Research Article

Performance Evaluation of Super Seeder for Wheat Sowing in Rice-Wheat Cropping System of Pakistan

Muhammad Tahir Latif[1]*, Muzzammil Hussain[1], Ali Zohaib[2] and Ishtiaq Hassan[3]

[1]Adaptive Research Farm Gujranwala 52200, Pakistan; [2]Cereals and Pulses Section, Agronomic Research Institute, Ayub Agricultural Research Institute, Faisalabad 38850, Pakistan; [3]Directorate General of Agriculture (Extension and Adaptive Research) Punjab, Lahore 54000, Pakistan.

Abstract | In rice-wheat cropping system the emerging Super Seeder (SS) is a tractor operated single pass solution to incorporate the standing and loose paddy residues into soil without burning, prepares land and concurrently sows wheat seed. This study was conducted during 2022 to assess the pros and cons of SS for wheat sowing as well as to compare the economics of wheat production to conventional tillage/broadcasting method (CT). As the SS has not been adopted on large scale to find out its adopters easily; therefore, twenty innovative farmers were included in sampling frame with non-probability sampling procedure for field survey as well as six field experiments were conducted in Gujranwala zone, Pakistan to evaluate four sowing techniques, i.e., CT, happy seeder, ridge sowing and SS with Randomized Complete Block Design. As compared to CT the SS has been estimated as resource conservation technique regarding sowing time (62.50%), irrigation time (7.69%), seed cost (14%), fertilizer cost (10.81%), and fuel cost (58.33%) with the constrained requirement of higher hp tractor (preferably 85 hp) for sowing operation. An increased wheat yield (13.11%) was estimated with SS (3450 kg ha^{-1}) as compared to CT (3050 kg ha^{-1}) in rice-wheat cropping system. The more net returns (36.15%) were calculated by SS with higher benefit cost ratio value (2.81) as compared to CT with lower value (2.16). Similarly, based on the field experiments data the SS resulted in significantly higher values of emergence count (211 m^{-2}), productive tillers (322 m^{-2}), grains count (38.93 $spike^{-1}$), 1000 grains weight (38.91 g) and grains yield (3497 kg ha^{-1}) delineating more yield (13.10%) over the CT. Thus, SS has conserved soil moisture, increased soil organic matter, better soil tilth and enhanced fertilizer uptake efficiency which ultimately increased the yield over the other comparative wheat sowing techniques.

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***Correspondence** | Muhammad Tahir Latif, Adaptive Research Farm Gujranwala, Pakistan; **Email:** tahirr.uaf@gmail.com
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Introduction

In Pakistan the wheat (*Triticum aestivum* L) is consumed as staple food and its availability always ensured the food security. Its cultivated area is 8.91 million hectares with share of 7.8% regarding value addition in agriculture as well as 1.8% of country's GDP (GoP, 2022). It has been cultivated in different

cropping systems like maize-wheat, sugarcane-wheat, rice-wheat and cotton-wheat but about 60% of the wheat area is recorded under cotton-wheat and rice-wheat cropping systems. In Pakistan wheat sowing starts from October and continues till the mid of January (Anwar, 2019). The wheat sowing may more be late due to pre-sowing irrigation (Rauni) to get proper soil moisture, which required additional 7-10 days' condition to weather situations and existing field capacity. Delay in wheat sowing from 3rd week of November has progressively reduced the grain yield (Iqbal *et al*., 2017).

In rice-wheat cropping system the farmers usually burn the paddy residues for ease of land preparation along with cost saving and timely wheat sowing. According to Lin and Begho (2022) the higher incorporating cost, scarcity of labour, no market of crop residue and the less time gap between crop harvest and next crop cultivation were the causing factors to burn crop residue. The residue burning damage the soil, raise the erosion risk, and enhance the soil temperature, subsequently destroying soil microbes. Hence, there has been the great scope to devise and use the agricultural machinery capable of crops sowing in standing crop residues/stubble along with introducing short duration varieties of crops.

