Development and Evaluation of Self-propelled Multicrop Planter for Hill Agriculture

Hijam Jiten Singh[1], Dipankar De[2], P.K. Sahoo[2] and M.A. Iquebal[3]

ABSTRACT

A two-row self-propelled multicrop planter for hilly areas was developed, and its performance evaluated for planting of maize and soybean seeds. Power was transmitted from a 1.57 kW engine to the drive wheels and metering mechanism through chain and sprockets. Inclined plate type seed metering mechanism was used in the planter. Seeds were placed in the furrows at desired depths through adjustable system. The average depths of seed placement were 22.50 mm and 21.50 mm for maize and soybean, respectively. The average draft requirement for the planter was 1.57 kN, which was within the capacity of the power source. Average field capacity of 0.11 ha.h^{-1} was obtained for continuous operation of the planter at an average forward speed of 1.36 km.h^{-1} for planting both maize and soybean. The average field efficiency and field machine index of the planter were observed to be 80.98 and 71.78 %, respectively. The man-hour requirement for planting of one hectare land with the planter was 9.09. The cost of sowing with the planter was Rs.1100/- per hectare, which saved 64.80 % operational costs as compared to manual planting. The savings in man-hours and cost of planting were substantial.

Key words: Inclined plate, self propel, multicrop planter, NEH region

North-eastern-hilly region of India is located between 21.5° to 29.5° N latitude and 85.5° to 97.5° E longitude. The region constitutes about 7.9 % of the country's total geographical area, but has only about 3.8 % of the total population of the country (Anon, 2011). Agriculture in this region can be distinguished from the rest of India in terms of its features, patterns and performance. The region is characterized by difficult terrain, high rainfall and humidity, wide variations in slopes and altitude ranging from near sea level to over 5000 m above MSL, as well as undulating topography with spread out hills interspersed by fertile plains. All these make the region unique, affecting agriculture in various ways. The agricultural practices in the region are broadly of two distinct types, *viz.*, (i) settled farming practiced in the plains, valleys, foothills and terraced slopes, and (ii) shifting cultivation practiced on the hill slopes (Ngachan, 2011). The maximum area falls under hill slopes and foot hills land with gentle slopes.

Farm equipment for the hilly regions must suit the terrain and small farm sizes. Machines designed for plains are not suitable in the hills due to topography and small size land holdings. The available small size plots limit the introduction of large size tractors and power tiller operated implements and, therefore, they are generally uneconomical due to high turn-around time, or often inaccessible to the plots. The weight of power source needed to operate equipment used in hill areas must be in the range of 100-110 kg, which can be lifted by one or two men from one terrace to another where vertical interval ranges from 0.5-1.0 m (Singh and Vatsa, 2007).

In the region, maize is the second important cereal crop after rice in terms of cultivated area. Soybean is also an important major crop, and declared as a potential crop and a viable option in the region for enhancing food security and livelihood of rural households (Baiswar *et al.*, 2012). Sowing is a critical field operation that makes the prospects of a crop. Farmers in the region still follow traditional methods of manually sowing as broadcasting or dibbling. These methods result in lower yield due to uneven distribution of seed, low germination and excessive weed growth. Largely, agricultural operations are labour intensive, and performed manually. Existing locally evolved tools give low output and involve excessive drudgery.

Gupta *et al.* (1999) developed a manually operated single-row, multi-crop planter for use in hilly areas. It could sow a number of crops, such as maize and wheat, combined with fertilizer. The total weight of the planter was 18 kg, and could be pulled either by employing two men or a pair of animals. Khura *et al.* (2011) evaluated a

[1]Ph.D scholar, Division of Agricultural Engineering, .IA.R.I, New Delhi-12; [2]Principal Scientist, Division of Agricultural Engineering, I.A.R.I, New Delhi-12; [3]Scientist, I.A.S.R.I, New Delhi-110012. Corresponding author email:hijam_jiten@yahoo.co.in

light weight manually operated planter for planting maize. The equipment with draft of 12 kg could be operated by a single person. Khura (2011) identified that CIAE seed drill, Naveen dibbler, manual oilseed drill and manual multicrop planter/garlic planter were suitable for sowing small to large seeds like wheat, soybean, maize, gram, pigeon pea, green gram, garlic, peas, groundnut, etc. in line in hilly region. Although a number of planters have been developed in the country for plains, these could not be adopted by the farmers of the hill areas due to their heavy weight and other criteria discussed earlier. Therefore, it was proposed to develop and evaluate an engine operated light weight multicrop planter suitable for hilly areas.

