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PERFORMANCE EVALUATION OF PNEUMATIC PLANTER FOR PEAS PLANTING

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In Pakistan, the pea is one of the leading and popular vegetables grown. Peas are usually sown manually by placing seeds one by one or by broadcasting method. Manual placing is very arduous and time-consuming practice, which limits the pea planting acreage. The broadcasting requires more seed rate causing high input cost. The local farmers were in a dire need of a planter for pea cultivation. The aim of this study was to evaluate a pneumatic pea planter in the field developed by a local manufacturer under the supervision of Agricultural Engineering Institute, National Agricultural Research Centre, Islamabad, Pakistan. It was a four-row pneumatic planter. It makes two beds of 0.76 m wide and plants four rows of peas on both ends of the raised beds 5 cm deep. Initially, row to row distance was kept fixed to 0.76 m, however, plant to plant distance was adjustable from 6 to 20 cm by using different combinations of sprockets or by changing the seed metering plate having different number of holes. The working width of the planter was 3 m and can be operated with a 65 hp or higher tractor. The seed sticks well against the holes of seed metering plate due to air suction pressure, when the aspirator blower is operated at 400 to 540 rpm of tractor PTO. The planter was field evaluated at Gujranwala and compared with manual sowing and broadcasting methods. The actual field capacity of the planter was 0.45 ha/h with a field efficiency of 58.6%, when operated in low-I tractor gear and at 1800 engine rpm. The pea planting cost by manual seed placement and broadcasting methods was Rs. 14,940 and Rs. 5,240 per hectare, respectively. The operating cost of the planter was Rs. 3,015, which was 395.52 and 73.8% lower than the manual seed placement and broadcasting methods, respectively. By using pea planter, a farmer can achieve Rs. 64,855 and 21,325 more benefit from one hectare than manual seed placement and broadcasting methods, respectively. Timely sowing, quality of work and less drudgery were additional vital benefits to the farmer using this machine. Similarly, the seed cost was reduced by 291.9% as compared with broadcasting method. In the first version of planter, the row spacing was more than the farmers' used spacing, therefore, plant population was less than recommended. In future manufacturing, the row to row distance would be decreased to get optimum plant density and a higher yield. The pea planter is a good initiative for improving vegetable mechanisation of the country.

Keywords: *Pisum sativum*, pea planter, pneumatic metering, bed sowing, precision planting

INTRODUCTION

Peas (*Pisum sativum*) is a cool season, hardy and annual vegetable belonging to the Fabaceae family. It is a famous winter vegetable cultivated all over Pakistan. However, Punjab is the leading province, which contributes about 78% of its total production (MNFS&R, 2017). For pea cultivation, seeds are placed manually at a depth of 5 cm on both sides of raised beds. The breadth of raised beds ranges from 0.5 to 1.0 m. The seed rate for early varieties varies from 60 to 75 kg/ha and 35-40 kg/ha for late varieties. The row to row distance for early varieties is kept up to 50 cm and 60-65 cm for late varieties (Hussain *et al*., 2001). Seeds are dibbled manually on the beds when sufficient moisture is present. As much as 20-25 viable seeds per meter of a row are generally sufficient and should not be planted deeper than 5 cm to facilitate emergence of sprout and should be covered after sowing (Hussain *et al*., 2001).

The vegetable mechanisation status of the country as a whole is not encouraging. Due to low level of mechanisation, the local practices followed for pea planting are either to place seeds manually 5 cm deep on the edges of raised beds or to broadcast seed manually in the field. These practices are labour-intensive and expensive. The broadcasting method needs higher seed rate than the recommended to compensate for missed seeds, which adds on the cost of inputs, whereas manual seed placement requires 190-200 man-hours for planting one hectare of pea crop, which is an expensive and time-consuming practice. High labour requirement affects planting of peas and other vegetables on a large scale. Timely sowing of peas is very important for harvesting optimum yield together with other important factors, such as seed quality, soil fertility and the use of suitable fertilisers.

