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Driving agricultural innovation:

Gurpreet Singh Sidhu's contribution to sustainable farming in Punjab

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Punjab's rice-wheat cropping system (RWCS) is confronting significant environmental challenges, including groundwater depletion, soil degradation and air pollution. S. Gurpreet Singh Sidhu, a visionary farmer from Mehraj village, Bathinda has emerged as a champion of sustainable agricultural practices by adopting resource conservation technologies viz. direct seeded rice (DSR) and Happy Seeder technology for wheat establishment. These innovative practices have led to substantial improvements in soil health, reductions in water and input costs, and enhanced crop yields. He has achieved substantial resource conservation with up to ~28% saving in irrigation water and ~37.3% in diesel fuel consumption, besides noteworthy improvement in soil health manifested as increase in organic carbon by ~43.8%. While horizontally extending these technologies across 12 adjoining villages, he has engraved technological footprints over 261 hectares under DSR and 286 hectares to in situ rice residue management before wheat establishment. Furthermore, his establishment of a custom hiring center (CHC) has provided small farmers with affordable access to innovative machinery, while amplifying the reach and impact of sustainable crop production practices. Widely recognized for his contributions with both national and international accolades, he exemplifies the potential of innovative solutions to reconcile agricultural productivity with environmental conservation. His efforts serve as a powerful model for sustainable agricultural development, offering inspiration for a greener, more efficient agricultural future.

Keywords: Direct seeded rice, Happy seeder technology, Resource conservation technologies, Rice residue management, Rice-wheat cropping system

THE rice-wheat cropping system (RWCS) is a cornerstone of Punjab's agricultural landscape, providing critical support for the region's food security, rural livelihoods, and economic stability. However, this long-established cropping sequence faces mounting sustainability challenges that threaten its viability and broader environmental health. RWCS, while highly productive, has led to serious environmental and ecological concerns, including the depletion of underground water resources, soil degradation, and severe air pollution caused by the widespread practice of rice residue burning. These issues not only endanger the long-term sustainability of agriculture, but also compromise nutritional security as the environmental impacts directly affect the quality and availability of food, and harm the health of local communities.

One of the most pressing sustainability concerns is the over-extraction of groundwater, a critical resource for irrigation in Punjab (north-western India). The reliance on groundwater for rice cultivation has led to rapidly declining water tables, with many areas facing chronic water scarcity. As rice is a water-intensive crop, this poses a significant challenge to the long-term viability of the RWCS. Additionally, the large-scale production of rice residue has become another major environmental concern. After harvesting rice, farmers often burn the leftover straw in the fields to prepare for the subsequent wheat crop, a practice that contributes significantly to air pollution, exacerbates health problems, and further degrades soil quality. In addressing these challenges, direct seeded rice (DSR) has emerged as a promising solution. It is a resource-efficient alternative to traditional puddling-based rice cultivation. By planting rice directly into dry soil without the need for water-intensive puddling, DSR significantly reduces water usage. In the context of north-western India, where groundwater depletion is a critical issue, DSR offers a way to arrest the rapid decline in water tables. With DSR, water savings can be substantial, reducing the overall water footprint of rice cultivation and helping to conserve this valuable resource for future generations. Another important innovation has been the happy seeder technology which is a modified zero-till drill that facilitates *in situ* rice residue management. Happy seeder allows farmers to sow wheat directly into fields where rice residue is still present, without the need to burn it. This technology helps manage rice straw in an environmentally friendly way, improving soil organic matter, enhancing soil health, and reducing air pollution.

In the face of pressing environmental challenges, including groundwater depletion, soil degradation, and the harmful practice of rice residue burning, S. Gurpreet Singh Sidhu of Mehraj village in Bathinda has become a beacon of change in Punjab's agriculture. At the age of 38, S. Gurpreet Singh has emerged as a leader in innovative farming in Punjab, revolutionizing traditional practices through eco-friendly technologies like the happy seeder and direct seeded rice (DSR). His journey began in 2011, driven by a commitment to conserve groundwater and manage rice residues sustainably. Over the years, he has significantly enhanced his farm's productivity, while showcasing the environmental and economic advantages of sustainable agricultural methods. He has shown how these issues can be addressed through innovation and a commitment to sustainable farming practices. By adopting direct seeded rice and happy seeder technologies, he has demonstrated how agricultural productivity can be maintained, while conserving precious resources. The use of the happy seeder has transformed how rice residue is managed.

