Generation of database for development of a control system for precision seed drill

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Abstract: The site specific application of seed to maintain crop growth is an essential part of precision agriculture and is required to minimize the cost of production. In this study the database of selected seeds was generated for the development of precision seed drill to enable variable-rate application with a significant reduced error compared to current seed applicators. The laboratory setup was designed and fabricated and was equipped with a fluted helical roller and a variable speed DC motor with controller. The experiment was conducted for three different exposures, two crops, six varieties, and three different seed sizes. The effect of different hopper filling, exposure length of fluted roller on seed delivery rate was measured and the speed ratio between motor gear to feed shaft for different seed rate of wheat and soybean were recommended. It was found that the seed delivery per revolution of feed shaft for small seed size varieties has more seed delivery rate as compared to medium and bold seed varieties. The database will help in designing a precision seed applicator in future.

Keywords: precision seed drill, helical fluted roller, exposure length of metering system, physical properties of seeds, seed drill experimental setup

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1 Introduction

In India, the technology of precision agriculture, such as the variable-rate seed application aims to develop the capability of site-specific crop management. Seeds (Wheat & Soybean) are one of the most expensive inputs, therefore it is important for growers to plant the right amount of seed to minimize input costs and increase profitability. Wheat sown at low seed rate of 125 kg ha^{-1} had better growth, yield, nutrient uptake and low lodging tendency. Maximum tillers, spike length, grains spike^{-1}, grain weight spike^{-1}, seed index, biological yield, grain yield, harvest index, dry matter, crop growth rate and low lodging were found with seed rate of 125 kg ha^{-1} (Laghari, 2011). Parish et al. (1972) cited the need expressed by some soybean growers for a soybean seeder that combines the narrow row capability and relatively low cost of a grain drill with a precision spacing of a row crop seeder. The seed drill includes seed metering unit which is driven from a ground wheel for metering seed at a rate proportional to the forward speed of the implement. For changing the seeding rate either the transmission ratio between the ground wheel and the drive shaft connected to the fluted feed wheels is changed, or the fluted feed

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wheels is shifted the drive shaft transversely within the meter housing to adjust the effective metering area of the wheels. Therefore it has been very difficult for the operator to calculate the exact seeding rate and to precisely adjust the seeding rate when moving to a new field or when changing seed varieties and it has been practically impossible to change the seeding rate on the go for varying conditions. Sohn (2004) performed studies on physical properties of granular fertilizer and design factors of the controller for variable-rate application. He suggested a motor control method in order to improve the performance of the controller. The researchers constructed and tested a prototype soybean metering unit using the seed bed principle. Karayel and Ozmerzi (2002) stated that the best sowing uniformity, the most uniform sowing depth and maximum emergence percentage occurred when a precision seeders was used after preparing the soil with a mouldboard plough, disc harrow, and roller. One of the solutions to overcome of this major cause of variation in application rate of seeds would be provided power to the metering unit shafts through a constant torque variable speed motor powered by tractor battery. Zhuang and Komatsu (1996) developed a feed control device in which the feed shaft speed of a seeder or a fertilizer applicator can be controlled according to the running speed signals from a ground wheel. The speed of motor could be synchronized with the speed of operation either by ideally rotating toed wheel or by using a ground speed sensor. For designing the precision seed applicator, it is necessary to know the amount of seed delivered per revolution of fluted feed roller, so we developed a laboratory setup of seed drill to measure the effect of operation speed and metering unit exposure length on seed delivery rate and recommend the optimum exposure length for desired seed rate. The database generated will be useful for designing a precision seed drill for soybean and wheat crop.

2 Material and methods

The study was conducted in Farm Mechanization division, Central Institute of Agricultural Engineering, Bhopal, India. Three popular wheat varieties HI 8498, HI 306, and HI 8627 and three popular soybean varieties JS 9560, JS 9305, and JS 335 were selected for the study. The impurities of seeds were removed manually and each variety of seed was graded in three grade sizes. The physical properties of seeds were determined before the start of the experiment.