Different types of planters have been developed worldwide for planting vegetables and other crops. Planting peas on raised beds is an efficient method, which gives a good crop stand and a better yield. An air-jet singulator was developed and evaluated by Shafii *et al*. (1991) and reported that both air-jet and mechanical singulation methods worked well with acceptable levels of planting efficiency, singles, skips, doubles and multiples. The effectiveness of mechanical singulation was deteriorated due to wear, whereas air-jet singulation was insensitive to back plate wear problem. Air-jet singulator yielded significantly higher planting efficiency and per cent singles compared with mechanical singulator. Murray *et al*. (2006) reported that pneumatic type seed metering system is most commonly used on planters for metering round to oblique seeds and has a better seed singulation accuracy and does not require any seed grading.

Zaidi et al. (1998) developed a pneumatic row-crop planter for planting oilseeds to replace the conventional drill, which requires post-emergence thinning operation that adds on their cultivation cost. The performance of the planter was very good, which reduced 60 % planting cost than the conventional seed drill for cotton and sunflower crops. Lara-Lopez et al. (1996) developed a direct planter for corn and faba beans. The main concern of the development was to apply the proper metering principle to ensure reduced damage of the large bean seed. It was a single row planter, which could be operated with a small tractor or animal draft. The planter performed well without seed damage and established recommended plant population in the field. Borlagdan (1994) developed four prototypes of seeders for sowing corn, soybean and mungbean. They include; 1) semi-automatic seeder; 2) automatic seeder; 3) plough attached seeder and 4) power tiller attached seeder.

A survey was conducted to assess the demand of a vegetable planter throughout the country (Zaidi et al., 2013). From this survey, it was established that farmers were demanding a planter for planting vegetables, especially peas. Manual seed placement and broadcasting methods were labour-intensive and expensive. The aim of this study was to address this national issue by designing, developing and evaluating a tractor rear-mounted indigenous pea planter by using local materials and facilities that could help enhance pea production in the country.

MATERIALS AND METHODS

***Planter description*:** The planter was a four-row tractor rear-mounted machine (Fig. 1). Row to row distance of the planter was 76 cm, plant to plant distance was 6-29 cm and the depth of seed placement was 5 cm (Hussain *et al*., 2001). The main parts of the planter were; bed shaper, aspirator blower, pneumatic seed metering mechanism, seed boxes and compactor or bed shaper. The planter makes 25 cm deep and 76 cm wide beds from the top. The compactor compacts the formed beds, whereas seeds are placed 5 cm deep on the both edges of the raised beds. Four seed boxes were provided each for individual row. Pneumatic seed metering discs were attached at the lower side of the planter with the bed compactor. The capacity of seed boxes was 40 kg. In this planter, row spacing was fixed, whereas plant to plant distance was adjustable by changing the sprockets combinations (Fig. 2).

Figure 1. Pneumatic planter.

Figure 2. Power transmission to metering mechanisms using ground wheel and sprocket system.

***Seed metering mechanism*:** The pneumatic seed metering system was employed on the planter as shown in Figure 3. The aspirator blower of the pneumatic seed metering system was driven by tractor PTO with a speed of 400-540 rpm. Seed metering mechanism uses air suction that is produced by the aspirator blower. The pneumatic disc of each row was connected to the inlet chamber of the aspirator blower through a rubber tube. The seed metering disc has 26 holes of 3 mm near its periphery to accommodate a single seed against each hole. Air suction from the holes of the seed metering disc causes the seeds to stick against them. Seed discs were driven by the ground wheel. The stuck seeds against the holes of a seed metering plate were released with the help of a baffle cut, which is situated near the opener. The absence of suction allows the seed to be dropped into the small furrow made by a small opener fixed below the bed shaper. The falling height of seeds was kept very low to reduce seed rolling and bouncing in the furrow. The plant to plant distance was maintained by using proper combination of sprockets. The pneumatic seed metering discs picked seeds at more than 1200 rpm of the engine due to big seed sizes. The overall technical specifications of the planter are given in Table 1.

Figure 3. Pneumatic seed metering mechanism.

Table 1. Technical specifications of the pneumatic planter.

