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Economic Impact of Salt-tolerant Wheat Varieties

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Soil salinity is one of the most severe forms of land degradation in India and poses a significant threat to crop production. Approximately 6.74 million hectares of land are salt-affected soils- comprising both saline (contains high levels of soluble salts (ECe > 4 dS/m) and sodic soils (characterized by high exchangeable sodium percentage (ESP > 15) and pH > 8.2), accounting for approximately 5% of the net cropped area[1]. Several factors, including sea-water intrusion and unsustainable irrigation practices, including excess groundwater withdrawal and the use of poor-quality water, are responsible for this problem. If timely preventive or ameliorative measures are not taken, it may spread to 16.2 million hectares or 12% of the net cropped area by 2050[1]. Several strategies, including subsurface drainage, agroforestry, and cultivation of salt-tolerant crops and crop varieties, are available to restore the productive potential of salt-affected soils. Among these, the cultivation of salt-tolerant crop varieties is particularly cost-effective, easy to implement, and rapidly adoptable by farmers. This brief examines the economic impact of salt-tolerant wheat varieties, focusing on wheat as the most severely affected crop, which spans 2.9 million hectares of saline land and suffers an annual production loss of approximately 4 million tons[2]. For sustaining the wheat production in salt-affected lands, and thereby food security, the ICAR-Central Soil Salinity Research Institute (CSSRI), Karnal, has developed several salt-tolerant wheat varieties (STWVs), among them KRL-210, KRL-213, and KRL-283 are widely adopted. However, their adoption patterns and economic impacts have not been understood beyond field trials, demonstrations, and success stories.

Salt-tolerant wheat varieties and domain area

The key characteristics of the STWVs are listed in Table 1[3]. These varieties, particularly KRL 210, are adaptable to a wide range of agro-ecosystems, including saline, sodic, saline vertisols, and waterlogged environments. Field trials conducted in Haryana, Rajasthan and Uttar Pradesh during 2018-19 to 2020-21 show that STWVs offer yield advantages in salinity-induced stress environments.

Table 1. Characteristics of salt-tolerant wheat varieties developed by ICAR-CSSRI, Karnal

Variety	KRL 210	KRL 213	KRL 283
Year of release	2012	2011	2018
Salinity tolerance (dS/m)	up to 6.6	up to 6.4	up to 7.5
Sodicity tolerance (pH_2)	up to pH_2 9.3	up to pH_2 9.2	up to pH_2 9.3
Yield in normal soil (t/ha)	5.2	5.1	5.5
Yield in salt-affected soil (t/ha)	3.5	3.3	3.5

Note: pH_2 and dS/m (deci Siemens per meter) stand for unit used to measure the level of sodicity and salinity, respectively.

The distribution of salt-affected wheat-growing areas is presented in Table 2. Wheat is grown on 2.89 million hectares of salt-affected land, comprising 1.93 and 0.96 million hectares of sodic and saline soils, respectively[2]. Uttar Pradesh has the largest salt-affected wheat area, followed by Gujarat, Haryana, and Punjab.

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[1] ICAR-CSSRI. (2015). *Vision 2050*, ICAR-Central Soil Salinity Research Institute, Karnal, Haryana, India, available at https://cssri.res.in/vision-2050/

[2] Sharma, D.K., Thimmappa, K., Chinchmalatpure, A.R., Mandal, Yadav, R.K., Chaudhury, S.K., Kumar, S., Sikka, A. (2015). *Assessment of Production and Monetary Losses from Salt-affected Soils in India.* Technical Bulletin, ICAR-CSSRI/Karnal/2015/05. pp. 99.

[3] Sanwal, S.K., Kumar, A., Singh, J. (2021). *Breeding Technique for Wheat, Mustard and Chickpea.* In: Minhas, P.S., Yadav, R. K., Sharma, P. C. (Eds.) Managing Salt Affected Soils for Sustainable Agriculture. DKMA, ICAR, pp 252-275.