2.1 Design development and fabrication of laboratory setup of seed drill

Auto-cad design and drawing were used for the fabrication of the setup. The base join with the main frame was fabricated by joining the two Mild Steel L-angle of size 100×20×10 mm. The total height of main frame was 400 mm, a supporting frame joint with the main frame at 300 mm height. Another lower supporting L-angle is added for more strength and tightness of frame. The seed box was made up of 2 mm mild steel sheet. The seed box having three sections were made as per designed. A rectangular opening was providing in a lower part of hopper for connecting the housing of metering unit. The metering unit with housing was connected with the hopper by 3 mm bolts. The seed delivery tube was connected with the housing.

The shafts of seed metering device having 15 mm diameter and 350 mm length cold rolled round section steel shaft was taken. Two smooth holes were provided for shaft at both ends. The metering device, helical roller (Figure 1) was made up of 15 mm thick white nylon with 30 mm exposure length. The numbers of helix on roller are 12 and the depths of helix were 8 mm. The cover of helical roller was made with the aluminum and it completely covered the helical roller so that the seed were smoothly going through seed delivery tube (Figure 2). The DC motor was attached in base at 140 mm from the front side. The small sprocket of motor and big sprocket of feed shaft were attached through the chain drive. The centre-to-centre distance of two sprockets was 350 mm. A controller was attached for controlling the RPM of motor and placed near the setup (Figure 3). The experimental setup was placed at suitable height of operation so that the hopper filling was easily done.

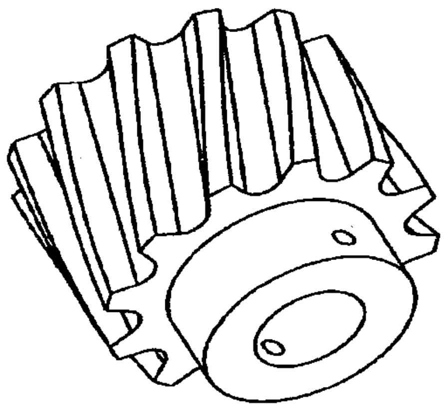

Figure 1 Fluted roller with helical grooves

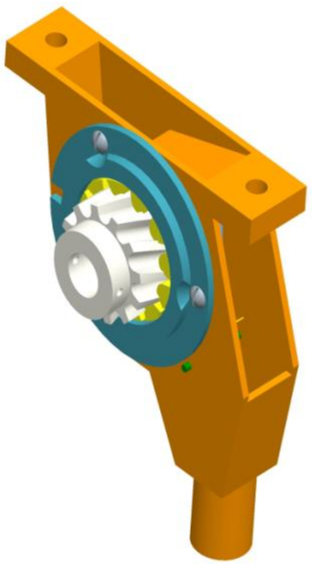

Figure 2 Seed metering unit

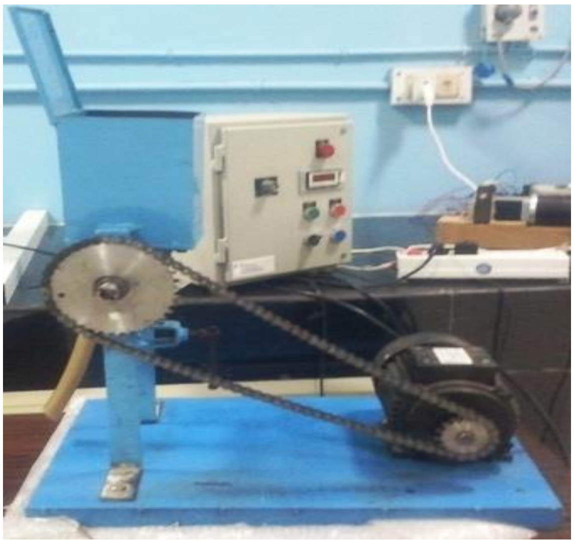

Figure3 View of experimental setup

2.2 Test procedure

2.2.1 Seed damage percentage

1 kg sample of soybean and wheat were randomly selected and passed through the metering device and seed tubes, the number of seeds that were damaged mechanically including any significant bruising, skin removal or crushing were counted.