Parameters	Specifications
Power source	65 hp or higher tractor
Local content by cost	100 %
Overall length	2.75 m
Overall width	3 m
Overall height	1.4 m
Overall weight	300 kg
Number of beds	2
Number of rows	4
Row to row spacing	0.76 m
Metering mechanism	Pneumatic
PTO rpm required	400-540
Operating field speed	1.5-6 km/h
Seed box capacity	40 kg
Fertiliser application provision	Not installed yet

***Calibration of planter*:** The planter was calibrated in a well-prepared seedbed. Calibration was necessary to determine tractor forward speed, effective diameter of the ground wheel, seed rate per hectare and row to row and plant to plant distance. Two points were marked at a distance of 50 m using a measuring tape. Time was noted when the tractor was reached at initial and the final points and calculated elapsed time. The process repeated for three times and averaged to determine elapsed time. The effective diameter of the ground wheel was calculated by measuring distance covered by the wheal in 20 revolutions under the same field conditions. The process was repeated three times and calculated their average. The machine was lifted up with the help of tractor hydraulic and operated the PTO at 540 rpm. The ground wheel was rotated for 20 revolutions and collected the seeds from tubes of 4 rows and weighed. This process was repeated three times to get average seed rate per hectare. The seed rate was calculated by using the formula given in Eq. 1.

$$Q = (L \times 10{,}000) / (\pi \times D_e \times n \times W) \qquad \text{Eq.1}$$

where, Q is seed rate per hectare (kg), L is the amount of seed delivered from all tubes (kg), n is the number of tubes, W is row to row distance (m) and D_e is the effective diameter of the ground wheel (m), which is the average distance covered by ground wheel in one revolution.

***Experimental procedure for field evaluation*:** An area of 0.8 ha was selected at Kot Saadullah, Gujranwala for conducting field evaluation of pea planter. This area was divided into four equal parts (0.2 ha each). Two fields were planted using planter with 9.5 and 11 cm plant to plant distances. The other two plots were planted with manual seed placement and broadcasting methods, respectively. After broadcasting of seeds, the beds were raised by a ridger (Fig. 4). Seedbed was prepared by multiple deep ploughing followed by planking. One bag of 50 kg of *Zarkhez* fertiliser (N = 8%, P_2O_5 = 23% and K_2O =18%) was applied in each plot as a recommended dose at the time of final seedbed preparation. Pea variety *Meteor* (Royal Sluice of Holland) was used for conducting this study. The first irrigation was applied three days after sowing. The germination data were collected 15 days after sowing. The manual harvesting/picking of each plot was done 95 days after planting as shown in Figure 5.

Figure 4. Field preparaiton for manual seed planting.

Figure 5. Manual harvesting/picking of peas.

RESULTS AND DISCUSSION

Calibration data of pea planter for 9.5 and 11 cm seed to seed distances are shown in Table 2. Three replications for both seed to seed distances were taken. Individual rows picked

Table 2. Calibration of pea planter in the laboratory for number of seeds in 10 revolutions of the ground wheel.

Replications	9.5 cm plant spacing							11 cm plant spacing						
	Row 1	Row 2	Row 3	Row 4	Mean	SD (cm)	CV (%)	Row 1	Row 2	Row 3	Row 4	Mean	SD (cm)	CV (%)
Rep 1	256	250	230	200	234.0	25.3	10.8	175	180	175	150	170.0	13.5	8.0
Rep 2	249	251	232	210	235.5	19.0	8.1	176	179	175	155	171.3	11.0	6.4
Rep 3	258	253	235	220	241.5	17.4	7.2	180	182	179	149	172.5	15.7	9.1
Average	254.3	251.3	232.3	210	237.0	20.6	8.7	177	180.3	176.3	151.3	171.3	13.4	7.8

Here, SD is standard deviation (cm) and CV is coefficient of variation (%).

Table 3. Comparison of planter with conventional method of manual sowing and broadcasting.

