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RESEARCH ARTICLE

EVALUATING PERFORMANCE OF WATER SEED DRILL FOR WHEAT PRODUCTION: A SUSTAINABLE TECHNIQUE UNDER RAINFED AGRICULTURAL SYSTEM

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ABSTRACT

Water content plays a significant role in seed development, especially during the seed sowing level, which ensures the germination of a good seed. A water seed drill (WSD) was tested in the farmer's field Koont, Rawalpindi, for the last five wheat seasons (2015-16 to 2019-20). WSD provides the optimum amount of water needed in the same furrow for the soil right after seed placement. In this study, a WSD conserves soil moisture for better plant germination and wheat growth in rainfed areas. The data recorded showed that the application of WSD enhanced soil moisture 50 to 67% in the existing soil available water. The Germination rate and counted tillers of wheat plants were improved up to 38% and 45%, respectively, compared to conventional wheat sowing. WSD had a significant effect on wheat yield with a maximum of 41% increment in output than conventional sowing. The WSD operational and output cost were 2.57 and 2.15 times more than Conventional seed drill sowing, respectively. The WSD helped advance wheat sowing, ensuring the crop's timely sowing in the absence of rainfall, especially in rainfed regions, and promoted drill sowing.

KEYWORDS

Seed, WSD, soil, drill.

1. INTRODUCTION

Wheat (*Triticum aestivum L.*) is a staple food for human beings and grown worldwide. It is a chief cereal crop worldwide, standing as more than 33% of the universal population takes it as a staple food, and its role for protein and calories to world diet is more significant than any other crop from cereal group (Ashraf et al., 2013). The enhanced worldwide population is a critical issue, as it demands the agricultural sector extra food to fulfill their needs. Efforts are in progress to increase crop production through an enhancement in yield per hectare. Imperfect planting techniques, deficiency of irrigation water, and late sowing are the reasons for low yields of wheat crops per hectare (Rehman-Ud-din and Khattak, 2018). Pakistan is one of the major wheat producers of the World (Dowswell, 1989). The average grain yield of wheat in Pakistan is meager compared to other leading wheat-growing countries (Ashraf et al., 2013).

In Pakistan, the total cultivable area is 34.54 Mha (39.3 % of total land area), of which 23.38 Mha areas are under cultivation. A place of approximately 4.22 Mha (4.8 % of the total land area) is under forest cover (Government of Pakistan 2008). On average, in Pakistan agriculture sector contributes about 25% to gross domestic product (GDP), and almost 44% of the country's working force is being engaged directly or indirectly. The largest cropped area is under wheat cultivation, over 8.6 Mha (Government of Pakistan 2008).

Wheat is the primary cereal crop of the *rabi* season and is grown in almost every part of Pakistan. It is cultivated under rainfed conditions. The average yield of wheat is relatively low in such areas, mainly due to a water shortage (Ali et al., 2019). The Agricultural activity in the potohar region contributes about 10 percent of total agricultural production. In the context of crop production, barren lands have often been underestimated. However, more than 1200 kg/acre of wheat have reportedly been produced in this area, revealing a high potential for crop production (Haq and Zamir, 2019).

The Potohar area has excellent agricultural potential to lower its imported load (Rashid and Rasul 2009). Climatically Potohar plateau lies in the semi-arid region, affected by summer monsoon (July-September) and partly from winter precipitation. Early rains during winter are beneficial for the timely sowing of the wheat crop in the Potohar region. The early spring rains result in healthier final growth and better yield of the wheat crop in the area (Naheed and Mahmood 2006).

In Pakistan, Rainfall is one of the significant sources of Agricultural production. However, Rainfall in Pakistan is highly variable both in amount and distribution from year to year. The wide diversity of climate, soils, relief, topography, and anthropogenic changes cause numerous constraint problems. Wheat crops in rainfed areas depend upon rain for soil moisture. If the rains are received at the proper time, the farmer can harvest reasonable yields. Due to rain uncertainty, agriculture in the rainfed area remains at high risk and low input enterprise for resource-poor farmers. Low yields in the regions could be attributed to poor quality seed, inadequate and imbalanced fertilizers, and poor crop management practices (Naheed and Mahmood 2006).