2.2.2 Effect of hopper filling on seed delivery rate

An experiment was conducted for measurement of effect of hopper filling on seed delivery rate. Three different levels of hopper filling were used for test; first for 1/3rd hopper filling, half hopper filling and full hopper filling. The setup was run for one minute and the amount of seed delivered in one minute is measured.

2.2.3 Effect of different exposures on seed delivery

The test conducted for three different exposure lengths of fluted roller. At full exposure, 3/4th exposure and half exposure and the exposure length was 30 mm, 22.5 mm and 15 mm, respectively. For more accuracy of the experiment, three replications of each reading were taken and averages of these readings are taken for final database.

2.2.4 Calculation of speed ratio

The ratio between ground wheels of tractor (motor gear) to the feed shaft was measured to feed the speed ratio in DSS. The process of calculating speed ratio:

Seed Rate =Q kg/ha

Row spacing= R cm

Speed = S km/h

Quantity drops in one revolution of fluted roller= Q_r (g)

$$Diameter\ of\ \ motor\ gear = Dw\ (m)$$

$$Speed\ Ratio = \frac{Nf}{Nw}$$

$$RPM\ of\ helical\ roller\ Nf = \frac{Q \times R \times S}{60 \times Qr}$$

$$RPM\ of\ motor\ gearNw = \frac{50 \times \pi \times S}{3 \times Dw}$$

3 Result and discussion

3.1 Effect of different exposures on seed delivery

The experiment conducted for three different exposures, two crops, six varieties, and their different seed sizes (Figure 4, Figure 5 and Figure 6). The result found that the different exposure, crop, variety and size are significantly different at 1 % level of significance (Table 1). The seed size affected the seed delivered per revolution of feed shaft at all three selected exposure lengths.

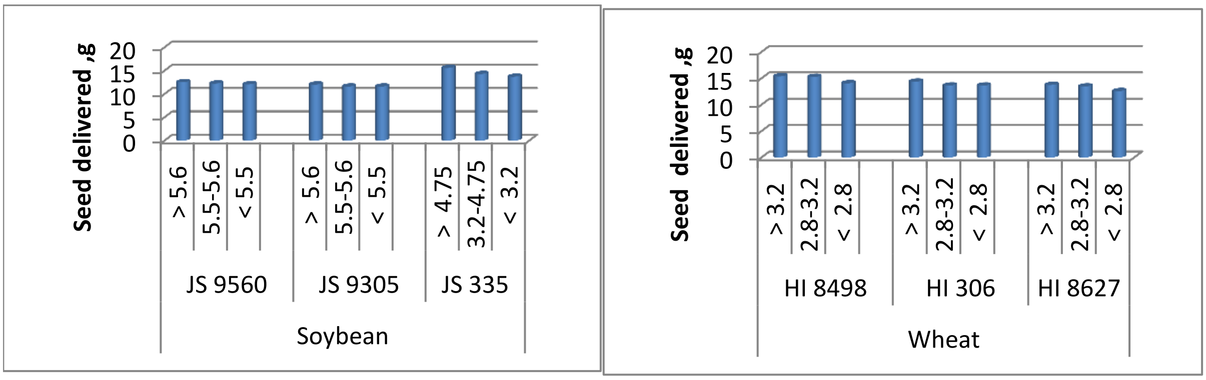

Figure 4 Seed deliverd per revolution (g) of feed shaft for soybean and wheat at full exposure