Parameters	Broadcasting	Manual seed placement	Planter 9.5 cm plant spacing	Planter 11 cm plant spacing
Type of soil	Sandy loam	Sandy loam	Sandy loam	Sandy loam
Variety of seed	Meteor	Meteor	Meteor	Meteor
Average seed dia (mm)	7.00	7.00	7.00	7.00
Actual field capacity (ha/h)	--	--	0.45	0.45
Field efficiency (%)	--	--	58.6	58.6
Average row to row distance (cm)	37.8	35.6	76	76
Average plant to plant distance (cm)	Random	9.2	9.5	11
Average depth of seed placement (cm)	Random	2-5	5	5
Planting uniformity (%)	Random	60	90	90
Number of plants per meter length	56	11.7	10.5	9.1
Time requirement (manhour/ha)	6	200	2.2	2.2
Operating cost (Rs./ha)	5,240	14,940	3,015	3,015

different number of seeds during calibration, which indicates variable pneumatic pressure across the tubes. Rows 3 and 4 picked the lower number of seeds as compared with rows 1 and 2. This is attributed to the uneven suction pressure on the pneumatic seed metering plates. Despite, the performance of seed metering plates for picking single seeds was very good. No multiple seeds were picked up by the metering plates. The coefficient of variation for picking seeds was < 9.0% across the tubes for both seed to seed distances. This shows a reasonably good precision for picking of pea seeds. Griepentrog (1998) reported that an acceptable precision for mechanical or pneumatic planters and drills is when its coefficient of variation is up to 20%. Similarly, Kachman and Smith (1995) suggested a 30% coefficient of variation as acceptable precision. Parish and Bracy (2003) stated that the coefficient of variation (precision) for seed pick-up for precision planters should be up to 10%. Keeping in view the 10% coefficient of variation as a bench mark, the pneumatic planter evaluated in this study was reasonably precise for planting of peas, other vegetables and crops. It was also observed that only a single seed was accommodated against each hole of the metering plate and the deviation between actual and desired seed rate was small. No mechanical seed damage was found during calibrating process of the planter.

The results of theoretical field capacity, actual field capacity, field efficiency and labour requirement for the three methods are shown in Table 3. The actual field capacity of the planter was 0.45 ha/h with a field efficiency of 58.6%, whereas the actual field capacity by manual sowing, when 5 persons were engaged, was 0.2 ha/h. This indicates that for manual sowing, 190-200 man-hours were required for planting one hectare. On the other hand, the planter can complete one hectare in 2.2 hours. The average row to row distance for manual seed placement method was 35.6 cm, whereas for planter it was 76 cm. The average plant to plant distance for both methods was nearly the same. Seeding uniformity with planter was 90%, whereas for manual seed placement, it was 60%. Singh *et al*. (2005) reported that with lower vacuum pressure and at higher speeds, the metering disc does not get enough time to pick up seeds, resulting in higher miss indices. The advantage of pneumatic planter is that no seed grading are required before planting. Placing seeds at variable distances can increase the competition among plants for uptake of water, nutrients and sunshine, which ultimately gives uneven maturity of crop and variable grain size. Rajan and Sirohi (2012) reported that faster planting speed can easily decrease seed depth, uniformity and seed to soil contact, causing uneven emergence. The broadcasting method is relatively quicker than manual seed placement method, but the seed cost is double, which is hardly acceptable by the poor growers. The average number of seeds per meter length in a row was < 11 with planter, which is less than the recommended 20-25 number of seeds per meter length as reported by Hussain *et al*. (2001). Data on depth of seed placement, planting uniformity, plant spacing and plant density and operating cost are also shown in Table 3. A planting depth of 5 cm was achieved with the planter, whereas variable seed depths were noted in broadcasted and manual seed placement fields. The seeds placed at more than 5 cm depth could not emerge. In case of planter, the average plant to plant distance was 9.5 and 11 cm, whereas for manual seed placement, it was 9.2 cm. The operating cost of the planter was Rs. 3,015/ha, whereas it was Rs. 14,940 for manual seed placement method.

A comparison of crop stand by pneumatic planter, manual seed placement and broadcasting methods is shown in Figure 6. It was visually clear the emergence was very precise in the field planted with the planter. An uneven plant spacing were seen in manual seed placement method, whereas irregular plants were emerged on different locations of furrows in broadcasting method.

