

## ENHANCING WATER PRODUCTIVITY IN WHEAT THROUGH IN-SITU RICE RESIDUE RETENTION BY HAPPY SEEDER IN NORTH-WESTERN INDIA

Rajbir Singh<sup>1</sup> and A.K.Singh<sup>2</sup>

### ABSTRACT

The rice-wheat system (RWS) is the most prevailing production system in North-Western (NW) states of Punjab, Haryana and western Uttar Pradesh, recognized as heartlands of Green Revolution which contribute bulk of rice and wheat in the national food basket. Cultivation of high yielding varieties of rice and wheat produces about 34 MT of paddy straw in this region of which Punjab alone contributes about 65%. It is estimated that in NW states of India about 23 MT of rice residues are burnt in the field as an easy and quick method of its disposal. Burning crop residue causes pollution problems in the atmosphere and huge nutritional loss and soil physical health deterioration. About 80-90% of N and S and 15-20% of P and K contained in rice residue are lost during burning. Total amount of N, P, K and S in 23 MT of rice residue is about 0.7 MT. Therefore, burning of 23 MT of rice residues will lead to a loss of about 9.2 MT of C equivalent to a CO<sub>2</sub> load of about 34 MT per year and a loss of about 1.4×10<sup>5</sup> t of N (equivalent to 3 million US Dollar, USD) annually. The science based evidence suggests that *in-situ* retention of crop residues can play an important role in buffering soil moisture and temperature (adaptation to climate risks), replenishing soil nutrients and organic matter, in addition to reducing environmental footprints (mitigation of greenhouse gas emissions, GHGs). Happy Seeder has been recognized as a key technological innovation for direct seeding of wheat in standing stubbles. Demonstrations on Happy Seeder were laid out in a systematic approach at research farm of Agriculture Science Centres popularly known as Krishi Vigyan Kendras (KVKs) and selected strategic locations in 16 districts of Punjab. A total of 675 and 962 demonstrations were laid out precisely during 2015-16 and 2016-17 respectively at these locations. The results of these demonstrations revealed a saving of 59.8 mm and 64.6 mm of irrigation water during 2015-16 and 2016-17, respectively in happy seeder sown wheat compared to conventional wheat cultivation resulting into saving of average 19.7 % of total irrigation water. The water productivity of direct-seeded wheat with Happy Seeder was found to be 20.7 kg/m<sup>3</sup> compared to 16.1 kg/m<sup>3</sup> with conventional wheat cultivation practices resulting into 28.6 % improvement in water productivity. Similarly, direct seeding of wheat with Happy Seeder resulted into net profit of INR 6500/ha. During 2018, Government of India has initiated Central Sector Scheme on *In-situ* Residue Management for promotion of mechanization with an outlay of 170 million USD for two years which had impact on scale covering about 0.8 million hectares area in Punjab and Haryana during 2018. If two million hectare area is covered under Happy Seeder in next two years under RW system in Haryana and Punjab states, this would result into saving of 1.1 billion cubic meter (BCM) water and net saving of 13 billion INR.

**Keywords:** Happy Seeder, Water Productivity, Direct-seeded Wheat, *In-situ* Retention, Paddy Straw

---

1 Director, ICAR-Agricultural Technology Application Research Institute (ICAR-ATARI), PAU Campus, Ludhiana-141004, Punjab, India; E-mail: rajbirsingh.zpd@gmail.com

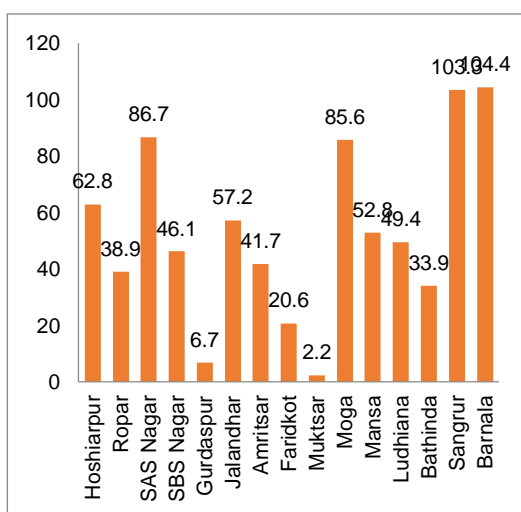
2 Deputy Director General (Agri. Extension), ICAR, KAB-1, New Delhi-110012, India, E-mail: aksicar@gmail.com