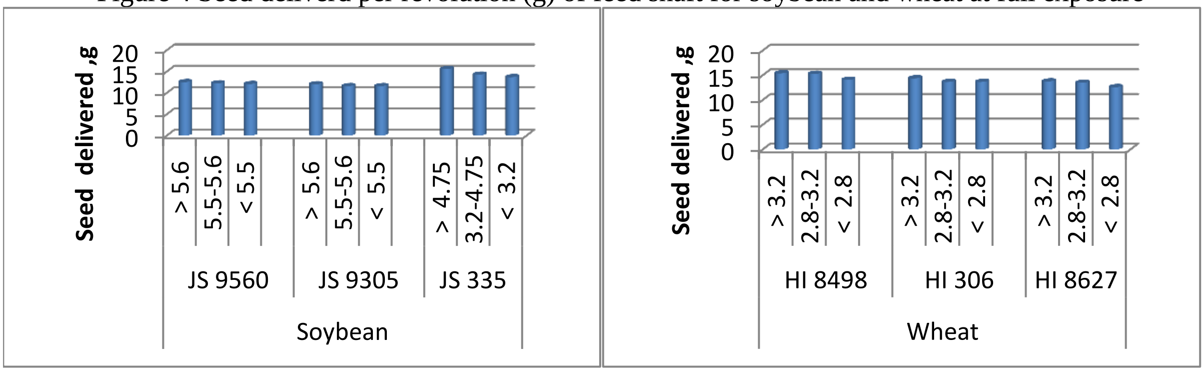

Figure 5 Seed deliverd per revolution (g) of feed shaft for soybean and wheat at 3/4th exposure

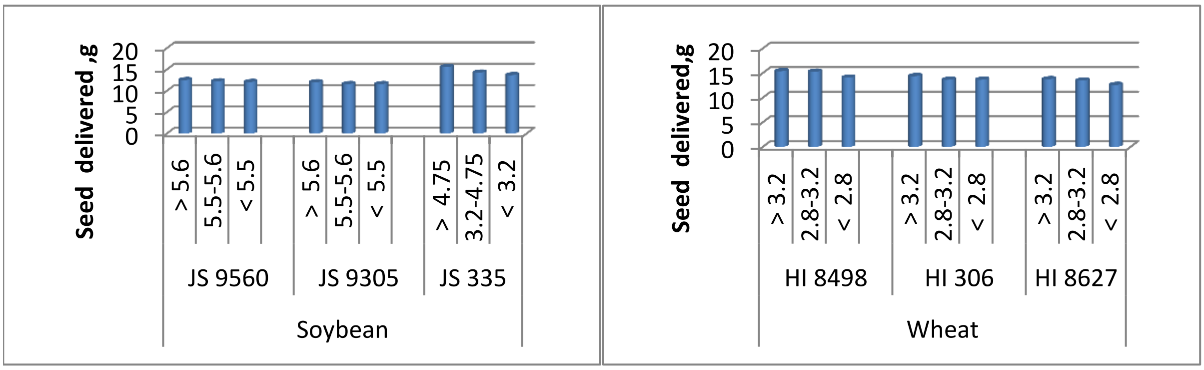

Figure 6 Seed deliverd per revolution (g) of feed shaft for soybean and wheat at half exposure

Table 1 ANOVA for effect on seed delivery rate for different exposures, crops, varieties, and seed sizes

Source	DF	SS	MSS	F -Value	Pr> F_{tab}
Exposure (E)	2	321.24	160.62	7419.22	<0.0001
Crop (C)	1	10.41	10.41	480.86	<0.0001
Variety (V)	4	36.87	9.21	425.83	<0.0001
Size (S)	6	9.65	1.60	74.29	<0.0001
E x C	2	0.72	0.36	16.69	0.0003
E x V	8	1.11	0.14	6.42	0.0023
E x S	12	0.33	0.027	1.29	0.3331
V x S	6	0.88	0.15	6.78	0.0025

3.2 Recommendation of exposure length

Recommendation of exposure length is made according to the actual amount of seed delivery per meter length and the required amount of seed per meter length. Table 2 shows the recommendation of different exposures for 100 kg/ha seed rate and 45 cm row spacing of soybean and 22.5 cm row spacing of wheat.