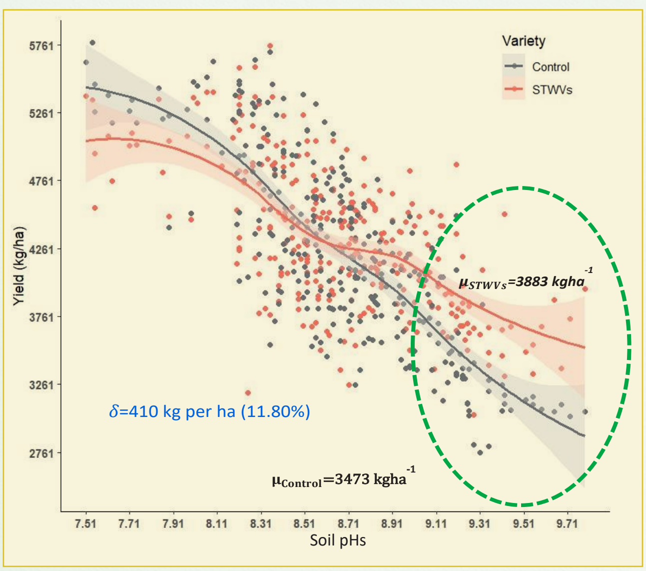
Table 2. Regional distribution of salt-affected wheat area

State	Salt-affected (mha)
Uttar Pradesh	1.06
Gujarat	0.76
Haryana	0.17
Punjab	0.07
Others	0.83
Total	2.89

Yield gains of STWVs over the prevailing wheat varieties in salt-affected soils

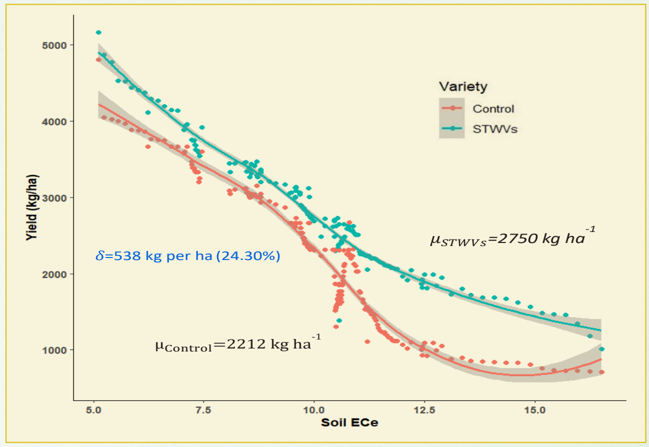
There is a negative association between soil pH and yield of all varieties including STWVs and non-STWVs (Figure 1). However, the yield gap between STWVs and non-STWVs widens with an increase in soil pH. At lower pH levels (7.50–8.5) non-STWVs perform better than STWVs in normal soils. The widening yield gap at higher pH levels (>8.5) highlights the superiority of STWVs over the prevailing varieties. As matter of fact, most of the sodic soils have pH > 8.5. Therefore, the yield advantage of STWVs in sodic soils is considered to be above this pH level. In this range of sodicity, the observations from the field show that the mean yield of STWVs is approximately 11.80% higher than that of non-STWVs. The yield advantage of STWVs in the saline soils (ECe > 4 dS/m) is estimated at approximately 24.30% (Figure 2**)**.

Figure 1. Yield response under increasing level of the soil sodicity



For analytical purposes, we calculated the weighted average of the yield gains of the varieties grown in sodic and saline soils, with weights being the cultivated areas. Thus, the overall yield gain is 14.82%.

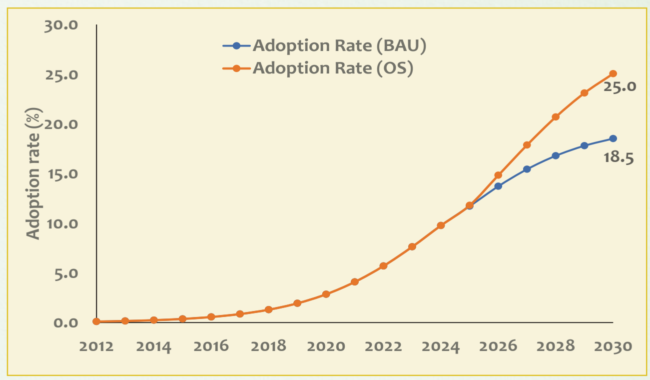
Figure 2. Yield response under increasing level of the soil salinity



Adoption rate of STWVs

The adoption rate of STWVs was estimated based on the breeder seed supply by the ICAR-CSSRI. From 2012 to 2024, the adoption rate of STWVs reached 9.77% (Figure 3).

Figure 3. Estimated adoption rate and projected adoption rate of STWVs in salt-affected lands



For ex-ante analysis, the adoption path of STWVs was traced using the logistic curve model up to 2030 under two cases: business-as-usual (BAU) and Optimistic Scenario (OS). The projected adoption rate may reach 18.5% under BAU and 25.0% under OS. The OS signifies a hypothetical scenario underscoring the increasing demands of breeder seeds of STWVs which is expected to increase further in future particularly by the private firms, and also improvements in seed supply chain. To factor-in these developments, we assume that, in future, the demand for STWVs is likely to increase significantly. Therefore, the economic gains due to the adoption of STWVs were computed for the period 2012 to 2024 and, also estimated upto 2030.