Impact of adoption of resource conservation technologies

His innovative spirit extends to the modification of a zero-till drill machine for DSR. Similarly, being cost-effective, happy seeder technology of wheat establishment following *in situ* rice residue management enabled him to directly sow wheat into standing rice stubble without pre-irrigation and preparatory tillage. By using advanced techniques like DSR and happy seeder sowing, he became successful in reducing diesel fuel consumption, human labour, besides substantial irrigation water saving. The data revealed that the irrigation water use was reduced substantially by ~28%, with the DSR field consuming 10,800 m^3 of water, compared with 15,000 m^3 in the adjacent field that did not implement resource conservation techniques. Additionally, labour requirements were reduced by ~25.9% in the DSR field, compared with the conventional fields without adoption of resource conservation technologies. These savings reflect the efficiency of DSR in optimizing resource use and reducing operational costs.

Similarly, the adoption of happy seeder technology contributed towards resource savings. Fertilizer-N use decreased by ~16.7%due to the adoption of happy seeder technology and *in* situ rice residue management over a long period of time (12-years) requiring 129.4 kg N/ha, compared to 155.3 kg N/ha in the adjoining fields without rice residue management. Water usage in happy seeder sown wheat was reduced by ~20% (2,400 m^3 in happy seeder vs.3,000 m^3 in the conventional fields). Diesel fuel consumption exhibited a significant reduction of ~37.3% due to the use of happy seeder technology employing no preparatory tillage for seed bed preparation as compared to 55 L/ha in the conventional fields involving multiple operations for residue management and seed bed preparation. These results demonstrate substantial savings in water, labour, fertilizer, and diesel fuel consumption with the adoption of DSR and happy seeder technologies, highlighting their effectiveness in enhancing resource efficiency while maintaining or improving productivity in the RWCS.

For DSR technology, significant cost savings were observed. The cost of irrigation water in DSR adopting fields was reduced by ~28%, amounting to a saving of ₹ 1,750/ha (₹ 4,500/- vs. ₹ 6,250/ha for conventional fields). Additionally, labour costs were also reduced by ~25.9%, with a saving of Rs. 4,950/ha (₹ 14,203 vs. ₹ 19,153/ha). These reductions reflect the efficiency gains achieved through DSR, leading to lower operational expenses.

Similarly, happy seeder technology demonstrated substantial economic benefits in wheat establishment. The fertilizer costs, irrigation water were decreased by ~16.7 and 20.0%, respectively over the conventional methods. Notably, herbicide costs were halved with a saving of ₹ 1,500/ha due to adoption of happy seeder technology of wheat establishment. Such differences could be ascribed to decreased incidence of weeds, particularly the grassy weeds due to residue mulch. Diesel fuel costs were also significantly reduction by ~37.3%

Table 1. Comparative performance of agri-input use and potential savings achieved by with the adoption of resource conservation techniques followed by Gurpreet Singh Sidhu in rice-wheat cropping system

Input type	Field with the adoption of resource conservation technology	Adjoining field where resource conservation technologies were not adopted	Saving (%)
Direct seeded rice (DSR) technology of rice establishment			
Water (m^3)	10800.0	15000.0	28.0
Labor (h/ha)	252.5	340.5	25.9
Happy seeder technology of wheat establishment			
Fertilizer-N (kg N/ha)	129.4	155.3	16.7
Water (m^3)	2400.0	3000.0	20.0
Diesel (L/ha)	34.5	55.0	37.3

Table 2. Economic indices of comparative performance appraisal of the adoption of resource conservation techniques followed by Gurpreet Singh Sidhu in rice-wheat cropping system

Input type	Field with the adoption of resource conservation technology	Adjoining field where resource conservation technologies were not adopted	Saving (₹/ha)	Saving (%)
Direct seeded rice (DSR) technology of rice establishment				
Cost of irrigation water (₹/ha)	4500.0	6250.0	1750.0	28.0
Cost of labor (₹/ha)	14203.0	19153.0	4950.0	25.9
Happy seeder technology of wheat establishment				
Cost of fertilizer-N (₹/ha)	1687.5	2025.0	337.5	16.7
Cost of irrigation water (₹/ha)	1000.0	1250.0	250.0	20.0
Cost of herbicide (₹/ha)	1500.0	3000.0	1500.0	50.0
Cost of diesel fuel (₹/ha)	3055.0	4871.0	1816.0	37.3