## 1. INTRODUCTION

The rice-wheat system (RWS) is the most prevailing production system in North-Western (NW) states of Punjab and Haryana covering almost 4.2 million hectares and recognized as heartlands of Green Revolution and provides bulk of rice and wheat in the national food basket. The area under paddy is about 3.0 and 1.2 million hectares in Punjab and Haryana respectively. The main source of irrigation is ground water and resulted into excessive indiscriminate exploitation of ground water thus created declining water table situation. Moreover, the area under paddy in Punjab is increasing (Fig.1) which is main cause of decline in underground water table (Fig. 2) thus threatening the sustainability of production system. The average rate of decline over the last few years has been 55 cm/ year in Punjab (Aggarwal *et al*, 2009). This has resulted in extra power consumption, affects the socio-economic conditions of the small farmers, destroy the ecological balance and adversely affect the sustainable agricultural production and economy of the NW states.

Further, cultivation of high yielding varieties of rice and wheat produces about 34 million tonnes of paddy straw in this region of which Punjab alone contributes about 65%. With progressive increase in mechanized harvesting of rice and wheat crops coupled with growing labour shortages, crop residue burning has become a serious problem and causes phenomenon environmental pollution (Singh *et al*, 2018a). Burning crop residue caused pollution problems in the atmosphere and huge nutritional loss and physical health deterioration to the soil. Air pollution from residue burning leads to losses of soil organic matter and plant nutrients and adversely affects soil health. About 80-90% of N and S and 15-20% of P and K contained in rice residue are lost during burning (IARI, 2012). Burning of 23 MT of rice residues will lead to a loss of about  $1.4 \times 10^5$  t of N (equivalent to 3 million USD) annually (NAAS, 2017).

A recent study by the International Food Policy Research Institute (IFPRI), based on the health data of 2.5 lakh persons has shown shocking economic and health implications of agricultural crop-residue burning (ACRB). The study estimated that ACRB is causing USD 30 billion economic losses every year to India. In addition, the study revealed that the risk of Acute Respiratory Infection to the exposed general population on account of ACRB rises by 3 times (Chakrabarti *et al*, 2019).



**Figure 1.** Year wise area ('000 ha) of paddy in Punjab



**Figure 2.** District wise rate of fall in water table (cm) during 1998-2016 in Punjab

## 1.1 Technological Interventions Available for Residue Management

Several options like *in-situ* incorporation, generating electricity, furnace fuel, composting, use as mulch, animal fodder, mushroom production, paper and cardboard industry, etc are available for residue management but presently these utilise less than 15% of the total rice residue produced in NW India. However, exporting the residues out of the field seems to be good option but may be detrimental for the soil health.

The science based evidence suggests that *in-situ* retention of crop residues can play an important role in buffering soil moisture and temperature (adaptation to climate risks), saving in water due to mulching effect, replenishing soil nutrients and organic matter, in addition to reducing environmental footprints (mitigation of greenhouse gas emissions, GHGs) (Lohan et al, 2018). Until recently, the availability of suitable machinery was a major constraint to direct drilling into heavy rice stubbles. Happy Seeder has been recognized as a key technological innovation for direct seeding of wheat in standing stubbles (Saunders, 2012, Sidhu *et al*, 2015). This innovative planter is also capable of direct drilling wheat after the rice harvest and taking advantage of residual moisture in the fields.