To cope with paddy residue burning issue the Happy Seeder started to adopt during 2006 in India which is a tractor mounted machine that cut and picks up rice straw or standing stubbles in front of the sowing tine and clean each tine twice in one rotation of rotor for proper seed placement without seed bed preparation in soil with its attached zero till drill (Sidhu *et al*., 2007). During machine operation the mulched rice residues resulted in immobilization of nitrogen, improve organic matter, conserve soil moisture and control weeds which caused better wheat yield. The happy seeder consumes about 24.70 L ha^{-1} and has a field capacity of 4.05-4.86 hectare a day (Jat *et al*., 2020). Köller (2003) had concluded that the direct seeding could save 73% of fuel energy as compared to conventional tillage.

Then to address the existing operational issues of available happy seeder machine the Super Seeder (SS) introduced by India during 2018 is claimed to complete plough the standing paddy residues and sow seeds for the next wheat crop, in a single operation. The SS is technologically superior to the prevailing Happy Seeder machine for zero tillage wheat sowing with fuel consumption of 19.76 Lha^{-1} (Dhanda *et al*., 2022). The SS required a tractor of 85 hp ideally to operate the machine. This is also tractor operated machine that cuts and fully incorporate rice straw or stubbles, cultivate wheat into the soil. Presently, a more updated form of emerging super seeder namely Pak seeder has also been introduced by National Agricultural Research Council (NARC), Islamabad, Pakistan in 2021 for timely adoption which needed to be assessed. Therefore to avoid delay in wheat sowing and to diminish the cost of production (land preparation); the Agriculture Department has demonstrated this machine at different farmer fields and Govt. agriculture farms i.e. Adaptive Research Farm Gujranwala and Govt. Agri. Seed Farm Chillianwala district M.B. Din. Meanwhile some innovative farmers have also been reported to adopt SS to cultivate wheat timely and efficiently. Hence, this research study was planned to evaluate the pros and cons of SS for wheat sowing as well as to compare the economics of wheat production to conventional tillage/broadcasting method (CT).

Materials and Methods

As the SS has been introduced recently and has not been adopted on large scale in Pakistan to find out its adopters conveniently for field survey during 2022. Therefore, a number of 20 available innovative farmers were included in sampling frame with non-probability (convenience and purposive) sampling methods similar to Bhardwaj (2019) and Latif *et al*. (2022). The same number of non-adopters was also interrogated from the same location of SS adopters for comparative economic analysis. Pre-tested and well-designed questionnaire was employed for field survey. According to the approach employed by Iqbal *et al*. (2022), Latif *et al*. (2018), Reddy *et al*. (2018), and Latif *et al*. (2022); the economic indicators like benefit cost ratio (BCR), net returns and percent change values were computed to compare the economics of wheat production with super seeder to conventional tillage/broadcasting method (CT). The employed indicators are given below as:

$$Net\ returns = Gross\ income - Total\ operational\ cost$$

$$Benefit\ cost\ ratio\ (BCR) = Gross\ income/Total\ operational\ cost$$

$$Percent\ change = (New\ value - Old\ value)/Old\ value \times 100$$

During Rabi 2021-22 Adaptive Research Farm, Gujranwala zone also conducted six research trials for demonstration and evaluation of Super Seeder; a newly emerging technology for wheat sowing. Four treatments as sowing techniques, i.e. conventional tillage/broadcasting, happy seeder sowing, Ridge sowing and Super seeder sowing were evaluated by using the Randomized complete block design (RCBD) with three replications. The net plot size of each treatment on each site was 66 m × 50 m. All the other agronomic and plant protection practices were kept as per departmental recommendations with only variations in seed variety and sowing time. The meteorological data on rainfall and temperature was also collected and considered to explain the yield parameters.