Table 3. Average crop grain yield, cost of cultivation (CC), average gross returns (AGRs), average net returns (ANRs) and benefit-cost ratio of different resource conservation technologies adopted by S. Gurpreet Singh Sidhu in rice-wheat cropping system

Parameters	At the beginning of resource conservation technologies (2014–15)				
	Grain yield (q/ha)	CC (₹/ha)	AGRs (₹/ha)	ANRs (₹/ha)	B:C
Rice	78.2	35,500	1,13,390	77,890	3.19
Wheat	55.3	23,900	80,185	56,285	3.36
	Now, after 12-years of adoption of resource conservation technologies (2023–24)				
Rice	80.4	52,820	1,86,528	1,33,708	3.53
Wheat	57.5	31,980	1,30,813	98,833	4.09

under happy seeder technology, compared with the conventional method of rice residue management. Overall, the adoption of DSR and happy seeder technologies resulted in substantial cost savings across multiple input categories, including water, labor, fertilizer, herbicide, and diesel. These economic efficiencies, in addition to their environmental benefits, underscore the value of resource conservation techniques in enhancing the sustainability and profitability of the rice-wheat cropping system.

The data illustrated significant impact of resource conservation technologies on the performance of the rice-wheat cropping system managed by S. Gurpreet Singh Sidhu over a 12-year period. At the onset of adopting resource conservation technologies (2014–15), rice grain yield (of 78.2 q/ha)was achieved with a cost of cultivation (CC) of ₹35,500/ha to produceaverage gross returns (AGRs) of ₹1,13,390/ha, and average net returns (ANRs) of ₹77,890/ha. However, after 12-years (2023–24), rice yield increased to 80.4 q/ha, with CC rising to ₹ 52,820/ha, and AGRs increased to ₹ 1,86,528/ha and ANRs increased substantially to ₹1,33,708/ha. However, in 2014–15, wheat yield was 55.3 q/ha, with a CC of ₹ 23,900/ha, AGRs of ₹80,185/ha and ANRs of ₹56,285/ha, resulting in a B:C ratio of 3.36. However, wheat yield increased to 57.5 q/ha by 2023-24, with the CC rising to ₹31,980/ha. AGRs increased to ₹1,30,813/ha, and ANRs reached ₹98,833/ha, with the B:C ratio improving significantly to 4.09.Overall, both rice and wheat crops exhibited enhanced yields and economic returns after adopting resource conservation technologies, with wheat experiencing a more substantial improvement in the B:C ratio. This demonstrates the success of sustainable farming practices in boosting productivity, reducing costs, and improving overall profitability.

Rice residue management impacts on soil health indicators

After 12 years of *in situ* rice residue management, there was a noteworthy change in soil health of the farm of S. Gurpreet Singh Sidhu. These improvements highlight significant gains, including a slight decrease in soil reaction (pH) and electrical conductivity (E.C.$_{1:2}$) following 12-years of *in situ* rice residue management. Rice residue management resulted in substantial (~43.8%) increase in soil organic C content in the surface soil layer. Available-P content in surface (0-15 cm) layer increased by ~18.7% following rice residue management, compared to the initial available-P value. Similarly, available-S exhibited substantial increase of ~46.4% after 12-years of residue management. Conversely, the availability of B, Ca and Mg did not change substantially following residue management. Amongst the micro-nutrients, there was ~113.6, 88.4, 12.3 and 7.3% increase in DTPA extractable Zn, Cu, Fe and Mn content after 12-years of *in-situ* rice residue management. These improvements have significantly enhanced the health and fertility of Gurpreet's soil, leading to higher crop yields and reduced reliance on chemical inputs.