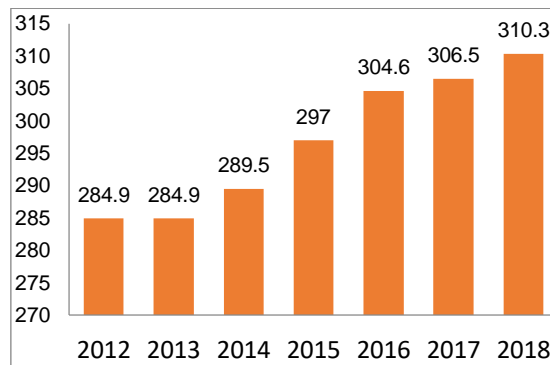


Figure 3. Site of Demonstrations in Punjab

## 1.2 Up-scaling of Happy Seeder

Up-scaling of innovative Happy Seeder technology is deemed vital for safeguarding objectives of sustainable growth of agriculture, for which government has made interventions such as financial support in the form of subsidy for purchase of Happy Seeder and legislation for completely banning residue burning in Punjab and Haryana. Fine imposition by government has also forcing farmers to stop residue burning. However, instead of '*forceful implementation*', '*wilful adoption*' of technology having '*multiple benefits*' of eliminating residue burning, facilitate farmers to plant their wheat crop in time and reduce cost of production need to be promoted to ensure sustainable farming.

## 2. METHODOLOGY

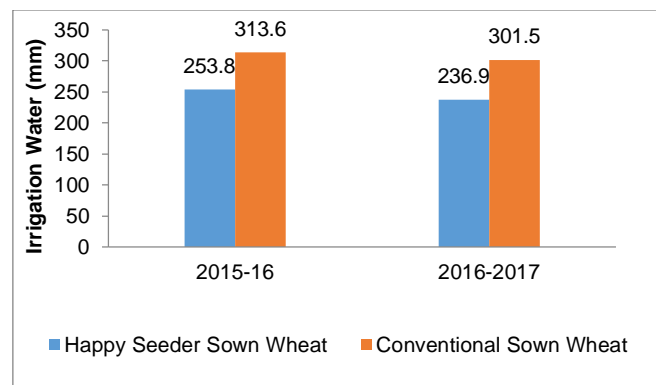
Demonstrations on Happy Seeder were laid out in a systematic approach at research farms of Agriculture Science Centres popularly known as Krishi Vigyan Kendras (KVKs) and selected strategic locations in 16 districts of Punjab (Fig.3). A total of 675 and 962 demonstrations were laid out precisely during 2015-16 and 2016-17 respectively at these locations. These demonstrations were laid out in 87 and 133 villages in 16 districts of Punjab. The selection of sites of demonstrations was based on the strategic locations and innovativeness of farmers so that the results can be

exhibited to farmers on large scale by the principle of ‘*Seeing is Believing*’. Full details of longitude and latitude of these sites is available at Singh *et al*, 2018c. Each demonstration consisted of one hectare area half of which was taken as control (conventional practice). Demonstration of happy seeder was laid out in half hectare area in which wheat sowing was done in standing stubbles taking advantage of residual moisture in the fields. The conventional practice involved the harvesting rice with combine followed by pre-sowing irrigation, after achieving field capacity, tillage was done with cultivator, harrow, rotovator and seeding of wheat.

The wheat varieties used in demonstration were HD-2967, HD-3086, PWB-725 and wheat sowing was done from 28 October to 18 November during both the years. Application of irrigation in demonstration was monitored scientifically and amount of water was calculated during the whole season. Soil moisture profile was studied at regular interval and based on need, precise irrigation was given in the demonstration plots. Rest of the recommended package of practices was followed to raise healthy crop. At harvesting, field harvest days were celebrated to convince other farmers to interact at site and results were highlighted during harvesting. At harvest, data on yield and yield attributing characters were collected with standard methods. Similarly, cost of cultivation and net returns were also calculated by using all the practices and inputs and minimum support price of wheat. Water productivity ( $\text{kg/m}^3$ ) was calculated by standard formula i.e., yield ( $\text{kg/ha}$ )/water applied per ha ( $\text{m}^3$ ).