MATERIALS AND METHODS

A two-row self-propelled multicrop planter was developed in the Division of Agricultural Engineering, IARI, New Delhi. The major components were power source, speed reduction unit, main frame, hopper, metering unit, seed tube and furrow opener, power transmission unit, drive wheels,

support wheel and handle (Fig. 1-2). The specifications of the planter are presented in Table 1.

Machine Components

Power source

A 49 cc, 4 stroke, 3600 rpm, 1.57 kW, recoil-start petrol run engine with 0.70 litre fuel tank for agricultural operation was used to drive the planter and its metering mechanism, making it a self-propelled machine.

Speed reduction unit

A gearbox with speed reduction ratio of 50:1 and load carrying capacity of 250 kg was used. The engine and the gearbox were coupled with a spline coupling. The directions of input and output shafts were parallel and perpendicular, respectively, to the direction of travel. The engine with the gearbox weighed 8 kg.

Main frame

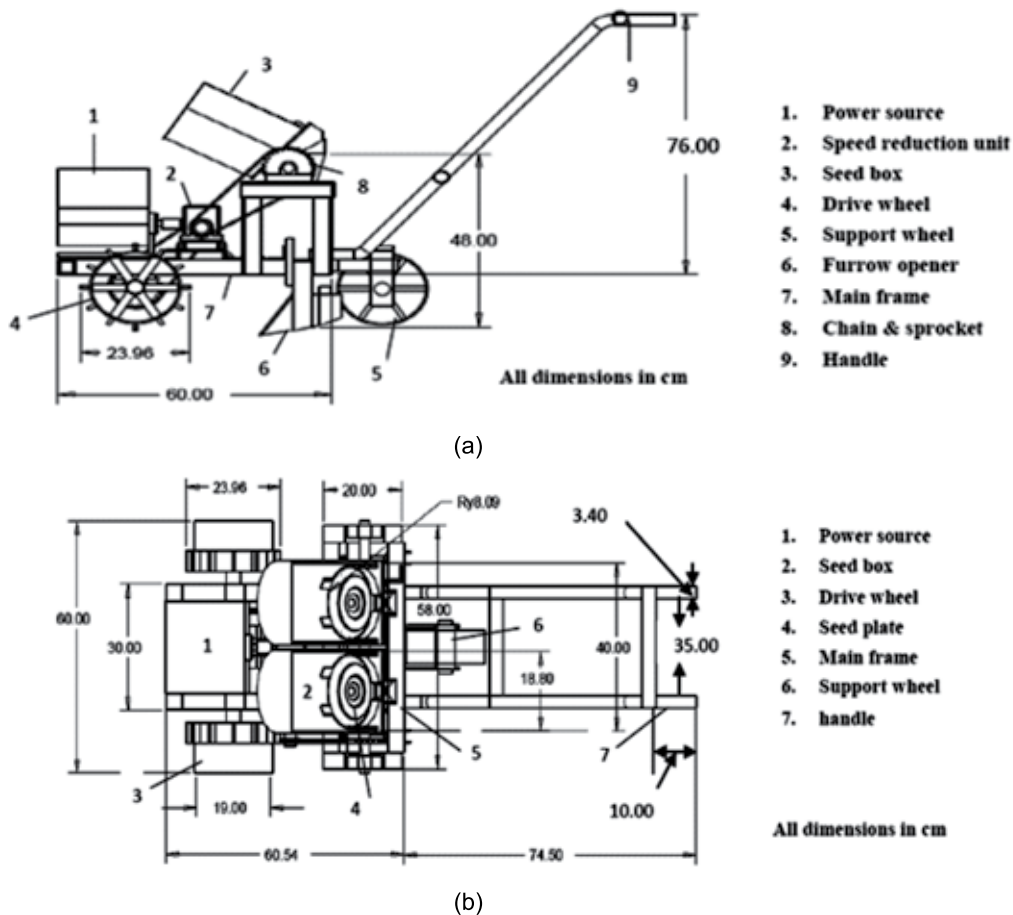The main frame of the unit (600 mm) was fabricated using