The research trials data was collected on different crop yield attributes like emergence count (plants m^{-2}), productive tillers m^{-2}, number of grains per spike, 1000-grains weight (g) and grains yield (kg ha^{-1}). It was in accordance to Iqbal *et al.* (2020) and Yousif *et al.* (2015). To verify the normality of data set the scatter plot technique was used. After verification of normality trend, the Fisher's analysis of variance (ANOVA) was used for analysis on different observations/treatments (Steel and Torrie, 1997). Treatments (sowing techniques) means were evaluated by adopting Least Significant Difference (LSD) as post-hoc test at probability of 5%.

Results and Discussion

It was estimated that adoption of super seeder (SS) facilitated the farmers to sow wheat about 10-15 days earlier than CT method. Hobbs and Gupta (2003) explained that due to sowing after 20th November the wheat yield potential decreases by 1.5% per day as terminal heat implies. Saharawat *et al.* (2010) concluded that 4-6 times ploughing along with 2-3 times planking operation is comparatively regular practice in fine textured soil which leads towards increase in sowing cost and delay in wheat cultivation.

Comparative performance of super seeder (SS) for wheat sowing based on survey data

About 14% less seed was recorded with SS thus reducing seed cost than CT. Franke *et al.* (2007) described that the seed should be placed at a depth of twice the width or diameter of the planted seed. Nielsen (2015) concluded that the optimum seed depth of 3.81 cm to 5.08 cm to get sufficient moisture for uniform water uptake is easily ensured with SS with definite seed saving. While the broadcasting (CT) is not an efficient way of wheat sowing due to the issues of non uniform seed distribution and uneven planting depths.

The saving of Fertilizer (Urea-DAP-Potash) (kg ha^{-1}) was estimated as 10.81% through adoption of SS due to the quick nutrients' availability in proper maintained depth by reducing losses factor. During Fiscal Year 2021-22 overall the respondent farmers were using minimal quantity of fertilizer due to prevailing shortage and sudden rise in prices soon after COVID-19 epidemic incident. However, potash application was negligible. According to Erenstein and Laxmi (2008) some zero tillage (ZT) adopters reported 20 kg ha^{-1} fertilizer saving. With SS it became possible to sow wheat just after rice harvesting through utilizing residual moisture for wheat germination. Moreover, due to water conservation in soil by rice residues which act as mulch, the number of irrigations/depths of irrigation is reduced resulting in water saving. Mishra and Singh (2012) explained the seed broadcasting for seed placement at different depths resulted in poor stand establishment and requirement of high seed rate. According to Raju *et al.* (2012) on an average, farmers saved 6.13%, 15.98%, 45.88% and 13.93% cost on fertilizer, irrigation, machine labour and human labour respectively in ZT than CT of wheat cultivation. According to Iqbal *et al.* (2002) the time (hours) involved to irrigate wheat (particularly during the first irrigation) varied much in different sowing methods. It consumed 6.18, 9.88 and 8.65 hours respectively to irrigate one hectare of wheat cultivated with ZT, Rauni and wad watter methods.

Diesel consumption (L ha^{-1}) for sowing operation was calculated in the range of 22.23-29.64 L ha^{-1} with 58.33% saving by adopting SS for wheat sowing. There might be different factors for varying diesel consumption like type of soil (i.e. sandy, loamy or clayey), model/horse power of operating tractor, SS machine condition (i.e. used blades 42-60 and machine weight 750-950 kg), extent of rice residue/ straw present in the field and existing soil moisture etc.

Similarly, time required for land preparation/ sowing as well as time required for irrigation with

SS was estimated with savings of 62.5% and 7.69%, respectively. The wheat sowing in the residual moisture resulted in saving of irrigation and time with SS. The higher yield (3450 kg ha^{-1}) was estimated with SS as compared to CT (3050 kg ha^{-1}) with 13.11% increase in rice-wheat cropping system (Table 1). The higher yield might be achieved due to better emergence, productive tiller, efficient uptake of soil moisture and nutrients. The more net returns (36.15%) were recorded by SS with higher benefit cost ratio (2.81) as compared to CT of wheat with lower value (2.16) (Table 2).

