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Development and evaluation of pulse planter in relation to crop, machine and operational parameters

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Abstract

The desired plant population and uniform plant spacing could be achieved by precision sowing technique. The levels of variables *viz*., 0.20 ms^{-1} peripheral velocity, 45° inclination of seed metering disc and cell geometry having 10 per cent more than maximum seed dimension were optimized using an experimental test rig under laboratory condition. A tractor drawn prototype five row inclined plate pulse planter was developed and evaluated in rectangular soil bin. There was no much variation in spacing between hills of individual rows of prototype pulse planter. The average standard deviation and coefficient of variation for five rows were 0.004 and 0.044 respectively which was well within the acceptable accuracy (20 %) achieved by mechanical and pneumatic machines when they are performing well as reported by Griepentrog (1998) [6].

Keywords: pulse planter, machine and operational parameters

Introduction

Pulse sowing is conventionally done by manual dibbling and broad casting. The seeds are sown in lines at a depth of 25-50 mm with one or two seeds per hill and maintaining the desired spacing between the rows and plants. The labour requirement for sowing pulses is high. Thus, it results in higher cost of cultivation. Prior to development of precision planters, appropriate machines were not available for planting of pulse crops. As a result there was no other option for the farmers except to use the conventional drill for planting which resulted in higher seed rate and thinning operations to be carried out thus increasing the production cost. With the use of planters, the seed germination efficiency has increased and seed rate has reduced.

The factor affecting the quality of the crop in mechanized crop production systems is the planting operation. The more precise the planting operation, more the quality of crop harvested. Precision planting is proper placement of seeds in row at desired depth and equal intervals. Precision planting reduces seed scattering and excessive use of seeds due to uniform distribution of seeds by preventing seed from bouncing in the furrow, which facilitates drill calibration on the basis of the number of seeds to be placed along a unit length of the row (Datta, 1974 and Domier, 1991) [4, 5]. This technique results in uniform plant spacing, germination and growth of plants and aids for further mechanization of intercultural farming operation that will reduce the total cost of cultivation (Domier, 1991) [5].

Materials and Method

An experimental pulse planter test rig was constructed as shown in plate 1 to investigate the influence of the selected levels of variables *viz.*, peripheral speed of seed metering disc (V), cell geometry (S) and inclination of seed metering disc (θ) on the seed rate, number of seeds per hill, missing hills and seed spacing. The predominant variety adopted by Tamil Nadu farmers namely black gram (VBN-4) and green gram (CO-6) was selected for the study. The interactive effect of selected levels of peripheral velocity of the seed metering disc (0.10, 0.15, 0.20 and 0.25 ms^{-1}), inclination of the seed metering disc (30° 35°, 40° and 45°) and cell geometry viz., maximum seed dimension (4.25 mm), 10 per cent more than the maximum seed dimension (4.67 mm) and 25 per cent more than the maximum seed dimension (5.31 mm) was investigated on seed placement index, hill spacing and seed rate. The combination level of 0.20 ms^{-1} peripheral velocity, 45° inclination of seed metering disc and cell geometry having 10 per cent more than maximum seed dimension yielded the maximum seed placement index (SPI) of 86.85 per cent and hill spacing of 10.50 cm and seed rate of 20.6 kg ha^{-1} closer to the desired value

Plate 1: Experimental pulse planter test rig

Prototype Pulse Planter

A tractor drawn prototype pulse planter was developed based on the optimized levels of variables for selected black gram and green gram varieties. The prototype essentially consisted of a main frame, inclined plate seed metering unit, ground wheel, power transmission system and furrow opener and seed covering device (Singh, 1984; Shrivastava *et al.*, 2003 and Isaac Bamgboye *et al.*, 2006) [18, 17, 10]. The prototype unit is shown in plate 2. The unit was designed to plant five rows at row spacing of 0.30 m covering a total width of 1.5 m.