(a)

(b)

Fig. 1: **Schematic diagram of prototype multi-crop planter (a)side view, and (b) top view**

Fig. 2: Prototype multi-crop planter (a) side view, and (b) front view

angle iron section of size 40 mm. Engine, gearbox and seed hoppers with metering mechanism were mounted on the frame. Two drive wheels, at both ends of a shaft, were fixed at the front side using bearings below the main frame. At the rear end of the main frame, a support wheel was also mounted to support the main frame. A transmission assembly of chain and sprocket system was used to transmit power from the engine through gearbox to the drive wheels and metering mechanism. To steer the machine, a handle was mounted at the rear end of the main frame.

Hopper

The planter was provided with two individual hoppers of 7006 cm³ volumetric capacity. The hoppers were

made of 2 mm thick mild steel sheet. The hoppers were designed considering the required volumetric capacity, angle of repose and seed bulk density. The slope of the hopper walls, which was required to be more than the angle of repose of the seeds (27° and 26° for maize and soybean, respectively), was 30 degrees (Hijam, 2013). The cross-section of the hopper was rectangular-cum-semi-cylindrical. Each hopper could hold 5.28 kg of maize and 5.25 kg of soybean seeds.

Metering unit

An inclined plate type metering system having metering plates one for each row with cells of proper size and shape was designed and developed for maize and soybean seeds.

Table 1. Specifications of multicrop planter

Component	Specification
Overall size (length x width x height)	1350x580x860 mm
Number of row	2
Row Spacing	450 mm
Plant spacing	100 mm and 200 mm (adjustable by changing plate)
Seed metering	Inclined plate type (175 mm Ø)
Number of seed hopper	2 , each having capacity of 7006 cm³
Number of furrow	2
Type of furrow opener	Shoe type
Power transmission	Chain and sprockets, bevel gears
Speed ratio (Ground wheel: seed plate)	1:0.52
Power source	1.57 kW petrol engine
Gearbox speed reduction ratio	50:1
Net weight	65 kg

The seed plate made of rubber was mounted over a set of bevel gears. The seed plate was mounted at an angle of 60° with horizontal so that extra seed dragged along were dropped before reaching the seed outlet of the seed bowl. The rubber plates were 175 mm in diameter and 5 mm in thickness. They had six and thirteen semi-circular shaped cells at the periphery for maize and soybean seeds, respectively. Each semi-circular cell had a diameter of 7 mm and 12 mm for maize and soybean seeds, respectively. The seed boxes were mounted on a rectangular angle iron 40×40×50 mm frame of 500×200 mm at a height of 100 mm above the main frame.

Seed tube and furrow opener

The seed tube and furrow opener were designed considering the required depth of seed placement. The seed tube was of 25 mm diameter transparent plastic pipes with 2 mm wall thickness. The height of the seed delivery spout was close to the ground to achieve seed spacing uniformity. Shoe-type furrow openers of 1500 mm length were provided with each seed outlet. The shank height of the furrow opener was 200 mm. The furrow opener was bolted to the main frame with rigid clamps, and the depth of operation of the furrow opener was controlled by vertical adjustments of furrow opener clamp (0-80 mm) and support wheel (0-60 mm) provided at the rear end of the main frame with respect to the bottom of the furrow opener. Seeds were adequately covered by the flow of loose soil during operation. Hence, there was no need of a covering device.