The adopters of SS were of the view that this method has conserved soil moisture, increased soil organic matter, better soil tilth and enhanced fertilizer uptake efficiency. Similar results were found by Sharma *et al*. (2008) who explained that enhanced root development resulted in higher uptake of nutrient which caused increase in crop yield. The study results are in accordance to the Sidhu *et al*. (2007) who estimated more yield (10%) with Happy Seeder sowing as compared to CT.

Performance evaluation of super seeder (SS) for wheat sowing based on field experiments

During Rabi 2021-22 Adaptive Research Farm, Gujranwala zone conducted six research trials for demonstration and evaluation of SS; a newly emerging technology for wheat sowing. Four treatments as sowing techniques, i.e. CT, happy seeder sowing, ridge sowing and SS were evaluated. The trials were conducted within the premises of Punjab province of Pakistan on the sites namely, Adaptive Research Farm Gujranwala (32°12′15″N,74°13′48″E) with 227 m altitude, Majju Chak (31°55'23"N, 74°5'30"E) with 228 m altitude in tehsil Noshehra Virkan district Gujranwala, Nand pur (32°23'45"N,74°20'40"E) with 229 m altitude in tehsil and district Gujranwala, Soiyan Wala (32°14′32″N,74°16′08″E) with 228 m altitude in tehsil and district Gujranwala, Raikay (32°25′60″N, 73°37′0″E) tehsil Phalia district M.B. Din with 252 m altitude and Govt. Agricultural Seed Farm Chillianwala (32°39'0"N, 73°36'0"E) district M.B. Din with 252 m altitude. The farmer gatherings were also arranged to introduce and disseminate the latest emerging wheat sowing techniques including super seeder operation.

Table 1: *Inputs and output estimation in wheat production based on mean values of survey data.*

Particular	Conventional tillage	Sowing with super seeder	Change (%)
Seed (kg ha^{-1})	123.50	106.21	-14.00
Fertilizer (Urea-DAP-Potash) (kg ha^{-1})	365.56	326.04	-10.81
Diesel consumption (L ha^{-1}) for sowing operation*	59.28	24.70	-58.33
Time required for land preparation/sowing (hr ha^{-1})	9.88	3.71	-62.50
Time required for irrigation (hr ha^{-1})	8.03	7.41	-7.69
Wheat yield (kg ha^{-1})	3050	3450	13.11
Bhoosa yield (kg ha^{-1})**	1586	1829	15.32

**Diesel average price @ 160 PKR/L during studied period. **After Combine harvester cutting and wheat straw chopping.*

Table 2: *Cost and returns estimation of wheat production based on survey data (PKR ha^{-1}).*

Particular	Conventional tillage (CT)	Sowing with super seeder (SS)	Change (%)
Land preparation and sowing (fuel cost)	9485	3952	-58.33
Seed	8645	7435	-14.00
Irrigation	10374	9633	-7.14
Fertilizer	33753	30104	-10.81
Plant protection	4199	4199	0.00
Harvesting & threshing	18525	18525	0.00
Total operational cost	84980	73848	-13.10
Wheat support price (PKR 40kg^{-1})	2200	2200	0.00
Mean market price of bhoosa (PKR 40kg^{-1})	450	450	0.00
Total Gross Returns	183365	207796	13.32
Net Returns	98385	133948	36.15
Benefit-Cost ratio	2.16	2.81	30.41

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Table 3: *Field experiments data on yield attributes at different locations during Rabi 2021-22.*