Discrete planting techniques are practiced in the World at the time of sowing the wheat crop. Inappropriate planting method results in barren plants. Ear and its size remain smaller; crops become susceptible to lodging, diseases, and pests resulting in lower yield per unit area (Liu and Ge 2008). Small farmers use traditional methods of cultivation (Aslam 2016). Deficiency of awareness about modern farming practices and technologies is the main reason for using traditional cultivation methods (Jehangir et al., 2007). Small farmers having 2 ha of land generally do not get credit facilities (Personal and Archive 2016; Phillip et al., 2009). Thereby they do not have access to improved quality inputs like seeds, pesticides, fertilizers, *etc.* (Planning Commission 2012; Sattar 2012). They also do not have access to extension services (Personal and Archive, 2016). This results in low yield output.

The planting technique has a significant consequence on soil properties, water, and energy economy (Khan et al., 2007). Wheat production can be improved by the application of new technology and development in the existing technology. As there is a lack of water in the potohar region, there is a need to establish new technologies to improve water use efficiency and enhance crop yield. In rainfed agriculture, soil moisture has always been a significant factor limiting crop yields (Adnan et al., 2009; Arshad 2015). In these rainfed areas, almost 50% of rainwater is being lost as runoff (Anjum, 2010).

Irshad and his coworkers (2007) believe that such landscapes absorb less water and are quite vulnerable to soil and water loss. This loss of rainwater in the form of runoff could be about 50 percent. More significant rainfall variance seems to the main factor behind dryland yield fluctuations. The amount and distribution of rainfall during crop season are essential. Distribution of Rainfall becomes extra remarkable for the lands with the low water-holding capability and the seasons with adequate soil moisture present at planting (Ganimede et al., 2015).

The objective of this study is to examine the feasibility of WSDs in wheat crops. Because with time, the availability of water decreasing day by day, and incoming decades, we will face an acute shortage of water for agriculture and household consumption. It is the need of time to develop such techniques through which we can increase water use efficiency. It is necessary to use a seed drill to improve the soil's moisture content, which ultimately enhances the wheat yield and reduces water losses by applying water through traditional methods. To attain this objective, Koont farmer's field, Rawalpindi, Pakistan, has originated, developed, and tested a WSD. In this study, WSD is used to conserve soil moisture for better plant germination and growth. This information will help grow wheat in rainfed areas and water shortage areas.

2. Material and Methods

A field study was carried to study the wheat yield sowing by WSD. The experiment was conducted at Koont farmer's field, Rawalpindi. The research area (semi-arid to sub-humid, sub-tropical continental) is located between 33° 1' N to 33° 6' N and longitude 73° 30' to 73° 45' E southeast of Rawalpindi as shown in Figure 1. The experimental site's soil texture was sandy clay loam (56% sand, 22.8% silt, 21.2% clay) with a pH of 7.7. The bimodal rainfall occurs in the late summer and winter seasons. Generally, about 60-70% of rain received in the monsoon season (15-June to 15-September). However, winter rainfall occurs as gentle showers of longer duration and are more productive for agriculture (Rehman, 2015). Mean monthly precipitation and temperature data were also recorded.

2.1 Machine Description

In Potohar, wheat is sown by broadcasting and by seed drill. A planting machine is specially designed to sow seed in the same way farmers usually sow seed named WSDs. This system contained Frames, injectors, tubes of water, a delivery pipe, and a tank of water, as shown in Figure 1. The width of the WSD is 2134, with nine furrows each. The only addition was supplementing the water application system with a seed drill; its purpose is to provide an optimal water quantity at the sowing time. The water was supplied with adjustable water injectors. The main valve can control the flow rate of all the injectors.