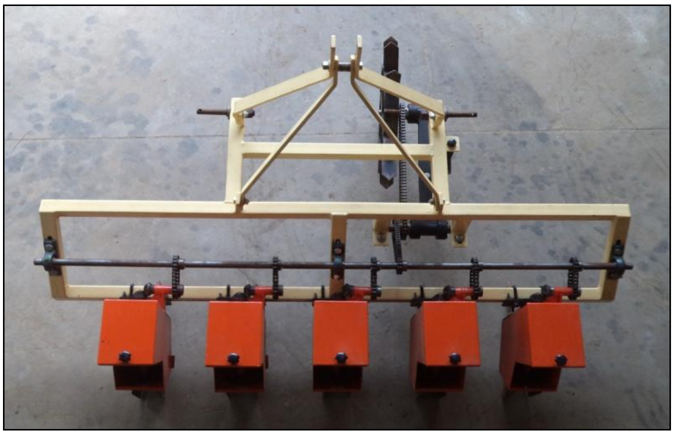

Plate 2: Tractor drawn prototype pulse planter

Main frame

The mainframe of the unit (1800 x 1420 x 1080 mm) was fabricated using a mild steel channel section of size 50 x 50 x 2.5 mm. The seed metering units are mounted on the main frame. Three point hitch assembly was provided in the front position of the main frame so as to hitch the unit with the tractor. The ground wheel was mounted in front of the main frame. A chain and sprocket transmission was used to transmit the drive from ground wheel to seed metering disc.

Seed metering unit

The inclined plate planter consists of five seed metering units fitted on the main frame. Each unit consists of a seed hopper, inclined plate seed metering disc and transmission system. The seed hopper consists of two trapezoidal sections viz., one for holding bulk pulse seeds and the other for holding the seeds to be metered. The seed hopper is constructed using 1.2 mm mild steel sheet. The capacity of trapezoidal sections of the seed hopper for holding and metering pulse seeds were 0.005 and 0.003 m^3 respectively. A sliding gate with an opening was provided in between the two trapezoidal sections for regulating the flow of seeds up to the desired level in the seed metering section. The seed hopper along with the shank of the furrow opener was fitted to the lower section of the main frame with adjustable brackets.

The seed metering disc was fabricated using 50 mm thickness and 120 mm diameter fiber sheet. Each seed metering disc has the optimized number of cells. The seed metering assembly consists of a circular disc, drive shaft and a sleeve. The disc was fitted on a mild steel sheet shaft of 18.5 mm diameter. The shaft runs through the entire length of seed hopper. The shaft rests on a bush at the outer end of the trapezoidal metering section at one end. The other end extends from the outer end of the seed holding section and it was fitted with a 19 teeth bevel gear at the other end. A mild steel sleeve of 20 mm inner diameter and 25 mm outer diameter was provided at a distance of 215 mm vertically from the top of the bulk seed holding section. The sleeve was kept at an inclination of 40 degree. The seed metering disc was fitted with a lock plate which rests on the seed metering disc drive shaft.

The seed metering disc with the lock plate was fixed on the drive shaft by means of a grip screw. The seed metering disc was fitted inside metering trapezoidal section closer to the side wall. A rectangular opening of 50x40 mm was provided in the outer wall of the metering section adjoining the seed metering disc. The seeds filled in the cells are carried securely with the support of side wall till it reaches the opening. The seed fall freely through the side wall opening. The quantity of seeds in the metering section was maintained at constant level up to the level of sleeve with the help of sliding gate. A 19 teeth bevel gear with 1:1 ratio was fitted at the other end of the seed metering drive shaft.

All the five seed metering units were mounted on the top of the main frame. The face of the seed hopper was kept at an inclination of 40° to the horizontal (more that the angle of repose of pulse seeds - 26°) to ensure free flow of seeds inside the hopper. The desired seed pacing of any planter mainly depend on height of metering device form ground level. The seed metering unit was kept at a minimum height of 150 mm from the furrow to obtain precision placement of seeds (Wanjura and Hudspeth, 1969) [19].