Yield parameter	Trial site	Adaptive research farm, Gujranwala	Majju Chak, Teh. N. Virkan (Gujranwala)	Nandpur, (Gujranwala)	Soiyan Wala, (Gujranwala)	Raikay, Phalia, (M.B.Din)	Govt. Agri. seed farm, Chillianwala (M.B.Din)	Overall average
	Sowing date	**10th Nov**	**15th Nov**	**17th Nov**	**19th Nov**	**20th Nov**	**25th Nov**	
Emergence count m^{-2}	Variety/sowing method	Zincol-2016	Borlaug-2016	Borlaug-2016	Borlaug-2016	Borlaug-2016	Fakhar-e-Bhakkar-2017	
	Conventional tillage	180	176	157	181	179	178	175 c
	Happy seeder	185	171	153	165	170	189	172 c
	Ridge sowing	193	192	181	196	187	190	190 b
	Super seeder	207	211	215	201	218	211	211 a
LSD at p 0.05								9.91
Productive tillers m^{-2}	Conventional tillage	267	302	285	291	310	293	291 b
	Happy seeder	287	297	269	295	285	299	289 b
	Ridge sowing	324	329	299	312	309	306	313 a
	Super seeder	311	323	327	314	334	320	322 a
LSD at p 0.05								13.40
No. of grains per spike	Conventional tillage	37.00	38.10	38.20	38.60	38.10	38.50	38.08 b
	Happy seeder	37.80	38.70	39.10	38.45	38.57	38.98	38.60 ab
	Ridge sowing	39.50	38.74	37.70	39.02	38.15	39.50	38.77 ab
	Super seeder	38.98	39.05	38.75	38.90	39.40	38.47	38.93 a
LSD at p 0.05								0.71
1000 grains weight (g)	Conventional tillage	35.50	37.83	36.50	38.17	38.17	37.83	37.33 b
	Happy seeder	35.70	38.33	38.33	37.45	37.25	37.10	37.36 b
	Ridge sowing	38.33	38.50	36.33	37.45	37.80	37.90	37.72 b
	Super seeder	38.45	38.95	39.12	38.87	39.00	39.05	38.91 a
LSD at p 0.05								0.97
Grain yield (kg ha^{-1})	Conventional tillage	2903	3198	3057	3014	3147	3233	3092 c
	Happy seeder	3207	3270	3192	3125	3210	3154	3193 bc
	Ridge sowing	3240	3493	3123	3298	3217	3399	3295 b
	Super seeder	3310	3481	3595	3572	3645	3378	3497 a
LSD at p 0.05								133.71

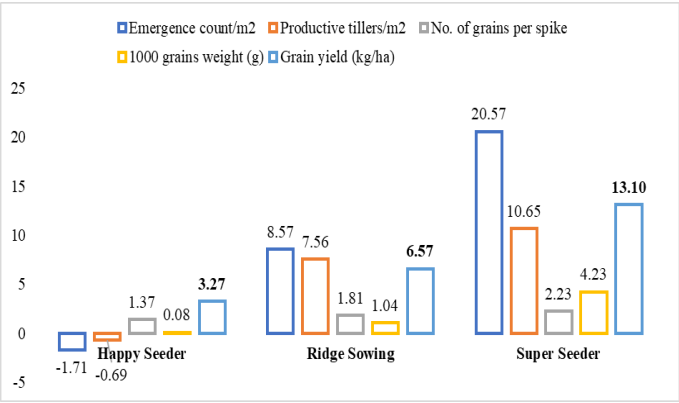

Figure 1: *Percent change in yield parameters for sowing techniques as compared to conventional tillage (CT).*

The higher emergence count was recorded in SS (211 m^{-2}) followed by ridge sowing (190 m^{-2}), conventional tillage (CT) (175 m^{-2}) and happy seeder (172 m^{-2}). The emergence count was significantly different between SS and ridge sowing. Accordingly, the emergence count (plants m^{-2}) was higher in SS (20.57%) and ridge sowing (8.57%), respectively as compared to CT (Table 3 and Figure 1). Khan *et al.* (2021) described that low tillage treatment provided maximum wheat emergence count m^{-2} as compared to traditionally ploughed and deep tillage treatments.