A frame is used to support the water tank, which is fitted behind the driver's seat. A metal tank was used for water application. This tank can store 400 liters of water approximately. A metal pipe of length 6' and dia 1.5" was adjusted with a water container and distribute water similarly into nine injectors separated by 229 mm of space. These injectors accept an equal amount of water and apply water at the same depth as that of the seeds, as shown in Figure 2. The detailed specification of the WSD is shown in Table 1.

Table 1: Technical Specifications of the WSD

Elements	Specifications
Working width of machine (m)	2.1
The total volume of the water tank (m^3)	0.40
Water tank capacity (liter) @ 1000 lit/m^3	400
Water delivery pipe (m)	183
Delivery Pipe Diameter (cm)	5.1
Maximum water nozzle flow	1.1 lit/sec
No. of rows of furrow openers	9
Row spacing (cm)	23
Seed box capacity	50 kg
Fertilizer Tank capacity	50 kg
Weight of WSD	750 kg
Power requirement	65 hp

Figure 1: Utilization of the WSD in the wheat sowing field

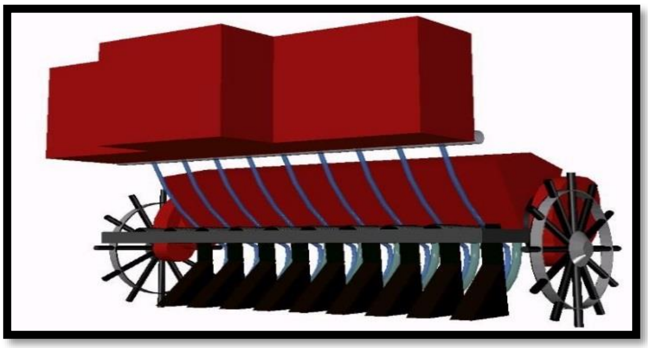

Figure 2: Pictorial View of WSD

2.2 Machine Field Parameters for Testing and Evaluation

2.2.1 Operating Speed

The speed of the machine was acquired using the following equation:

$$\text{Speed (km/hr)} = \left[\left(\frac{\text{Distance taravel}}{\text{time in seconds to travel the given distance}}\right)\left(\frac{3600\ sec/hr}{1000m/km}\right)\right] \quad (1)$$

2.2.2 Field capacity

The field efficiency, effective and theoretical field capacity were computed by recording the time used for the actual work and turning adjustment under the field utilizing conditions. The theoretical field capacity (TFC) is a covered rate of implements consisted of 100% of effective working width and effective speed of operation, and the following equation computed it:

$$TFC = \frac{WS}{10} \quad (2)$$

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Where;

W = Working width, m
S = Speed of operation, km/hr

The effective field capacity (EFC) is computed by noting the implementation's covered actual area, consisting of its width and total time utilized. It is calculated by given equation:

Where;

$$EFC = \frac{A}{T_p + T_1} \quad (3)$$

EFC = Effective Field Capacity, ha/hr
A = Covered Area, ha
T_p = Productive time, h
T_1 = Non-productive Time, h

Field Efficiency is the ratio of EFC and TFC showed in percent. It is calculated by following equation:

$$EF = EFC/TFC \quad (4)$$

Where;

EF = Field Efficiency, %

System testing of the machine is conducted on a complete, integrated system to evaluate its compliance with its specified requirements. The system testing and evaluation were done for the Water tank capacity, Water tank calibration, and Seed drill calibration. Water flow was measured at different openings of the main valve for water tank calibration, as shown in Figure 3. For seed drill calibration, the circumference of the transport wheel was measured. Several turns of transport wheel for1acre length were counted. To calibrate the drill, its seed box was filled with seed. The wheel was rotatedby hand, and all the emitted seed was collected and weighted, as shown in Figure 4. This measured weight of the collected seed was compared with the calculated seed weight by utilizing the below equation.

$$W = [(RD \times NR \times \pi \times ED \times N) \times SR] / 10{,}000 \quad (5)$$

Where;

RD = row to row distance (m)
NR = number of rows
ED = Effective diameter of the drive wheel (m)
N = number of revolutions of the drive wheel
SR = Rate of seed (kg/ha)

