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Development and evaluation of the Turbo Happy Seeder for sowing wheat into heavy rice residues in NW India

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ABSTRACT

In the extensive rice–wheat system of north-west (NW) India, harvesting is by large combines and the rice residues are normally burnt after harvest, followed by irrigation and intensive tillage prior to sowing wheat. While in-field retention of crop residues can play an important role in replenishing soil quality and reducing environmental pollution from stubble burning, until recently, there has been no suitable technology for seeding wheat in rice residues. To address this need, a series of machines ('Happy Seeders') was developed over the past 10 years, culminating in the development of version 2 of the 9-row Turbo Happy Seeder (v.2). The 9-row Turbo Happy Seeder(v.2) has a weight of 506 kg and can be operated by a 33.6 kW tractor at a work rate of 0.3 ha h^{-1}. Numerous on-farm trials show that yield of wheat sown into rice residues with the 9-row Turbo Happy Seeder is similar to or higher than yield with straw burning and conventional tillage prior to sowing, while providing many benefits to the farmer. These include greatly reduced fuel consumption and cost of crop establishment, and the ability to sow as soon as desired after harvest, ensuring the possibility of sowing at the optimum time and reducing the need for irrigation. However, adoption has been low to date, despite a 50% price subsidy. Constraints to adoption include the low window of operation of the machine (25 days per year), the low machine capacity compared with conventional seed drills, the inability to operate in wet straw, and the lack of straw spreaders on combine harvesters. Removal of subsidies for diesel and electricity (for pumping groundwater) and implementation of the policy banning in-field straw burning would help to accelerate adoption of technology for direct drilling wheat into rice residues.

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1. Introduction

Rice–wheat (RW) cropping systems are practiced on around 13.5 Mha across the Indo-Gangetic alluvial plains of South Asia. Cultivation of high yielding varieties of rice and wheat results in the production of large quantities of crop residues, particularly in north-western (NW) India where yields are high. Combine harvesting of rice and wheat predominates in this region, with large amounts of loose and anchored crop residues left in the fields after harvest (Gajri et al., 2002). While much of the wheat straw is collected for use as cattle fodder, rice straw is considered to be a poor feed due to its high silica content, no other local economic use has been found.

The loose rice residues generated during combine harvesting hamper tillage and seeding operations for the subsequent wheat crop, therefore open-field burning of rice residues is the common practice in NW India. Substantial losses of plant nutrients (especially N and S) and organic C occur during burning, with important implications for soil quality. In-field burning of rice straw is also a major contributor to air pollution (particulates and greenhouse gases), with serious impacts on human and cattle health in intensive rice-production areas (Bijay-Singh et al., 2008; Huang et al., 2012b; Yadvinder-Singh et al., 2010). In-field retention of crop residues can play an important role in replenishing soil nutrient stocks and organic matter, thus contributing to sustainable RW production systems (Bi et al., 2009; Yadvinder-Singh et al., 2005).

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Cost-effective management of crop residues is thus both a major challenge and a major opportunity for increasing the sustainability of the intensive RW systems of the Indo-Gangetic plains of India.

In-situ incorporation of rice residues is energy- and time-intensive and delays wheat sowing thereby adversely affecting wheat yield (Yadvinder-Singh et al., 2010). Minimum and zero-till (ZT) technologies for wheat seeding after removal or burning of rice residues are beneficial in terms of economics, irrigation water saving and improved timeliness of wheat sowing in comparison with conventional tillage (Malik et al., 2004; Singh et al., 2008; Erenstein and Laxmi, 2008; Erenstein et al., 2008). However, there are problems with direct drilling of wheat into combine-harvested rice fields using the standard ZT seed drill due to: (1) straw accumulation in the seed drill furrow openers, (2) poor traction of the seed metering drive wheel due to the presence of loose straw, and (3) the need for frequent lifting of the implement under heavy residue conditions, resulting in uneven seed depth and thus crop establishment.

Until recently, the availability of suitable machinery was a major constraint to direct drilling into heavy rice stubbles. However, in 2002, the development of a new line of machines for seeding into rice residues commenced with the construction of the Happy Seeder (Sidhu et al., 2008). The original Happy Seeder comprised a seed drill attached behind a forage harvester, with the chute extended to drop the straw on the sown rows behind the harvester. The final improvement to this concept came in the form of the 9-row Combo Happy Seeder, developed in 2004, in which the straw handling and seeding functions were combined into a much more compact single machine (Sidhu et al., 2007, 2008). A further improvement involved removing some of the straw cutting flails so that only a narrow strip (7.5 cm) of straw in front of the sowing tynes was removed. The final version in this series, the Combo+ Happy Seeder, also provided the option of strip tillage to improve seed soil contact and thus crop establishment and yield.