Dry period during November-December, 2021 helped out in harvesting of long duration fine rice varieties but wheat sowing and germination delayed due to improper soil moisture conditions. Occurrence of terminal heat stress during wheat reproductive stage also raised the need of more irrigation and resulted in increasing the cost of irrigation. As

negligible rainfall recorded for the whole months of November and December during 2021 which raised the issues of wheat emergence particularly for happy seeder method. GoP (2021a, b) also reported that November 2021 rainfall was 94.4% below the average in Pakistan and stood 6th driest November month on record as well as Punjab suffered with deficient rainfall (-92.0%) and stood 12th driest November month in history. Similarly, December 2021 rainfall was 66.3% below the average in Pakistan as well as Punjab (-86.2%) suffered with deficient rainfall (Table 4). Poudel *et al.* (2020) described that wheat is much responsive to heat stress. It is calculated that per 1°C rise in temperature cause reduce in universal wheat production by 6%. Heat stress in wheat cause poor seed emergence, lower in grain filling period, decrease in number of grains, deactivation of Rubisco enzyme, decline in photosynthetic capacity, decrease in rate of assimilate translocation, untimely leaf senescence, decline chlorophyll content and finally decline in yield.

The profitable yield of cereals is generally based on productive tillers count. The productive tillers count m^{-2} was non-significantly varied between SS and ridge sowing but significantly varied as compared to CT and happy seeder. Higher productive tillers count was estimated in SS (322 m^{-2}) followed by ridge sowing (313 m^{-2}), CT (291 m^{-2}) and happy seeder (289 m^{-2}). Accordingly, the higher productive tillers m^{-2} was recorded with SS (10.65%), ridge sowing (7.56%) and happy seeder (3.27%), respectively as compared to CT (Table 3 and Figure 1). Khan *et al.* (2021) described that higher tiller count (278.5 m^{-2}) was estimated in low tillage treatment as compared to conventional tillage treatment (267.8 m^{-2}) and deep tillage treatment (261.7 m^{-2}).

Higher grains count was estimated in SS (38.93 $spike^{-1}$) followed by ridge sowing (38.77 $spike^{-1}$), happy seeder (38.60 $spike^{-1}$) and CT (38.08 $spike^{-1}$). Similarly, higher value of 1000 grains weight was calculated in SS (38.91 g) followed by ridge sowing (37.72 g), happy seeder (37.36 g) and CT (37.33 g). The data showed that there were non-significant variations among sowing techniques except SS (Table 3 and Figure 1). According to Shah *et al.* (1994) the yield parameter of grains per spike is affected by several factors like seed rate, sowing time, soil type, fertilizer plan, temperature range and variety.

The economic yield of wheat is ultimately linked with grains yield. The grains yield (kg ha^{-1}) was significantly varied among all the sowing techniques/treatments. Higher grains yield was estimated in SS (3497 kg ha^{-1}) followed by ridge sowing (3295 kg ha^{-1}), happy seeder (3193 kg ha^{-1}) and CT (3092 kg ha^{-1}). The data showed that there were significant variations among all the sowing techniques. Accordingly, the higher grains yield was recorded with SS (13.10%), ridge sowing (6.57%) and happy seeder (3.27%), respectively as compared to CT (Table 3 and Figure 1).