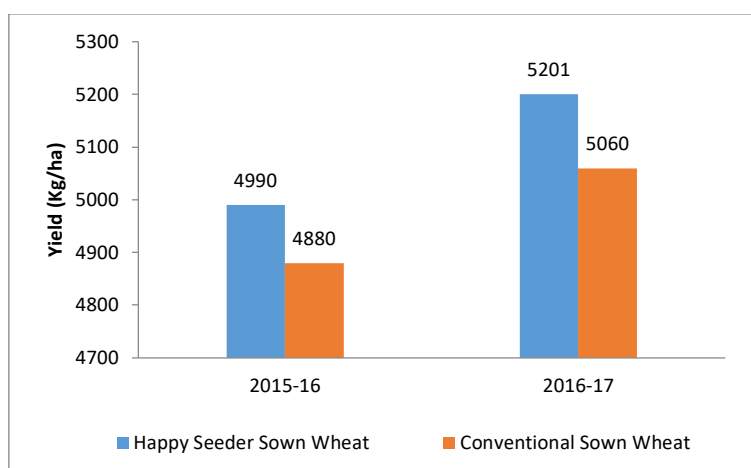
### 3. RESULTS AND DISCUSSION

The results obtained from demonstrations were analysed with respect to irrigation water applied revealed that wheat sown with happy seeder resulted into less use of irrigation water compared to conventional practice (Fig. 4). The irrigation water applied was 253.9 mm and 236.9 mm in happy seeder sown wheat compared to 313.6 mm and 301.5 mm in conventional practice (control) during 2015-16 and 2016-17 respectively (Fig 4).



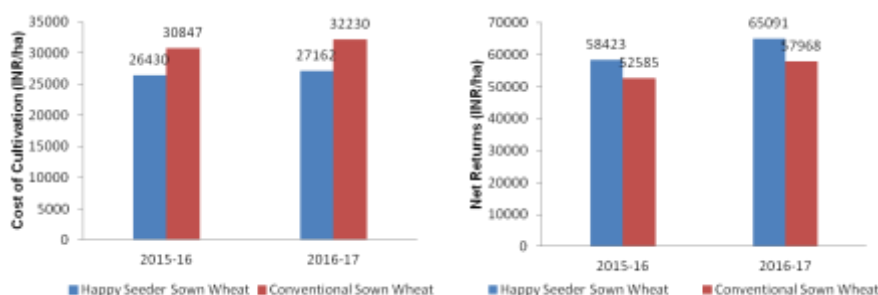
**Figure 4.** Amount of Irrigation water applied (mm) in demonstrations

The data clearly indicated that there was on an average 25.3% saving of water in wheat when it is sown with happy seeder compared to control i.e. conventional method or farmers’ practices. Our finding clearly supports that when wheat is grown in paddy stubbles with happy seeder, it requires less water mainly due to mulching effect of paddy straw which is available in the field. The residue in the field also played positive role in buffering the soil moisture & temperature and also helped in saving of water. Such positive effect of *in-situ* retention of crop residues has also been reported earlier (Jat, 2017, Yadvinder-Singh et al, 2014, Yadvinder-Singh et al, 2015).



**Figure 5.** Effect of happy seeder and conventional sown wheat on yield (Kg/ha)

The demonstration of wheat sown by happy seeder resulted into slightly higher wheat yield. The average yield of wheat under demonstrations conducted was found to be 4990 kg/ha in 2015-16, which is slightly higher (2.3%) as compared to yield of control or conventional plots. Similarly, demonstrations conducted during 2016-17, the average yield was found to be 5201 kg/ha which is 2.8% higher than the control plots (Fig.5).

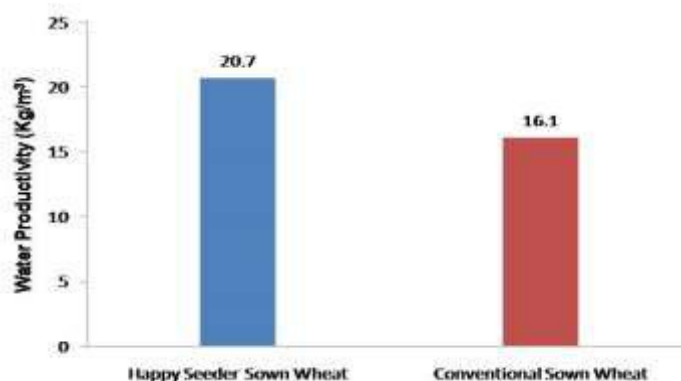


**Figure 6.** Effect of happy seeder and conventional sown wheat on cost of cultivation and net returns

In contrast, wheat sown with happy seeder resulted into reduction of cost of cultivation significantly. Data revealed that the cost of production of wheat cultivated with happy seeder was INR 26430/ha, during 2015-16 which is 14.3% less as compared to control or conventional plots. Similarly, during 2016-17, average cost of production of wheat was found INR 27162/ha with happy seeder which is 15.7% lower than the control plots (Fig. 6). Our studies clearly indicated that wheat sown with happy seeder impacted wheat yield slightly (Av. 2.5%) but cost of cultivation reduced remarkably upto 15% mainly because wheat was directly sown after the harvest of paddy and the cost incurred on field preparation was reduced to one operation i.e. sowing wheat with happy seeder in standing stubbles of previous paddy crop taking advantage of residual moisture in the fields.