Drive wheel and rear support wheel

Two drive wheels of 200 mm in diameter were fabricated using 50 mm wide and 4 mm thick mild steel flat. Eight mild steel round spokes having 10 mm diameter were provided. Twelve lugs of 20 mm in height were welded at regular intervals at an angle of 20˚ with the axis of rotation to reduce slip. Two wheels of 190 mm diameter were also fabricated from 75 mm wide and 3 mm thick mild steel sheet, and attached to the drive wheels to reduce machine sinkage in the field. A support wheel without lugs having same dimensions of the drive wheels was provided to support the machine. It was fitted below the main frame, 100 mm behind, at the centre of rear end of the main frame. The support wheel could be adjusted vertically from 0-60 mm.

Power transmission

Power transmission was achieved from the engine (through gearbox) to the drive wheels and to the metering device through two set of chain-sprocket arrangements. The power transmission system consisted of two mild steel sprockets of 49 mm diameter having 13 teeth, one of 94 mm diameter having 25 teeth, and the other one of 136 mm diameter having 30 teeth. Two sprockets were fixed on output shaft of the gearbox on two ends, each of 49 mm diameter and 13 teeth. The shaft of the drive wheels had a sprocket of 94 mm diameter and 25 teeth. A sprocket of 30 teeth was used on the shaft of metering unit. Chains of 12 mm pitch were used for power transfer from drive sprocket of gearbox output shaft from the right end to the driven sprocket of drive wheels shaft through a chain-sprocket arrangement. From the left end drive sprocket of gearbox output shaft, power was transmitted to seed plate by a set of bevel gear through another chain-sprocket arrangement. The speed ratio between the drive wheels and seed plate was maintained at 0.52.

Handle

Based on anthropometric data of the NEH region's agricultural workers (Agrawal *et al.*, 2010), the handle was designed with height of 860 mm, grip diameter of 34 mm and minimum length of grip of 100 mm, so that an average worker could comfortably operate the machine.

Performance Evaluation of Planter

The planter was evaluated in the laboratory and in field for its performance with maize and soybean seeds. The planter was evaluated at forward speed of 1.36 km.h^{-1}. The forward speed was maintained by setting the throttle of the engine at a pre-determined position considering the engine speed, gearbox ratio and number of teeth of the sprockets used. The row-to-row and plant-to-plant spacing adopted on the field was 452 mm and 451 mm for maize and soybean, respectively. In the laboratory calibration, row-to-row variation in seed metering were evaluated (IS: 6316-1993).

Laboratory calibration

Maize seed was filled in the two hoppers. Ground wheel was jacked up and 20 revolutions were given to the ground wheel. The seed discharged from each of seed tube were collected and measured separately. Ten replications were taken. Statistical analysis was performed on the data and "t" test was used to test the hypothesis of mean seed discharged between the two rows. The same procedure was repeated for soybean seed.

Field evaluation

Field experiments for performance evaluation of the self-propelled planter were conducted in the experimental farm of Agricultural Engineering Division, IARI, New Delhi (2013). The field was prepared into fine tilth by twice harrowing, followed by levelling for operation of the planter. The field was divided into two plots of size

20×15m each for sowing each crop at depth of 20-40 mm. Each plot was further divided into three sub-plots of 20×5 m. Experiments were conducted in sandy loam soil. The planter was operated at forward speed of 1.36 km.h^{-1} in straight rows. Recommended agronomic practices were followed in raising the crops. Germination percentage was recorded on the 21st day after sowing. Observations were taken on time taken to cover the area, actual depth of placement, fuel consumption, soil bulk density before operation, soil moisture content before operation, soil resistance and emergence rate. The performance of the planter was indicated by field capacity, field efficiency, field machine index and draft.

Field capacity and field efficiency

Theoretical field capacity is the rate of field coverage that would be achieved if the planter was operated continuously without interruption like turning at the ends and filling of hopper. The effective field capacity is the actual average rate of coverage including the time lost in filling and turning at the ends of rows. Theoretical field capacity is given as:

$$C_t = \frac{W \times S}{10} \qquad \text{... (1)}$$

Where,

C_t = Theoretical field capacity, ha.h^{-1},

W = Width of coverage, m, and

S = Speed of operation, km.h^{-1}.

Effective field capacity is the actual average rate of field coverage by the machine, based upon the total field time and it is given as:

$$C_e = \frac{\text{Area of plot(m}^2) \times 0.36}{\text{Time taken (s)}} \qquad \textbf{... (2)}$$

Where,

C_e = Effective field capacity, ha.h^{-1}.