Table 4: *Meteorological Data for FY 2021-22.*

Month	Gujranwala			Sialkot			Kot Nainan district Narowal			M.B.Din		
	Temperature °C		Rainfall (mm)	Temperature °C		Rainfall (mm)	Temperature °C		Rainfall (mm)	Temperature °C		Rainfall (mm)
	Max.	Min.		Max.	Min.		Max	Min.		Max.	Min.	
July 2021	35.02	26.42	301.2	33.5	26.5	54.4	36.1	5.6	130.4	35.19	25.61	288
August 2021	36.5	27	60.5	31.3	22.5	67.12	38.02	6.4	0	33.38	24.54	53.6
September 2021	33.66	24.45	80.1	30.6	21	165.75	35	18	51.37	33.23	24.26	129
October 2021	31.76	18.59	54.2	31.4	21.4	34.12	32.8	16.5	51.06	28.87	17.09	72.5
November 2021	26.30	10.67	1	24.1	12.8	2.25	30.02	18	0	24.2	10.86	0
December 2021	21.55	6.40	0	15.5	7.6	0	25.5	10	0	19.38	6.35	7
January 2022	16.20	8.96	149.6	15.8	7.5	152.1	20	4	127.28	17.12	6.64	149.6
February 2022	20.38	7.93	0.6	17.5	7.4	30.36	25.05	6	20.2	19.28	7.64	0.6
March 2022	29.48	15.67	5	20.3	12.5	3.37	29	10.08	0	28.64	14.931	5
April 2022	36.91	18.35	0	32.2	22.3	0	30	15	0	35.43	21.43	0
May 2022	40.69	23.55	10.6	36.5	25.15	15.5	35	18	16.88	37.5	24.67	10.6
June 2022	40.46	25.79	62.5	39.5	27.5	47.15	41	17	61.52	38.5	25.46	62.5

Source: *Meteorological Observatories located at district level under Pakistan meteorological department.*

Kathpalia *et al*. (2023) estimated the significant savings in fuel consumption (60.71%), labour requirement (77.80%), sowing cost (53%) and gross returns (7.22%) by adopting super seeder sowing as compared to conventional/broadcasting sowing. According to Iqbal *et al*. (2022) ridge and bed sowing techniques resulted in higher yield and water use efficiency than broadcast tillage of wheat. GoP (2022) has also reported that production of wheat crop during fiscal year 2021-22 remained low due to reduction in cultivated area, lower fertilizer usage because of short supply and price hike, and sudden rise of temperature during the month of March and April despite Govt. has fixed a reasonable wheat support price i.e., PKR 2200 for 40 kg.

Reasons for non-adoption of happy seeder machine on large scale

Based on field survey some following reasons for non-adoption of Happy Seeder were recorded as:

- As the yield with Happy Seeder sowing differs keeping in view the soil type and fertility status. Like some farmers reported that this method was more successful in light soil; a soil high in sand relative to clay.
- Small land holding is also one of the reasons for non-adoption of happy seeder. Hence some farmers could not purchase the machine due to higher investment cost.
- It could not be used properly if there was excess soil moisture due to rains or seepage.
- As the machine is used for wheat sowing only and it is not multipurpose like newly emerged SS; therefore, some farmers are reluctant to purchase it.
- The issue of the unevenly spread of residue straw by happy seeders was described by few farmers.
- The more stiffness nature of stubbles forced the farmers to partially burn the field before operating the machine.

Why super seeder is needed?

Based on field survey and field experiments data some following key points related to importance and scope of SS are enlisted as:

- It saves money (58.33%) for sowing operation as less time is needed to carry out field operation, which in turn reduces fuel and labor costs.
- This technology is eco-friendly and single pass solution to stop burning of paddy residue/straw, lower soil pH and improve soil health and fertility by adding organic matter.
- Timely sowing of wheat become possible even after long duration of basmati rice varieties.
- Partially levels the field with attached roller.
- Direct sowing just after rice harvesting reduces soil disturbance.
- Increase in infiltration rate of water in soil due to improved soil porosity as well as Increase in water holding capacity of soil.
- Opportunity of wheat cultivation in residual moisture and ultimately saving of irrigation cost (7.14%).
- Wheat sowing in residue moisture of rice and sowing in wet soils is also possible
- Less weed growth may occur due to less tillage/ soil disturbance.
- Higher yield (13.10%) achieved as emergence was much better (211 plants m^{-2}) in soft soil if compared with other seeding solution.
- Improved fertilizer use efficiency due to fertilizer placement along with seed.
- It has unique tine design which can be used for tillage and fully functional as rotary tiller as per seasonal requirements.
- It may be used as a multi crop planter. Other than wheat it may be used for sowing of soybean and grass etc. SS is a combination of seed planter and rotary tiller with press wheels.
- The issue of the crop residue and straw which was not being spread uniformly by happy seeder but it has been addressed successfully with super seeder. It is operational for removing and incorporating of stubble and residue of paddy as well as cotton, sugarcane, banana, maize etc.
- It has a simple and easy metering system that allows changing of seed rates with less seed waste and provides assurance of better emergence. The metering device is designed with a combination of aluminum and cast iron for better performance and durability.
- Hence it has proved as resource conservation technology regarding sowing time (62.50%), irrigation time (7.69%), fertilizer cost (10.81%), seed cost (14%) and fuel cost (58.33%) with the constrained requirement of higher hp tractor (preferably 85 hp) for operation.