The net income was calculated by taking into consideration of total income and cost of cultivation. The net income from wheat sown with happy seeder was observed INR 58423/ha, which is 11.1% (INR 5838/ha) higher than the net income from control plots during 2015-16 (Fig.6). Similarly, demonstration conducted during 2016-17, average net income from wheat sown with happy seeder was found to be INR

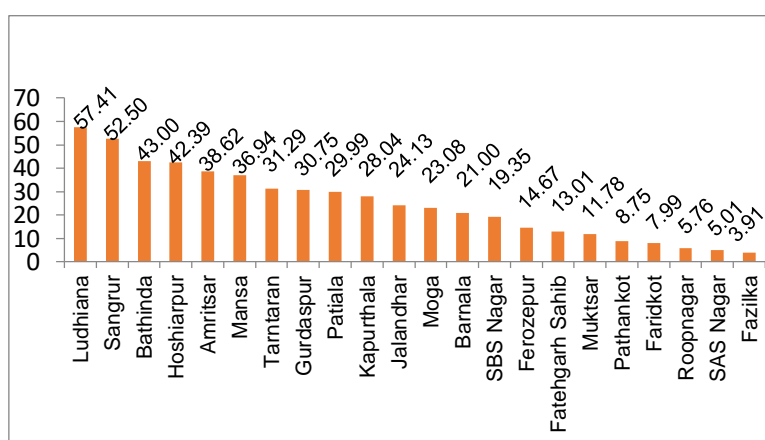
65091/ha, which is INR 7123/ha (12.3%) more than the control plots. Thus taking the average of 675 and 962 demonstrations laid out during 2015-16 and 2016-17 respectively indicated that direct seeded of wheat with Happy Seeder resulted into net profit of INR 6500/ha. The water productivity (WP) of direct-seeded wheat with Happy Seeder was found to be 20.7 kg/m<sup>3</sup> compared to 16.1 kg/m<sup>3</sup> with conventional wheat cultivation practices (Fig 7) resulting into 28.6 % improvement in water productivity (average of 2015-16 and 2016-17). The higher WP clearly indicate the cumulative effect of saving water, higher yield and higher net returns when wheat is directly seeded with innovator plant i.e. Happy Seeder. Similar findings have also been reported by Aryal et al, 2016, Jat, 2017, Singh et al, 2018c, Yadvinder-Singh et al, 2015.



**Figure 7.** Effect of happy seeder and conventional sown wheat on water productivity

### 3.1 Impact of demonstrations

Adoption of in-situ crop residue management practices was found to be best remedy against crops residue burning and Ministry of Agriculture and Farmers Welfare, Government of India (GOI), promulgated a comprehensive Central Sector Scheme on Promotion of Agricultural Mechanization for *In-Situ* Management of Crop Residue in the States of Punjab, Haryana, Uttar Pradesh and NCT of India on 7 March 2018 with an outlay of 170 million USD for two years (2018-19 and 2019-20).



**Figure 8.** District wise Happy Seeder wheat Area ('000 Ha) in Punjab during 2018-19

Subsequently, the scheme implementation happened at unprecedented pace and wheat area under zero paddy straw burning during 2018 increased to 0.8 million hectares. The district wise Happy Seeder sown wheat area in Punjab (Fig. 8) was the highest in Ludhiana (57410 Ha) followed by Sangrur 52500 hectare while the minimum area was in Fazilka (3910 Ha). Print media reported the estimated figure of 6 lakh Ha wheat sown area under paddy residue management (zero paddy straw burning) using various approaches during 2018 (Chaba, 2018). If two million hectare area is covered under Happy Seeder in next two years under RW system in Haryana and Punjab states, this would result into saving of 1.1 Billion Cubic Meter (BCM) of water and net saving of 13 Billion INR. This extra-ordinary increment of wheat area under Happy Seeder technology made experts to perceive it as a revolution from conventional wheat cultivation to conservation agriculture.