Data on number of tillers and pods per plant were collected at flowering stage and before picking to assess difference in planting methods. Table 4 shows that the number of tillers were more in the fields sown with planter due to uniformity in sowing. All plants got judicious water, nutrients and sunshine availability for growth. The plants in broadcasting field were mostly single tillers and reached maturity early than plants having more than one tiller. The highest number of tillers and pods were observed in the field sown with planter at 11 cm plant to plant distance (Table 4). Similarly, the weight of mature pods per plant was also more in the field sown with the planter at 11 cm plant spacing. There were more immature pods in all fields except broadcasting field. The fields with immature pods needed more than one picking. Root development data of plants were also collected to see the different among different sowing methods. Plants were uprooted to visualise the root structure at flowering stage. A large number or roots and nitrogen fixing nodules were seen in the planter fields because their roots were established uniformly. In the contrary, a low number of roots and nitrogen fixing nodules were seen in manual seed placement and broadcasted fields (Fig. 7).

Table 4. Plant data just before picking.

Parameters	Broadcasting	Manual seed placement	Planter (9.5 cm)	Planter (11 cm)
No. of tillers per plant	1.4	2.2	2.6	3.2
No. of matured pods	8.6	11.8	12.0	16.6
No. of immature pods	2.2	7.0	8.0	10.0
Weight of matured pods (g)	38.3	49.1	51.3	72.0
No. of matured grains/plant	37.4	51.0	54.7	70.0

Figure 6. Comparison of three pea planting methos: planter (left); manual sowing (middle) and broadcasting (right).

Figure 7. Root development structure of plants under the three planting methods: planter (left); manual sowing (middle) and broadcasting (right).

Different costs for pea production are shown in Table 5. These costs included seed cost, planting cost and harvesting cost. Total cost in manual seed placement and broadcasting methods was higher than planter due to more labour cost in manual dibbling and more seed cost in broadcasting method. The operating cost of planter was Rs. 3,015/ha (Table 6). The planting cost in manual seed placement and broadcasting methods was Rs. 14,940 and Rs. 5,240 per hectare, respectively which is higher than planter. The operating cost of planter was calculated based on its fixed cost and variable cost (Table 6). The fixed cost included its depreciation cost, interest, tax, insurance and shelter. The variable cost included fuel cost, lubricant cost, operator and labour cost and repair and maintenance cost. The total operation cost of planter was R. 3,015/ha.

A comparison of planting cost, picking/harvesting cost, yield and economic benefit is shown in Figure 8. The cost of seedbed preparation has not been included in this comparison as it was same for all fields. An average yield of 5,733 and 5,869 kg/ha was obtained with planter with 9.5 cm and 11cm plant spacing, respectively.

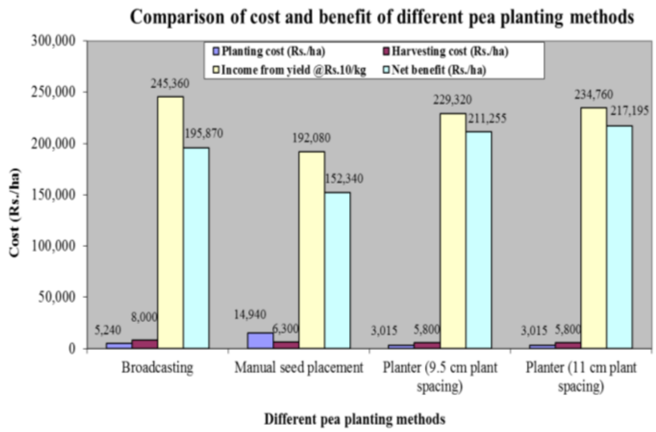

Figure 8. Comparison of cost and benefit of different pea planting methods.

Table 5. Different costs for pea production.

Method	**Seed rate (kg/ha)**	**Seed cost @Rs.250/kg (Rs./ha)**	**Planting cost (Rs./ha)**	**Harvesting cost (Rs./ha)**	**Total cost (Rs./ha)**
Broadcasting	145	36,250	5,240	8,000	49,490
Manual seed placement	74	18,500	14,940	6,300	39,740
Planter (9.5 cm)	37	9,250	3,015	5,800	18,065
Planter (11 cm)	35	8,750	3,015	5,800	17,565

Table 6. Operating cost of the planter.