Precautions and necessary guidelines in operation of super seeder

Based on field survey and field experiments data some following key points related to guidelines in operation

of super seeder are enlisted as:

- After attaching the super seeder to the tractor, check the connection of top link, lower link and list link before lifting the machine by the position control lever.
- Always use the lower gear of tractor to obtain fine tilth of soil and good cutting of straw residue.
- The super seeder is a multi seeder machine therefore its calibration regarding seed and fertilizer must be performed before operation. Like seed rate range of 98 to 185 kg ha^{-1} was available in some machines while found during field survey.
- Depth of fertilizer, seed boot can be adjusted by raising or lowering the depths skids position.
- The working of machine having 'J' type blades is better as compared to 'V' shaped blades.
- The dry wheel and roller adjustment is necessary for up and down position of machine.
- For a very fine seedbed, drive tractor very slowly in forward (first low).
- The rice crop should not be over matured at harvesting time and rice residues must not be fully dry to ease the cutting operation through super seeder machine.
- Proper soil moisture must be present during operation to ease the mulching and seed bed preparation by SS. But the Happy Seeder cannot be used properly if there is excess soil moisture due to rains.
- The existing Super Seeder requires a tractor of higher energy like 85 hp to pull the machine.
- Most of the farmers have 50 hp tractors, so small sized super seeders should also be manufactured to promote this technology.

Small and uneconomic land holding is biggest constraint in adopting farm mechanization like Super Seeder; as currently, 90% of the farmers (7.4 million) have recorded as small land holder in Pakistan as they possess below 5 hectares of land. Distribution of land in Pakistan is greatly skewed like all other developing countries (Khan, 2022). Also, higher energy tractor (≥75 hp) is requirement to operate this machine while 85% farmers don't have that. Therefore, eligible service providers should be encouraged and supported with Govt. subsidy scheme to propagate this technology for farming community on rental basis.

Conclusions and Recommendations

After comparative analysis of all the prevailing sowing techniques of wheat in rice-wheat cropping system; the use of Super Seeder (SS) has resulted with significantly higher values of Grains Yield, Net Returns and Benefit Cost Ratio. The SS has emerged as best sowing machine due to possible factors like conserving soil moisture, increasing soil organic matter, and enhancing fertilizer uptake efficiency.

Thus, the wheat sowing with Super Seeder has proved as saving/resource conservation technology regarding time, labour, water, fertilizer, seed and fuel with the constrained/requirement of higher hp tractor for its operation.

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Novelty Statement

In rice-wheat cropping system the farmers usually burn the paddy residues for ease of land preparation along with cost saving and timely wheat sowing. The emerging Super Seeder has proved as a single operational solution to conserve soil moisture with timely sowing, increase soil organic matter by avoiding residue burning, reducing smog and air pollution, better soil tilth through incorporating paddy residue and enhance fertilizer uptake efficiency to ultimately get optimum wheat yield.

Author's Contribution

Muhammad Tahir Latif: Conducted the study, collected data, performed data analysis and manuscript writing.
Muzzammil Hussain: Facilitated in conducting field survey and critically reviewed this manuscript.
Ali Zohaib: Conducted field experiments and collected data.
Ishtiaq Hassan: Facilitated in conducing field survey.
All the authors read and approved the manuscript to be published.

Conflict of interest
The authors have declared no conflict of interest.

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