Field efficiency is the ratio of effective field capacity to the theoretical field capacity, and expressed as:

$$E_f = \frac{C_e}{C_t} \times 100 \qquad \text{... (3)}$$

Where,

E_f = Field efficiency, per cent,

C_e = Effective field capacity, ha.h^{-1}, and

C_t = Theoretical field capacity, ha.h^{-1}.

Field machine index

Field machine index, indicating the influence of field geometry on working capacity of the machine, was calculated using the following formula:

$$FMI = \frac{(T_p - T_o - T_t)}{(T_p - T_o)} \times 100 \qquad \text{... (4)}$$

Where,

FMI = Field machine index, per cent,

T_o = Theoretical field time, min per plot,

T_p = Total productive time, min per plot, and

T_t = Total turning time, min per plot.

Draft

Draft is the horizontal component of the pull, parallel to the line of motion. It can be calculated as:

Draft, N = Soil resistance (N.cm^{-2}) × Furrow cross section (cm^2) ... (5)

Power, W = Draft (N) × Speed (m.s^{-1}) ... (6)

Cost Economics

The total cost of planting was determined based on fixed cost and variable cost (IS: 1964-1979). The total cost of operation of planter on hourly basis as also on per hectare basis was determined.

RESULTS AND DISCUSSION

Laboratory Calibration

In the laboratory, row-to-row variation in seed metering and uniformity of seed delivery were studied. The variation of seed discharged from the average of two rows, was non-significant (Table 2, 3). The average quantity of seeds discharged in 20 revolutions of the ground wheel was 9.98g and 31.56 g for maize and soybean seeds, respectively. The maximum deviation of seed discharge of any row from the average was less than 3 per cent. All the deviations were within the range of 7 % prescribed by the Bureau of Indian standards.

Field Evaluation

The performance data of the planter are presented in Table 4. The average soil resistance per unit area of 0.65 N.mm^{-2} was recorded using cone penetrometer. The planter had a draft and power requirement of 1.56 kN and 0.61 kW, respectively, during field operation at soil moisture of 12.5 per cent and bulk density of 1.25 gm.cm^{-3}. The installed 1.57 kW petrol engine could thus easily operate the planter. The average field capacity of the machine was 0.11 ha.h^{-1} for continuous operation at an average forward speed of 1.36 km.h^{-1}. The average field efficiency was 80.74 % for

Table 2. Laboratory calibration of seed distribution in rows of the planter

| | Seed collected in 20 revolutions of ground wheel | | | | | |
| | Maize seed (g) | | | Soybean seed (g) | | |
	Row 1	Row 2	Average	Row 1	Row 2	Average
Average	10.08	9.89	9.98	31.32	31.79	31.56
Maximum deviation from average, %	+1.49	+2.12		+2.07	-2.11	
SD	0.13	0.16		0.45	0.45	
C.V., %	1.32	1.66		1.42	1.41	

Note: SD=Standard deviation, C.V.= Coefficient of variation

Table 3. Laboratory calibration of seed discharge variation between two rows

| Seed | t-test for equality of means | | |
	t	d.f	Sig. (2-tailed)
Maize	2.68*	18	0.015
Soybean	2.34*	18	0.013

*Note: * Difference is non-significant at 5 % level of significance*

planting maize and soybean seeds. Similar results were reported by Kepner *et al*. (1987). Field tests indicated that the machine index was 71.78 per cent. The man-hour requirement of the prototype planter was 9.09 per hectare. The major loss in efficiency was due to the turns at the head land and adjustment of the planter position before a run so that required spacing was maintained with planted rows of the previous pass. The average seed placement depth was 22.50 mm and 21.50 mm for maize and soybean against recommended depths of 20 to 30 mm and 30 mm for NEH region, respectively (Anon, 2013).