	Cost components	**Pea planter**	**Tractor**
Machine data	Purchase price (Rs.)	150,000	725,000
	Life (years)	10	10
	Life (hours)	2,400	12,000
	Annual usage (hours)	220	1,200
	Salvage value (Rs.) (10 % of purchase price)	15,000	72,500
Fixed cost	Depreciation (Rs./h) (difference of purchase price and salvage value)	613.64	54.38
	Interest (Rs./h) (15 % of the average of purchase price and salvage value)	56.25	49.84
	Insurance (Rs./h) (1 % of the average of purchase price and salvage value)	3.75	3.32
	Tax (Rs./h) (1 % of purchase price)	6.82	6.04
	Shelter (Rs./h) (1 % of purchase price)	6.82	6.04
	Sub Total (Rs.)	**687.27**	**119.63**
Variable cost	Cost of diesel (Rs./h) (@ Rs. 4.95 l/h; Rs.80/l)	0.00	396.00
	Lubricants/engine oil (Rs./h) (10 % of fuel cost)	0.00	39.60
	Driver cost (Rs./h) (Rs. 500/10h day)	0.00	50.00
	Helpers' wages (Rs./h) (Rs. 500/10h day)	0.00	0.00
	Repair and maintenance (Rs./h) (5 % of purchase price)	34.09	30.21
	Sub Total (Rs./h)	**34.09**	**515.81**
	Operating cost (Rs./h)	**687.27+119.63+34.09+515.81 = 1,357**	
	Operating cost (Rs./ha)	**1,357×2.22 = 3,015**	

The average yield for broadcasting and manual seed placement methods was obtained 6,134 and 4,802, respectively (Table 7). The higher yield was obtained in broadcasting method due to emergence of greater sprouts. The labour requirement for planting peas with the planter was 2.22 man-hours per hectare, whereas the broadcasting and manual seed placement methods required 6 and 200 man-hours per hectare, respectively (Table 8). Besides the saving in cost of sowing, the planter would be of great help in achieving timeliness of sowing operation. For adoption of this machine for peas and vegetable production, its price should be reduced. Field planting with planter was monitored together with farmer and visualised clear difference from manual seed placement and broadcasted fields (Fig. 9).

Table 7. Economics of different pea planting methods.

Method	Total cost (Rs./ha)	Yield (kg/ha)	Income from yield @Rs.40/kg (Rs./ha)	Net benefit (Rs./ha)
Broadcasting	49,490	6,134	245,360	195,870
Manual seed placement	39,740	4,802	192,080	152,340
Planter (9.5 cm)	18,065	5,733	229,320	211,255
Planter (11 cm)	17,565	5,869	234,760	217,195

Table 8. Labour requirement (man-hours/ha).

Method	Planting	Harvesting	Total
Broadcasting	6	160	166.0
Manual seed placement	200	126	326.0
Planter (9.5 cm)	2.2	116	118.2
Planter (11 cm)	2.2	116	118.2

Figure 9. Farmer's point of view about planter performance.

***Conclusions*:** A pneumatic pea planter was developed and field evaluated. The actual field capacity of the planter was 0.45ha/h with an efficiency of 58.6%. Seed placement depth of the planter was 5 cm, which was variable in broadcasting and manual seed placement methods. Maximum germination and uniformity in row spacing and plant spacing were visualised in the fields sown with the planter. The operating cost of the planter was Rs. 3,015/ha, which was 395.52 and 73.8% lower than the manual seed placement and broadcasting methods, respectively. By using the pea planter, a farmer can achieve Rs. 64,855 and 21,325 more benefit from one hectare than manual seed placement and broadcasting methods, respectively. Timely sowing, quality of work and less drudgery were additional vital benefits to the farmer using this machine. Row to row distance of 76 cm was too large to give required yield. Therefore, in future fabrication, the pant to plant distance needs to be reduced up to 45 cm, whereas the row to row distance needs to be reduced up to 45 cm for better yield and economic benefits. The pea planter is a good initiative for improving vegetable mechanisation of the country.

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