Figure 3: Water tank calibration of WSD

Figure 4: Seed drill calibration of WSD

2.3 Crop sowing and Data Collection

The experiment was set down in a complete randomized design (CRD) with three replications. An area of 1 hectare was divided into two subplots, one for water seed sowing and one for conventional sowing at the seed rate of 50 Kg/acre. The sowing operation was executed with a forward speed of 4.2 km/h and a maximum water flow rate of 1.1 lit/s, and the conventional plot was sown at the same speed, with no water application (Table 2). Fertilizer was applied to the field in two dozes. Full does of Di-ammonium phosphate and Urea at the 50 kg/acre rate was applied uniformly to all plots at the sowing time. The data (%), germination count (GC/m^2), number of tillers (tiller/m^2), and wheat yield (kg/ha) were collected for moisture content. A wheat yield comparison for the last 20 wheat seasons from 2000-01 to 2019-20 was also performed.

Table 2: Description of treatment plots

Treatment	Abbreviation	Description
WSD	Tw	Flow rate of water nozzle (1lit/sec)
Conventional	Tc	No moisture applied

The moisture content in the field was calculated at two discrete depths, i.e., 3 and 6 inches, both before and after the sowing of the crop with the WSD. Utilizing a soil moisture sensor (HH2, ΔT devices), the seed germination rate was calculated to notice how many plants emerged in a unit area (m^2) by counting the number of plants that emerged every day after emergence started. In every plot, three points of m^2 were randomly selected to observe plant emergence. The plant tillers were also measured from the same unit area chosen as described (Heidari, 2009). The average value of these three replications was then used. The data of rainfall for the last 20 wheat seasons, including the currently studied crop periods (2019–20), was collected from the Pakistan meteorological department (Govt. of Pakistan), Chakwal regional station (Pakistan Meteorological Department, 2017). The local standard rental cost of land preparation implements and the market price of crop input were used to estimate the operational cost for WSDs and conventional methods. The economic comparison was also performed by using the costs of agricultural machinery and crop inputs.

3. Results and Discussion

3.1 Machine field parameters

Table 4 contains the measured parameters of the WSD, i.e., their field capacity, theoretical field width, effective working width, operating speed, and field efficiency. These were computed from the formulas which are given above. Related to measured parameters, it was noted that the WSD was found to be efficient as compared to the conventional source.

Table 3: Measured parameters of the WSD

Parameters	Values
Theoretical working width (cm)	213.5
Effective working width (cm)	183
Operating Speed (km/hr)	4.2 km/h
Field Capacity (ha/hr)	2.5-3 ha/h
Efficiency (%)	>90%

3.2 Water tank calibration

Calibration is a comparison between a known measurement (the standard) and the measurement using your instrument. Calibration of the water tank was done for 1 acre. It depends upon the tractor forwarding speed. Tractors move at the speed of 1.2 m/sec, and they cover a 1-acre length in 0.43 hr discharge is 0.54 liter/sec. So, it required 900 liters for 1 acre, as shown in Tables 4 & 5.

Table 4: Water tank capacity calculation

Width (W)	Hight (H)	Length (L)	W*H*L (Inch^2)	Ft^3	Total length (ft^3)	Total water (liter)
12”	19”	72”	16416	9.5	13.8	392.21
12”	19”	33”	7524	4.35		

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Table 5: Water tank calibration for 1 acre					
Tractor Speed (m/s)	**S (Km/hr)**	**1 acre Length (Km)**	**T (sec)**	**Q (liter/sec)**	**V=Q*t Liter (for 1 acre)**
1.2	4.32	1.89	1548	0.54	835

3.3 Seed drill calibration

The WSD was tested in the field under different flow rates and tractor speeds. The water applied was determined at discrete flow rates and tractor speeds. Many wheels turn for 1 acre were rotated, and seed emitted from the drill was collected and weighted. The flow rate at three different openings, 60, 57 & 54 ml/sec, was observed, but sowing was performed with a maximum flow rate, and the seed rate utilized was 100 kg/acre, which include fertilizer and seed in 100 kg proportion (50 kg+ 50 kg). The seed rate calibration was accomplished, and the seed rate was computed as 50 kilograms per acre.