Economic surplus model

The economic surplus model provides net benefits to producers and consumers owing to the adoption of a technology. The widespread adoption of salt-tolerant STWVs is expected to benefit both wheat producers and consumers. Increased adoption of STWVs directly benefits producers through a shift in the supply curve and indirectly benefits consumers through a downward shift in prices. Assuming linear demand and supply curves, the incremental changes in producer surplus (ΔPS) and consumer surplus (ΔCS) in the closed economy case are computed using Equations 1 and 2, respectively[4].

$$\Delta PS = P_0 Q_0 (K - Z)\,(1{+}0.5\varepsilon_d Z) \ldots\ldots (1)$$

$$\Delta CS = Z P_0 Q_0 (1 + 0.5\varepsilon_d Z) \ldots\ldots (2)$$

Where, P_0 is the price of wheat, Q_0 is the pre-adoption level of production, Z is the relative change/reduction in price, K-shift parameter, measuring the cost reduction per unit of output, ε_s and ε_d is the absolute value of the price elasticity of supply and demand, respectively. The values of the parameters used in the economic surplus model were either estimated through a primary survey or from available publications relevant to the economic impact assessment of salt-tolerant wheat varieties (Table 3).

Table 3. Parameters of economic surplus model

Parameter	Symbol	Value	Sources
Production quantity in domain areas (mt, TE 2012)	Q_0	9.93	Authors' estimation based on the domain area and yield
Price (Rs /t, 2023-24)	P_0	23300	GoI (2025)[5]
Increase in yield (%)	$E(Y)$	14.82	Authors' estimation
Increase in variable cost per ha (%)	$E(C)$	4.64	Authors' estimation
Maximum adoption rate (%)	A_{max}	18.5 (BAU) & 25.0 (OP)	Expert opinion and authors' estimation using the logistic model
Supply elasticity	ε_s	0.22	Kumar and Mittal (2022)[6]
Demand elasticity	ε_d	-0.34	Kumar et al. (2011)[7]
Exogenous growth rate	EGR	1.50%	Authors' estimation-based data GoI (2025)[8]

[4] Alston, J. M., Norton, G. W., Pardey, P.G. (1995). *Science under scarcity: principles and practice for agricultural research evaluation and priority setting.* Cornell University Press. University of California, Davis, Department of Agricultural Economics, Davis, California 95616, USA pp.618.

[5] GoI. (2025). Farm harvest prices of principal crops 2023-24, Ministry of Agriculture and Farmers Welfare, Government of India, New Dehi https://eands.dacnet.nic.in.

[6] Kumar, P. and Mittal, S. (2022). Agricultural price policy for ensuring food security in India. NABARD Research and Policy Series No. 1/2022.

[7] Kumar, P., Kumar, A., Shinoj, P., Raju, S. S. (2011). Estimation of demand elasticity for food commodities in India. Agricultural Economics Research Review 24(1): 1-14.

[8] GoI (2025). https://upag.gov.in/ accessed on: July, 2025.

Economic impact of STWVs

For the period 2012–2024 under BAU, the consumer surplus is estimated at Rs. 22850 million, with an annual value of Rs. 1757.7 million. The producer surplus is Rs. 35320 million or Rs. 2716.9 million per annum. The total economic surplus amounts to Rs. 58170 million, with an annual value of Rs. 4474.6 million. For the period 2012–2030 under BAU, the consumer surplus may increase to Rs. 101750 million (annualized at Rs. 5355.3 million), and the producer surplus may rise to Rs. 157250 million, with an annual value of Rs. 8276.3 million. With this, the value of the total economic surplus is projected to reach Rs. 259000 million, with an annualized value of Rs. 13631.6 million. Similarly, under optimistic scenario, the estimated value of the total economic surplus may reach Rs. 278050 million, with an annual value of Rs. 14634.2 million (Table 4). These estimates underscore the potential of STWVs for enhanced economic benefits by ensuring the proper management of salt-affected lands, and the projected benefits highlight the need for proper policy support to realize these benefits in the future.