Table 2 Recommendation of fluted roller exposure for different seed rate

Crop	Variety	Seed size, mm	Required amount of seed/ meter length, g	Actual amount of seed per meter length (g) for different exposures			Recommended exposures
				Full	$3/4^{th}$	Half	
Soybean	JS 9560	> 5.6	4.5	4.721	3.55	2.532	Full
		5.5-5.6	4.5	4.617	3.465	2.476	Full
		< 5.5	4.5	4.552	3.43	2.441	Full
	JS 9305	> 5.6	4.5	4.532	3.453	2.431	Full
		5.5-5.6	4.5	4.371	3.333	2.345	Full
		< 5.5	4.5	4.369	3.324	2.346	Full
	JS 335	> 4.75	4.5	5.87	4.638	3.452	$3/4^{th}$
		3.2-4.75	4.5	5.384	4.112	3.029	$3/4^{th}$
		< 3.2	4.5	5.162	3.852	2.879	$3/4^{th}$
Wheat	HI 8498	> 3.2	2.25	5.801	4.388	3.264	Half
		2.8-3.2	2.25	5.757	4.351	3.239	Half
		< 2.8	2.25	5.303	4.035	2.974	Half
	HI 306	> 3.2	2.25	5.424	3.994	3.053	Half
		2.8-3.2	2.25	5.145	3.788	2.895	Half
		< 2.8	2.25	5.144	3.789	2.897	Half
	HI 8627	> 3.2	2.25	5.187	3.94	2.922	Half
		2.8-3.2	2.25	5.081	3.708	2.862	Half
		< 2.8	2.25	4.743	3.249	2.644	Half

3.3 Speed ratio for different exposure length of fluted roller

Figure 7 shows the speed ratio at different exposure lengths. The speed ratio shows in the figure is calculated for 100 kg/ha seed rate with row spacing of 45 cm for soybean and 22.5 cm for wheat.

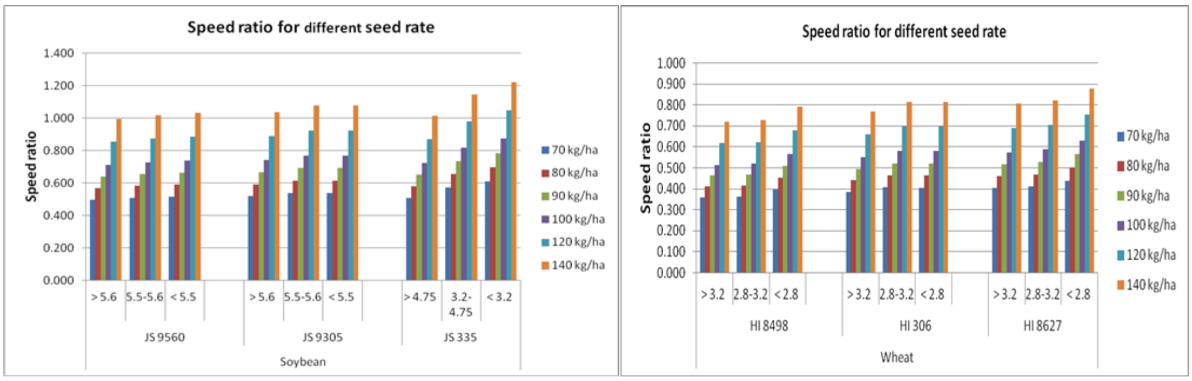

Figure 7 Speed ratio for soybean and wheat

4 Conclusions

The seed delivery per revolution of feed shaft for small seed size varieties has more seed delivery rate as compared to medium and bold seed varieties. For soybean JS 335 variety the seed delivery rate is more as compared to the JS 9560 and JS 9305. The seed delivery rate of wheat seed HI 8498 is more than the other two varieties HI 306 and HI 8627. The recommended exposure length of fluted roller for wheat is low (15 mm). The recommended exposure length of fluted roller for soybean variety JS 335 is 22.5 mm and soybean variety JS 9560 and JS 9305 are 30 mm. The speed ratio for bolder varieties of soybean and wheat are more as compared to smaller seeds. The speed ratio for soybean JS 335 is less and for wheat variety HI 8627 is less as compared with HI 8498 and HI 306.

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