3.4 Moisture Content

Soil physical property under consideration is soil moisture content. The field's moisture content was measured at 3 inch and 6-inch depths before and after sowing with a WSD. The working of WSD increased the average moisture content in all plots, i.e., 15.90% soil moisture content at 3inches (soil depth 10cm), which was double the already present soil moisture content in the similar plots (7.95%) as represented in Figure 5. The data represented the significant difference among plots at a 3-inch and 6-inch depth. At 3-inch depth, the highest moisture content, 15.90%, was noted during the 2018-19 wheat sowing year, followed by 2017-18 (12.33%). While the lowest moisture content, 12.07%, was observed during the 2019-20 wheat sowing year. Meanwhile, moisture content considerably varied for its time of application. The highest moisture content (24.23%) was observed after sowing for 2016-17, 2017-18, and 2018-19 wheat sowing years, while the lowest moisture content (8%) was observed before sowing during 2018-19 wheat sowing year as shown in Figure 5. While at 6-inch depth highest moisture content (25.889%) was noted after sowing during 2016-17 and 2018-19, the lowest moisture content was observed before sowing (10.63%) during 2017-18 shown in Figure 5.

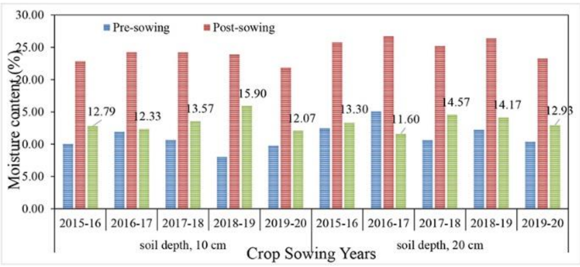

Figure 5: Soil moisture contents of discrete wheat sowing years at different depths

3.5 Germination count

The tillage technique ensuring in timely growth of seed tends to have the highest yield, and the plant emergence rate might give a fitter conception of soil conditions originated by a specific tillage system than an assessment of soil's physical properties (Busari et al., 2015). Plants required some nutrients to grow, almost start growing 4 to 5 days after seed sowing as recorded. When germination started, several emerged plants were counted every day so that we come to know that how many plants emerged daily per square meter area. Figure 6 shows the records of cumulative plant germination per meter square. The germination count in every plot showed a significant impact of the WSD compared to the conventional sowing. Plant germination counts (plants/m2) both per day wise and cumulative wise are represented in Figure 6. The analysis shows that the wheat daily germination is high on day 7 in the WSD, and after that, it starts decreasing.

In contrast, the wheat daily germination is high on day 8 in the convention sowing. However, the daily emergence seed in conventional sowing was little than that of the WSD technique. The maximum daily emergence of 40 and 21 was noted with the WSD and traditional sowing techniques. The cumulative plant germination trend is also shown in Figure 6, where it is visible that germination results are different for WSD and conventional methods. It also shows that the cumulative emergence seed in conventional sowing was also little than that of the WSD technique. The maximum final seed germination was noted to be 253 plants per meter square with the WSD compared to conventional sowing as 156 plants. The total emergence of plants in each pot is also shown in Figure 6. The greater germination rate of plant was observed in WSD sowing, while the lowest germination rate was noted in conventional sowing.