Ground wheel

A spike toothed ground wheel of diameter 360 mm was fabricated using 50 mm wide mild steel flat. 12 numbers of lugs (120 x 50 mm) were welded at equidistant on the circumference of the ground wheel to prevent from slippage during the operation. The ground wheel was attached to the mainframe with necessary supporting frame works.

Power transmission system

The power was transmitted from the ground wheel shaft to an intermediate shaft fitted below the main frame through chain and sprocket transmission with speed ratio of 1:1. The intermediate drive shaft gets its support from the main frame with necessary support arms. From the intermediate shaft, the drive was transmitted to the shaft fitted on the main frame through chain and sprocket transmission with speed ratio of 1.46:1. The shaft on the main frame has six sprockets fitted at equal intervals. The main shaft rests on UCB bearing at the ends and at the centre. From the shaft fitted on the main frame, the drive was transmitted to the bevel gears fitted on the cross shaft of the seed metering units with a gear ratio of 1:1. The bevel gear fitted on the seed metering shaft drives the seed metering disc.

Furrow opener and seed covering device

A hoe type furrow opener fitted below the main frame in the front of each seed metering unit opens the furrow. The furrow opener was fitted to the lower section of the main frame with brackets. The position of the brackets can be adjusted along the main frame to suit the row spacing of the pulse crops. The cells in the seed metering disc pickup one seed and drop it through the outlet opening. The seeds dropped from the outlet opening, travel by gravity onto the opened furrow. The two wings that extend rearward from the furrow opener open a furrow and also prevent the soil sliding back onto the opened furrow. The deposited seeds in the opened furrow are covered by the soil that slips at the rear end of the wings.

Uniformity of seed distribution under soil bin

Before conducting the performance evaluation of the unit in the field, laboratory tests were carried out in the soil bin for obtaining the correct seed spacing and uniformity of seed distribution at 1.5 km h-1 forward speed (Allen *et al*., 1983; Halderson, 1983; Ozmerzi, 1986; Panning, 1997; Karayel and Ozmerzi, 2002 and Moody *et al*., 2003) [1, 7, 14, 15, 12, 13].

To find the uniformity of seed distribution, tests were conducted in soil bin. The soil bin consists of two sections, each with inner dimensions of 40 m length and 2.2 m width. One portion was filled with clay loam and the other with sand to a depth of 0.75 m. Three 'I' sections of length 41 m were fixed at 2.60 m intervals to serve as rails for the loading car. The various systems used in the rectangular soil bin were the power driven and loading car consisting of soil processing implements (cultivator, leveller and compaction roller), power transmission system, controls, hitch system and trolley.

A gear box, differential and rear axles of an old tractor was used to construct the power drive system for the soil bin. At one end of the soil bin, the above transmission system was fixed on a mild steel frame of size 3.850 m x 1.350 m x 1.15 m. To the gear box, a 7.5 hp electrical motor was coupled. Two drums of 170 mm in diameter and 910 mm each in length, fitted with shaft, were fixed on each side of the transmission system. The drums were mounted at the same height of the transmission system such that center of each drum fall in line with the center of the each soil portion of the soil bin. Wire ropes of 10 mm in diameter and 50 m in length were wound on each drum. Six forward and one reverse gear position are available in the gear box. So the wire rope can be drawn at 1.5, 2.25, 3.75, 5.50, 8.50 and 14.0 kmh^{-1} forward speed which can be connected to the loading car and hence the loading car speed.

The loading car frame of size 1.750 m length, 2.850 m width and 1.40 m height was mounted on four iron wheels with one side projected rims fitted to two axles. Two more guide wheels were provided opposite to each other to avoid slippage of loading car from the rails. The soil processing implements like cultivator, leveller and compaction roller were fitted to the bottom portion of the loading car. The power transmission system along with electrical motors and control systems for driving the loading car in the reverse direction, for operating the active tool of the active-passive tillage machine and to lift or lower the cultivator up and down were mounted on the loading car.

