Dharwad.

Basavaraja G T, Patil P V, Salimath P M, Jahagirdar S, Athoni B K, Hosmath J A and Patil R H. 2009. Breeding for resistance to rust in soybean (*Glycine max* (L.) Merrill). (In) *Proceedings of World Soybean Research Conference VIII* held at Beijing, China from 10-15 August, 2009.

Dadke M S. 1996. 'Studies on rust of soybean (*Glycine max* (L.) Merill) caused by *Phakopsora pachyrihizi* Syd'. M Sc (Agri.) thesis, University of Agricultural Sciences, Dharwad, Karnataka.

Hegde G M. 2001. 'Epidemiology, crop loss assessment and management of soybean rust in Karnataka'. Ph D (Agri) thesis, University of Agricultural Sciences, Dharwad, Karnataka, India.

Hundekar A R. 1999. 'Studies on some aspects of soybean rust caused by *Phakopsora pachyrhizi* Syd'. Ph D thesis, University of Agricultural Sciences, Dharwad.

Ono Y, Buritica P and Hennen J F. 1992. Delimitations of *Phakopsora*, *Physopella*, *Cerotelium* and other species on Leguminosae. *Mycelial Research* **96**: 825–50.

Patil P V, Basavaraja G T and Husain S M. 2004. Two genotypes of soybean as promising sources of resistance to rust caused by *Phakopsora pachyrhizi* Syd. *Soybean Research* **2**: 46-47.

Sarbhoy A K and Pal M. 1997. Soybean rust; A threatening disease in India. (*In*) *Management of Threatening Plant Disease of National Importance*, pp 69-76. Malhotra Publishing House, New Delhi.

Sharma N D and Mehta S K. 1996. Soybean rust in Madhya Pradesh. *Acta Botanica Indica* **24**: 115–16.

Thapliyal P N. 1971. Pathological studies. Soybean at Pantnagar, pp 121–33. M C Saxena (Eds). G B Pant University of Agriculture and Technology, Pantnagar, Nainital, U P, India.