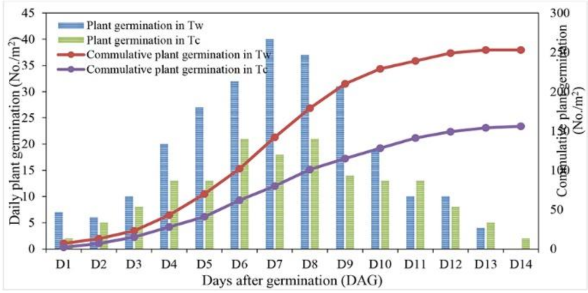

Figure 6: Daily and cumulative seed germination count for WSD and conventional sowing of the wheat crop at different plots

3.6 No. of tillers

Data related to the number of tillers at two depths, i.e., 3 and 6 inches, as shown in Figure 7. The figure shows a trend of the number of tillers affected by SWD and conventional sowing at both depths. The data analysis indicated that a greater number of tillers (539 tillers/m^2) was noted in the crop years sown with the WSD, while the minimum number of tillers (255 tillers/m^2) was indicated in the crop years sown with the conventional seed drill. The difference of 284 tillers was noted in the crop years sown with the WSD and conventional. The crop years with greater soil moisture content had a greater number of tillers. Comparing Figure 7 with Figure 5 revealed that the same wheat growing year has greater moisture content and several tillers. Moisture stress directly impacted the development, growth, and yield of a crop, and the outcomes were like those announced by (Mohammed and Kadhem, 2017; Qadir et al., 1998).

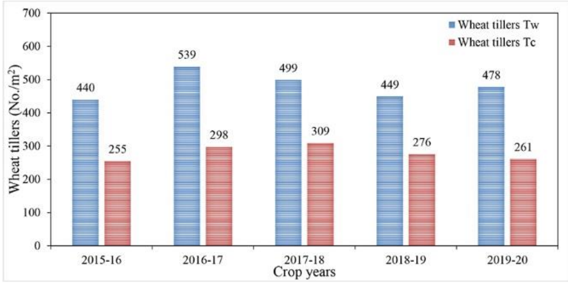

Figure 7: Evaluating Number of tillers for the WSD and conventional sowing during the different Crop sowing years

3.7 Rainfall and wheat yield analysis

Rainfall's annual data and an average yield of the wheat crop were collected from the Regional Agromet center Shams Abad and Crop reporting office, Rawalpindi. This data was used to analyze the annual wheat yield with rainfall variation over the last fifteen wheat seasons. There is a direct relation of wheat crop with rainfall. As rainfall increases, the wheat crop also increases. The minimum yield of 611 kg/ha was recorded in 2000-01 and 2002-03 due to low seasonal rainfall of about 74 mm, and the maximum yield of 2711 kg/ha was recorded in 2015-16 due to the increase in seasonal rainfall of about 911 mm. While during 2005-06 and 2009-10, low rainfall was observed compared to last years, as shown in Figure 8. In the wheat season of 2012-2013, the research farm acquired 250 mm of seasonal rainfall and had a wheat yield of 150 kg/ha. The plots sown with WSD gave 1606-2537kg/ha wheat yield. The variability in wheat yield with the seasonal rainfall is represented in Figure 8. The correlation between the yield of wheat and annual rainfall was observed to be positive, with an R-square value equivalent to 0.95.

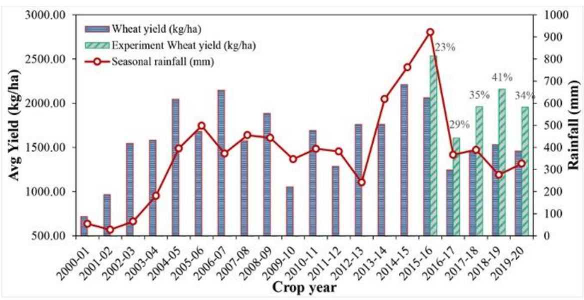

Figure 8: Evaluating seasonal rainfall and wheat yields for conventional sowing (2000-01 to 2019-20) and WSD (2015-16 to 2019-20).