Operational costs for sowing wheat with the Combo Happy Seeder were 50–60% lower than with conventional sowing and with additional benefits of soil moisture conservation and improved air quality (Singh et al., 2008). However, there were many issues limiting the adoptability and performance of the Combo HS, in particular: the high power requirement (>33.6 kW), the heavy weight and thus cost of the machine, choking of the machine under heavy straw loads (>7–8 Mg ha^{-1}), poor germination under heavy straw loads due to coverage of the sown rows with a thick mulch (and difficulty in lining up adjacent sowing rows for the same reason), the requirement for spreading of the loose residues prior to sowing, the high levels of dust generated, and leaving one unsown row adjacent to the field boundary due to the rear position of the ground wheel.

Therefore, the development of improved versions of the Happy Seeder (known as Turbo Happy Seeders), with focus on the ability to perform well in heavy straw loads and with lower energy requirement, was undertaken. This paper describes the improvements made and provides an evaluation of the improved versions in terms of fuel consumption, wheat grain yield and other energy consumption.

2. Development of the Turbo Happy Seeder

2.1. The original Turbo Happy Seeder (9-row Turbo Happy Seeder v.1)

The Combo+ Happy Seeder developed in 2005 included a rotor with flails for cutting and picking up the rice residues in front of the sowing tynes, a chute for depositing the residues behind the machine, on top of the sown area, and a strip till unit (Sidhu et al., 2007). In 2006 a new version of the Happy Seeder named the Turbo Happy Seeder (v.1) was developed in collaboration with Dasmesh Mechanical Works, Amargarh, Punjab (India). The Turbo model does not have a chute and the residues are cut and chopped finely in front of the sowing tynes. The cutting and shredding is achieved with hinged J-type flails mounted on a high speed (1000–1300 rpm) rotor inside the straw management drum. The flails cut (shear) the anchored residues close to the soil surface and smash them and the loose residues against serrated blades fixed on the internal walls of the straw management drum, and against the seeding tynes which are also inside the straw management drum, thus chopping and shredding them into small pieces. At the same time, flails sweep past each sowing tyne twice per rotation, clearing the residues away and enabling the tynes to pass freely through the residues. This technology also results in much less straw deposition on the seed rows than between the rows, and greatly reduces the generation of dust. The Turbo Happy Seeder thus leaves the seeded rows exposed and clearly visible, enabling accurate lining up of adjacent sowing passes. The Turbo Happy Seeder v.1 had 9 sowing tynes spaced at 20 cm, and other specifications are provided in Table 1. While this version had many advantages over the Combo HS, it still had a high power requirement (>33.6 kW) and low capacity, both of which are major barriers to adoption by most farmers in NW India. Furthermore, there were still problems of choking with very heavy loads of straw (>9 Mg ha^{-1}), heavy weight (595 kg empty, 755 kg when full of seed and fertilizer) and machine overhang length (distance between the Turbo Happy Seeder and the 3-point linkage) resulting in poor maneuverability, excessive vibration leading to fatigue failure of welds and inaccurate seed and fertilizer metering, and leaving one row unplanted adjacent to the field boundary. Therefore, improvements to the Turbo Happy Seeder v.1 were needed.

2.2. Improving the Turbo Happy Seeder

Two improved versions of the THS, the 7-row Turbo Happy Seeder and the 9-row Turbo Happy Seeder v.2 were developed. Both machines incorporated the same improvements, the main differences being the higher weight and power requirement of the 9-row than the 7-row machine (Table 1).

2.2.1. Reducing the power requirement and increasing the fuel use efficiency of the THS

The power requirement of the Turbo Happy Seeder was reduced by increasing the row spacing between the sowing tynes from 20 to 25.7 cm, and changing the shape of the rotor flails from 'J' to inverted gamma 'γ' type (Figs. 1 and 2). This reduced the number of sowing tyne and flail assemblies from 9 to 7, and, together with other measures to reduce the weight (see below), the power requirement was reduced from 33.6 kW to 28.3 kW. However, the 7-row THS, maintained the same capacity (0.27 ha h^{-1}) as the original 9-row Turbo Happy Seeder (v.1).

It was surmised that provision of serration on the cutting edges of the inverted γ flails could help in better straw chopping and fuel efficiency. To test this, fuel consumption with J, γ, and serrated γ flails was compared by installing a flow meter on the fuel line of the tractor. The average fuel consumption for each type of flail was recorded after 7 runs (replications) of the tractor with Turbo Happy Seeder in 40 m (Field 1) and 80 m (Field 2) long strips in the combine harvested rice fields. Serrated knives were fixed on both edges of the γ blades. Fuel consumption in 9-row Turbo Happy Seeder v.1 was reduced by 14.9% and 4.1% by changing the flail shape from J to inverted γ and serrated inverted γ, respectively (Table 2). The fuel consumption with serrated inverted γ blades was higher than

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