Seed germination in field commenced on 8th day after planting. Late germination might be due to early sowing and harsh weather conditions at the time of sowing. Average germination percentages in field were 76.67 and 73.33 % for maize and soybean, respectively. After germination, the average plant spacing on the 21st day post-sowing was 167.40 mm and 85.10 mm for maize and soybean, respectively, against the calibrated seed spacing of 174.80 mm and 96.50 mm. These were within recommended spacing of 200 mm and 100 mm, respectively (Anon, 2013). The average plant population per meter length of bed was 6 and 12 against theoretical plant population of 5 and 10 for maize and soybean, respectively. This was due to the slip of driving wheels (9.52 %) which led to higher

Table 4. Field performance parameters of planter

| Sl. No. | Performance parameter | Value | |
		Maize	Soybean
1	Depth of placement, mm	22.50 ±12.30	21.50±14.20
2	Forward speed, km.h^{-1}	1.36±0.01	1.36±0.01
3	Draft, kN	1.56±0.01	1.56±0.01
4	Fuel consumption, l.h^{-1}	0.75±0.00	0.75±0.00
5	Field capacity, ha.h^{-1}	0.11±0.00	0.11±0.00
6	Field efficiency, %	80.74±0.60	81.23±0.34
7	Field machine index, %	71.76±0.51	71.90±0.96
Note:	Soil moisture content before sowing:	12.5 % (d.b)	
	Soil bulk density before sowing:	1.25 g.cm^{-3}	

Table 5. Cost of operation of multicrop planter

Assumptions:			
Initial cost	: Rs. 35290	Salvage value	: Rs 3529
Service life	: 10 years	Annual use	: 250 h
(A) Annual fixed cost (Rs):			
Depreciation			= 3176.10
Interest @ 12 % per annum			= 2329.14
Insurance, taxes and housing @ 3% of initial cost per annum			= 1058.70
Annual fixed cost			= 6563.94
Fixed cost of planter per hour			= 26.25
(B) Variable cost (Rs):			
Repair and maintenance cost @ 10 % of initial cost per h			= 14.12
Fuel cost @ 0.75 l/h			= 48.75
Lubrication cost @ 30 % of fuel cost			= 14.63
Wages of labour @ Rs. 100 per day for 8 hours			= 12.5
Total variable cost per hour			= 90
Total cost per hour			$\approx$ 120
Cost of operation of planter (Rs/ha) with field capacity 0.11 ha/h			$\approx$ 1100

Cost involved in manual planting (manual dibbling):
Man-hour required to plant one hectare = 250
Wage rate per man per day of 8 h = Rs. 100
Total cost of manual planting per hectare = Rs. 3125

seed drops. These performance indices indicated that the prototype multicrop planter performed satisfactorily under field conditions.

Field tests also indicated that the machine was laterally balanced due to equal weight distribution along its longitudinal axis, and was thus convenient to the operator during transportation. During field operation, the two furrow openers located 225 mm apart from the longitudinal

Fig. 5: Field operation of multi-crop planter

axis provided additional lateral ground support to the machine. The weight of the machine was 65 kg, and thus could be lifted by two persons from one terrace to another. The machine was thus found to be comfortable by the operator (Fig. 5). No breakdown, repairs and adjustment requirements of components during the operation were observed. The cost of the planter was estimated as Rs. 35,290/- with hourly cost of operation of Rs. 120/-, Table 5. The cost of operation of the planter per hectare was Rs.1100/-. The cost of sowing with the planter was 64.80 % lower than cost of manual dibbling method of planting.

CONCLUSIONS

The deviations from the average of seed discharge between the rows were within the range of 7 % and statistically insignificant.

At forward speed of 1.36 km.h^{-1}, the draft and power requirement of the planter was 1.56 kN and 0.61 kW, respectively. The average seed placement depth was 22.50 mm and 21.50 mm for maize and soybean, respectively. The average plant spacing on the 21st day post-sowing was 167.40 mm and 85.10 mm for maize and soybean, respectively. Effective field capacity of the planter was

0.11 ha.h^{-1} for planting of maize and soybean crops, with field efficiency of 80.98 per cent. Field machine index was 71.78 per cent.

The saving in man-hour requirement and cost of planting with multicrop planter were substantial as compared to manual method.

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