The prototype pulse planter was fitted to the loading car of the soil bin as shown in plate 3. The sand in the soil bin was compacted by operating the roller of the loading car. After compacting the sand, the loading car was operated above the leveled compacted sand at 1.5 km h^{-1} forward speed. The spacing between the metered seeds placed on the sand and the numbers of seeds dropped in each hill were noted for a length of 15 m. The spacing between the seeds was measured to analyze the uniformity of plant spacing (Jasa and Dickey, 1982; Brooks and Church, 1987; Hofman, 1988; Parish *et al.*, 1991 and Hollewell, 1992) [11, 3, 8, 16, 9]. The co-efficient of variation and standard deviation were calculated by using following expressions.

$$\text{S.D} = \frac{(Xi - X)^2}{n}$$

$$\text{CV} = \frac{SD}{X}$$

Where,

SD = Standard deviation

CV = Coefficient of variation

n = Total number of seeding actions

Xi = Ith spacing

X = Mean spacing.

The above procedure was repeated three times and means values were taken.

Plate 3: Loading car assembly with pulse planter

Results and Discussion

The spacing between the metered black gram (VBN 3) seeds on the compacted sand in the soil bin was measured as explained in section II. From the measured values, the mean, standard deviation and coefficient of variation was computed and the values are furnished in table 1.

Table 1: Uniformity of seed distribution in soil bin

Sl. No.	Spacing between hills in soil bin, m					
	Row 1	Row 2	Row 3	Row 4	Row 5	Average
i	0.108	0.102	0.105	0.101	0.098	0.104
ii	0.110	0.104	0.102	0.095	0.100	0.103
iii	0.095	0.100	0.096	0.102	0.109	0.105
iv	0.105	0.095	0.098	0.101	0.11	0.101
v	0.102	0.094	0.010	0.101	0.11	0.100
vi	0.098	0.104	0.102	0.104	0.104	0.102
vii	0.10	0.102	0.100	0.106	0.106	0.102
viii	0.105	0.104	0.101	0.102	0.098	0.102
ix	0.102	0.098	0.099	0.10	0.094	0.098
x	0.096	0.103	0.104	0.102	0.102	0.101
Mean	0.102	0.100	0.104	0.102	0.103	0.102
S.D	0.0049	0.003	0.008	0.002	0.005	0.004
C.V	0.048	0.030	0.076	0.0196	0.048	0.044

It was observed that the average hill spacing was slightly higher than the recommended spacing of 0.10 m. This may be due to the slippage of ground wheel in sandy soil (Bjerkan, 1947) [2]. It is evident that there was no much variation in spacing between hills of individual rows of prototype pulse planter. The average standard deviation and coefficient of variation for five rows are 0.004 and 0.044 respectively which was well within the acceptable accuracy (20 %) achieved by mechanical and pneumatic machines when they are performing well as reported by Griepentrog (1998) [6].

Conclusion

Based on the analysis of results, the following conclusions were drawn

- For the cell geometry having 10 per cent more than maximum seed dimension, the combination of all selected levels of peripheral velocity and inclination of seed metering disc yielded the desired seed rate of 20 kg ha^{-1}.
- At 0.20 ms^{-1} peripheral velocity of seed metering disc, the cell geometry 4.67 mm (10 per cent more than the maximum seed dimension) yielded higher SPI than the cell geometry of 4.25 mm and 5.31 mm.
- The effect of peripheral velocity and inclination of seed metering disc on hill spacing was negligible at all selected levels of cell geometry.
- In soil bin test, there was no much variation in hill spacing of the individual rows of prototype pulse planter. The average standard deviation and coefficient of variation for five rows are 0.004 and 0.044 respectively.

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