Temporal and spatial spread of resource conservation technologies

For DSR technology, the total area under adoption increased significantly by ~3.5-times over the 12-years. This increase was achieved through a combination of his own land, leased land and land of other farmers. Additionally, the number of villages where DSR was implemented expanded from 1 in 2012 to 12 in 2024. Similarly, over the years, the total area under rice residue management increased by ~3.1-times (from 92 ha in 2012 to 286 ha in 2024). Rice residue management was implemented in 2 villages in 2012, which grew to 10 villages by 2024, and such growth in the adoption of resource conservation technologies indicates the increasing success and scalability of Gurpreet Singh Sidhu's sustainable farming practices. His efforts have significantly impacted not only his own farm but also the broader farming community,

Table 4. Important soil health sustainability indicators of his farm after *in situ* rice residue management

Soil properties	Before rice residue management (2012)	After rice residue management (2024)
pH	8.13	8.09
Electrical conductivity (E.C.$_{1:2}$) (dS/m)	0.36	0.33
Soil organic carbon (SOC) (%)	0.32	0.46
Phosphorus (P; mg/kg)	13.4	15.9
Sulfur (S; mg/kg)	9.77	14.3
Boron (B; mg/kg)	0.16	0.18
Calcium (Ca; mg/kg)	189.0	195.5
Magnesium (Mg; mg/kg)	42.2	45.3
Zinc (Zn; mg/kg)	1.10	2.35
Copper (Cu; mg/kg)	0.43	0.81
Iron (Fe; mg/kg)	31.8	35.7
Manganese (Mn; mg/kg)	3.84	4.12

demonstrating the potential for widespread adoption of resource-efficient technologies.

Global recognition and awards

His exceptional journey in sustainable agriculture has garnered widespread recognition on both national and international platforms. In 2024, he was honoured with the prestigious *National Millionaire Farmer of India Award* by ICAR-Agricultural Technology Application Research Institute (ATARI), PAU Campus, Ludhiana, and the *Champion Farmer Award* at the esteemed C-SUCSeS Project Forum in the Maldives. These accolades celebrated his pioneering role in advocating climate-smart agricultural practices. That same year, he received an *Appreciation Letter* from ICAR Karnal, acknowledging his exemplary work in crop residue management, which has played a pivotal role in tackling the environmental challenges associated with stubble burning.

Throughout his career, he earned numerous prestigious awards in recognition of his contributions to sustainable farming. He was bestowed with the *Best Innovative Farmer Award* by CRIDA in 2021, a testament to his innovative approaches in resource conservation. In 2015, he received the *Sardar Dalip Singh Memorial Award* from Punjab Agricultural University (PAU), Ludhiana, and was honoured with *Dr. Ravinder Singh Memorial Award* for his work in crop residue management at the Jatt Expo Kisan Mela. Additionally, his efforts in reducing environmental pollution earned him appreciation from the Punjab Pollution Control Board in 2017–18, along with recognition from the State Department of Agriculture and Farmers' Welfare in the same year. These prestigious honours collectively reflect his unwavering commitment to transforming agriculture through sustainable, climate-smart practices and his profound impact on the farming community. His leadership continues to inspire positive change and set a benchmark for innovation in agricultural practices.

Table 5. Brief description of temporal and spatial spread of different resource conservation technologies adopted by Gurpreet Sigh Sidhu

Particulars	Direct seeded rice		Rice residue management	
	Year 2012	Year 2024	Year 2012	Year 2024
Own land (ha)	10	11	10	11
Leased land (ha)	20	25	20	25
Other farmers' land (ha)	45	225	62	250
Total area covered (ha)	75	261	92	286
Villages covered (No.)	1	12	2	10

His initiatives resonate strongly with India's broader mission to strike a sustainable balance between agricultural productivity and environmental conservation. By embracing PAU-recommended crop varieties and implementing resource conservation techniques, he has not only boosted productivity but also ensured the protection of the ecosystem. These conservation practices have yielded a combined input savings of 26.6%, highlighting both their economic feasibility and significant environmental benefits.

SUMMARY

From the fields of Mehraj to global platforms like the Maldives, Gurpeet Singh Sidhu embodies the spirit of a new green revolution. His journey is a testament to the transformative power of innovation, determination, and collaboration in overcoming challenges. His story goes beyond agriculture—it is about crafting a sustainable future for generations to come. As Sidhu's wisely puts it, "Farming is not just about growing crops; it's about nurturing life."

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