Table 4. Estimated value of economic surplus due to STWVs in India

Economic surplus	Value (Rs Million)		
	Business as usual		Optimistic scenario
	2012-2024	2012-2030	2012-2030
Consumer surplus	22850 (1757.7)	101750 (5355.3)	109230 (5748.9)
Producer surplus	35320 (2716.9)	157250 (8276.3)	168810 (8884.7)
Total economic surplus	58170 (4474.6)	259000 (13631.6)	278050 (14634.2)

Note: Figures in parentheses are the annual values of surplus.

Seed demand of the STWVs

Data from the seed rolling plan of year 2022-23, 2024-25 and 2025-26 of DAC Seednet show that, surprisingly, not a single variety was included in Gujarat and Haryana (Table 5). In terms of total seed requirement, STWVs account for only 0.34% in Punjab and 0.71% in Uttar Pradesh of the total seed requirements.

The current adoption rate of salt-tolerant wheat varieties (STWVs) is 9.77 %, implying that approximately 90% of the salt-affected wheat area remains unaddressed in terms of STWV seed supply. To cover the remaining salt-affected wheat area, approximately 6,503 quintals of breeder seeds is required. The ICAR-CSSRI, the primary and only institution for breeder seed production, faces challenges in executing its STWVs

Table 5. Varieties in the seed rolling plans

State	Year	No. of varieties
Gujarat	2022-23	12
	2024-25	10
	2025-26	16
Haryana	2022-23	11
	2024-25	19
	2025-26	7
Punjab	2022-23	29(1)
	2024-25	13
	2025-26	12
Uttar Pradesh	2022-23	55 (3)
	2024-25	76 (3)
	2025-26	78 (3)

Source: https://seednet.gov.in/; Note: figures in parentheses indicate the number of STWVs.

seed production plan due to year-to-year inconsistent seed indent requests from the MoA&FW. However, ICAR-CSSRI has engaged local small-scale firms, often a single firm caters to the needs of merely 2000-3000 ha with multiplied seeds. Second, the ICAR-CSSRI facilitates the direct delivery of truthfully labelled (TL) seeds to farmers and encourages farmer-to-farmer exchange of seeds. Innovatively, smallholder farmers from salt-affected regions such as Rajasthan, Haryana, and Punjab collectively procure STWV seeds from ICAR-CSSRI in bulk to reduce transportation costs and meet the scattered and small-scale seed requirements. Keeping these issues (small and scattered demand patterns of STWVs seeds) in mind, there is an urgent need to strengthen the STWVs seed supply chain through collaboration with State Agricultural Universities (SAUs) and KVKs located in salt-affected areas to bolster seed production and distribution efforts.

Policy implications

Based on the interaction with stakeholders (*e.g.*, farmers, KVKs, private firms, and extension field functionaries) and ground insights of experts, the following issues merit attention:

Accelerating the development of STWVs: Currently, only a limited number of STWVs are widely accepted. To address this limitation, it is recommended that future wheat breeding programs incorporate speed breeding techniques and gene editing tools.

Targeted and collaborative research: Gujarat encompasses a substantial area of salt-affected land dedicated to wheat cultivation, measuring 0.76 million hectares. Notably, to date, no STWV has been specifically released for Gujarat, nor has it been included in the state's seed rolling plan. This represents a significant gap in research and development efforts. Addressing this issue necessitates a targeted and collaborative approach involving State Agricultural Universities (SAUs) for seed multiplication and the establishment of seed delivery outlets in salt-affected regions.

Multiple stress tolerance with biofortification: In light of the growing emphasis on nutritional security and climate resilience, particularly concerning terminal heat stress in wheat, there is a need for a strategic shift in breeding programs. This shift should move from focusing solely on salt tolerance to encompassing multiple stress tolerances, including biofortification traits.

Physical and economic access to STWVs: Strategic initiatives involving public-private or public-public partnerships are essential for establishing robust seed supply chain systems that engage stakeholders and collaborate with farmers for the large-scale dissemination of STWVs. Furthermore, given the dispersed nature of salt-affected soils, there is a need to address the scattered and small-scale demand for STWVs seeds. To this end, the establishment of an "online portal for seed supply" is necessary to ensure timely and doorstep delivery of seeds to farmers. Collaboration with other ICAR institutes, particularly *Krishi Vigyan Kendras* (KVKs), could be transformative in facilitating the development, demonstration, and dissemination of STWVs seeds.

STWVs must be aligned with soil's nutrient status: It is important to acknowledge that farmers frequently prioritize high-yielding crops without adequately considering their soil conditions, even when dealing with salt-affected soils. In addition to soil health parameters, it is essential that recommendations for salt-tolerant crop varieties be communicated to farmers via soil health cards.

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