3.8 Cost Analysis

WSD's cost analysis was performed to evaluate the total operational cost per hour (Table 6). The WSD's operating cost was Rs. 2686.18/h compared with the conventional drill (Rs. 1042/h). The maximum operational cost of the WSD was because of its maximum purchase price, Rs. 125,000, and the water cost, Rs. 1561.25, at 0.25/L, as shown in Table 7. A comparison of the costs, both for the WSD and the conventional seed drill, was made to evaluate the differences, as shown in Figure 6. The cost comparison included the cost of machinery, the land preparation cost, crop inputs cost, and labor cost. The total fixed cost/hour of the WSD was 2.77 times more than that of the conventional seed drill, while the total one-hour operational cost of the WSD was 2.57 times greater than that of the conventional seed drill. The WSD's additional cost was 1561.25 Rs/ha for water application, but the yield obtained with WSD sowing was 2.15 times more than conventional seed drill sowing. The benefit-cost ratio for the WSD and the conventional seed drill is 2.22 and 1.67, respectively.

Table 6: Economics of wheat sowing with the WSD and the conventional seed drill.

Particulars	**WSD**	**Conventional Seed Drill**
Land Preparation MB plow (1 pass), disk plow (2 passes), rotavator (1 pass), a cultivator with planker (3 passes)	16500/-	16500/-
Sowing Seed, DAP and Urea, and irrigation	20000/-	18000/-
The total cost of sowing	36500/-	34500/-
Wheat yield (kg/ha)	2160	1532
Wheat yield cost @ 1400/40 kg	81000/-	57450/-
Benefit–cost ratio (BCR)	2.22	1.67

Table 7: Operational cost Comparison of the WSD and the conventional drill for wheat crop.

Item	**Tractor (Fiat-640)**	**WSD**	**Conventional Drill**
Purchase price	800,000	125,000	45,000
Useful life (h)	10,000	2000	2000
(Year)	10	8	8
Salvage value	80,000	12,500	4500
Depreciation	72	56.25	20.25
Interest (14% on average investment)	11.2	8.75	3.15
Taxes, insurance, and shelter (2.5% of initial cost per annum)	2	1.56	0.56
Fixed cost (Rs./h)	**85.20**	**66.56**	**23.96**
Field capacity (ha/h)		0.79	0.79
Labor input (man-h/ha)		1.32	1.32
Fuel consumption (L/h)		8.50	8.50
Water applied (L/h)		6245	0
Labor cost @ Rs 125/h		165	165
Repair & maintenance	80	62.50	22.50
Fuel cost (diesel) Rs. 85/L		722.50	722.50
Lubrication cost (15% of fuel cost)	108.38	-	-
Water cost @ 0.25/L		1561.25	0
Variable cost (Rs./h)		**2619.62**	**1018.375**
Total operational cost (Rs./h)		**2686.18**	**1042.3375**

4. Summary

Soil moisture content is the crucial factor that plays a vital role during the entire crop period, especially at the seed germination stage. Pothwar Agriculture is entirely dependent upon rainfall, which is insufficient and unreliable for getting better crop yield. This disparity in rainfall pattern causes severe problems for a wheat grower in rain-fed areas, and the ultimate result of this situation is the reduction in seed germination and plant growth, and low crop yield. This study was accomplished to examine the WSD performance for wheat sowing at farmers' fields, Koont, and Rawalpindi. The study focused on estimating the impact of WSD on soil moisture content, seed germination, and the No. of tiller per square meter. A conventional method of wheat sowing was also applied to compare with WSD sowing. The sowing operation was executed with a forward speed of 4.2 km/h and a maximum water flow rate (60, 57 & 54 ml/sec), depending on the already present moisture content in the soil, while the conventional plot was sown with the same speed, but with no application of water.

The data recorded showed that the application of WSD enhanced soil moisture 50 to 67% in the existing soil available moisture. The Germination rate and counted tillers of wheat plants were improved up to 38% and 45%, respectively, compared to conventional wheat sowing. WSD had a significant effect on wheat yield with a maximum of 41% increment in yield than conventional sowing. The total investment cost with the WSD was 2.77 times more than the conventional seed drill. However, the wheat cost produced with the WSD was 41% greater than that of the conventional seed drill. The wheat sowing with the WSD led to Rs. 23550/ha more than that of the conventional seed drill. The WSD helped advance wheat sowing, ensuring the crop's timely sowing in the absence of rainfall, especially in rainfed regions, and promoted drill sowing.

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