#### 4. REFERENCES

- Aggarwal, R., Kaushal, M., Kaur, S. & Farmaha, M. S. 2009 Water resource management for sustainable agriculture in Punjab, India. *Water Science Technology*. 60, 2905-2911.
- Aryal, J.P., Sapkota, T.B., Stirling, C.M., Jat, M.L., Jat, H.S., Rai, M., Mittal, S., & Sutaliya, J.M. 2016 Conservation agriculture-based wheat production better copes with extreme climate events than conventional tillage-based systems: A case of untimely excess rainfall in Haryana, India. *Agri. Ecosys. Env.* 233: 325–335.
- Chakrabarti, S, Khan, M T, Kishore, A, Roy, D & Scott, S P. 2019 Risk of acute respiratory infection from crop burning in India: estimating disease burden and economic welfare from satellite and national health survey data for 250 000 persons. *International Journal of Epidemiology*, 2019, 1–12 doi: 10.1093/ije/dyz022
- Chaba Anju Agnihotri. 2018. Punjab Agriculture Secretary: Direct Sowing in 17 per cent of wheat area. *The Indian Express*, 21 December 2018
- IARI, 2012 Crop residues management with conservation agriculture: Potential, constraints and policy needs. *Indian Agricultural Research Institute, New Delhi*, vii+32 p.
- Jat, M.L. 2017 Climate Smart Agriculture in Intensive Cereal Based Systems: Scalable Evidence from Indo-Gangetic Plains. In: *Agriculture under Climate Change-Threats, Strategies and Policies* (eds Belavadi, V.V. et al.). Allied Publishers Pvt. Ltd. P. 147-154.
- Lohan, S.K., Jat, H.S., Yadav, A.K., Sidhu, H.S., Jat, M.L., Choudhary, M., Peter, J.K. & Sharma, P.C. 2018 Burning issues of paddy residue management in north-west states of India. *Renewable and Sustainable Energy Reviews* 81: 693-706.
- Sidhu, H.S., Singh, M., Yadvinder Singh, Blackwell, J., Lohan, S.K., Humphreys, E., Jat, M.L., Singh, V. & Singh, S. 2015 Development and evaluation of the Turbo Happy Seeder for sowing wheat into heavy rice residues in NW India. *Field Crops Res.* 184: 201-212.
- NAAS, 2017 Innovative Viable Solution to Rice Residue Burning in Rice-Wheat Cropping System through Concurrent Use of Super Straw Management System-fitted Combines and Turbo Happy Seeder. *Policy Brief No. 2, National Academy of Agricultural Sciences, New Delhi*. 16 p.
- Saunders C., Davis, L. & Pearce, D. 2012 Rice–wheat cropping systems in India and Australia, and development of the 'Happy Seeder, *ACIAR Impact Assessment Series Report No. 77*, 48pp. Canberra.
- Singh, R, Mahajan, G, Kaur, S & Chauhan, B S. 2018a Issues and strategies for rice residue management to unravel winter smog in North India. *Current Science*, 114 (12):2419
- Singh, R, Murai, A S, & Kumar, A. 2018b. KVKs celebrate harvest field day on wheat sown with happy seeder. *ICAR-ATARI, Ludhiana*, p. 1-16.
- Singh, R; Kumar, A; Sidhu, R.S. & Mahal, J.S. 2018c Upscaling Happy Seeder Technology: Scientific evidences from demonstrations. *ICAR-ATARI, Ludhiana, Punjab* pp: 120.
- Yadvinder-Singh., Thind, H.S. & Sidhu, H.S. 2014 Management options for rice residues for sustainable productivity of rice-wheat cropping system. *Journal of Research Punjab Agricultural University* 51: 239-245.

Yadvinder-Singh, Manpreet Singh, Sidhu, H.S. Humphreys, E., Thind, H.S., Jat, M.L., Blackwell, J. & Vicky Singh. 2015 Nitrogen management for zero till wheat with surface retention of rice residues in north-west India. *Field Crops Res.* 184: 183-191.