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Determination of Energetic and Ergonomic Parameters of a Semi-automatic Sugar-beet Steckling Transplanter

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ABSTRACT

Manual planting of sugar-beet stecklings is a very laborious and time-consuming operation. To overcome the problems, and decrease the cost of operation to a reasonable level, a semi-automatic steckling transplanter was designed. The suitability of the steckling transplanter with regard to the agrotechnical requirements of sugar-beet stecklings was studied and the main field performance parameters of the machine were measured. The results showed that the transplanter was able to place the stecklings with a row spacing of 65 cm and a plant spacing of 50.3 cm at a selected depth of 13 cm. Deviations of the steckling placements relative to their theoretical positions were 4.5 % and 3.6 % along the row and in a direction perpendicular to the row respectively. For a forward speed of 0.6 km/h and a maximum planting depth (18 cm), the required draft was 4.05 kN.

Keywords: Semi-automatic, Steckling, Sugar-beet, Transplanter.

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INTRODUCTION

Sugar-beet steckling transplanting is a very laborious and time-consuming operation. It is therefore very important to minimize the time and labor required for this process.

Bornscheuer *et al*. (1993) reported that early planting gives higher seed yield. The commonest method of producing hybrid seeds is strip planting with the female and male components planted separately. Stecklings must be planted vertically in the soil at the correct depth, with the top of the crown covered with soil. For optimum seed yield, a plant population of 30,000 plants/ha must be achieved with row spacings of 65 cm and a 50 cm plant spacing along the row. Smith *et al*. (1984) described field-tested automated machines to transplant sugar-beets, while Hauser (1985) described a transplanter for grass seedlings. Suggs *et al*. (1986) designed and constructed a self-feeding transplanter for tobacco and vegetable crops. They demonstrated that the machine operated well at speeds up to 100 plants/min. They also constructed and evaluated an automatic feeding bare-root transplanter. It was operated at speeds up to 43 plants/min, but 30% misplanting occurred. A mechanism for transplanting seedlings extracted directly from a commercial growing flat was designed and tested by Munilla and Shaw (1987). Brewer (1988) conducted an experiment using an automatic feeder for seedling transplanter. He described a laboratory bench model of a new feeder mechanism for free-cell seedlings. It transferred 90% of the seedlings at a rate of 30 to 60/min. Accord Land Machine Company (1963) developed a semi-automatic transplanter, in which fingers were fitted in pairs to the feed in along with disks to hold the steckling and feed it past the share. Odighboh (1978) described a two-row automatic cassava-cutting planter. Ardalan and Hassan (1982) described a method for the automatic feeding and storing of bare-root seedlings: after singulation, bare-root seedlings could logically be stored on a tape and transplanted later. Graham and

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Rohrbach (1993) constructed and evaluated a hook device to withdraw tree seedlings from a container. Also, several other varieties of transplanters were designed, constructed and evaluated by Boa (1984), Penley (1981), Pretzer (1984), Maw (1984), Khan and Gunkel (1988) and Kohli (1985). To mechanize sugar-beet transplanting some work was done by Kazmeinkhah (1997), resulting in a two-row semi-automatic sugar-beet steckling transplanter design, construction and evaluation.

MATERIALS AND METHODS

The machine designed comprises transport wheels, a hopper, two furrow openers, a metering disk with two grippers, a covering device consisting of two disk type ridgers, two driving press wheels and two operator seats (Figure 1). Ground driven press wheels powered the metering mechanism of the machine; therefore, within-any row spacing of the stecklings, the mechanism was independent of the tractor forward speed.

The operators sitting on the transplanter seats pick the stecklings from the hopper, feeding them into the grippers with the crown downward. The motion of the grippers was provided by the profile of a stationary cam. The steckling was held firmly between the jaws of the gripper. When the steckling was at it's lowest position in the furrow, the jaws of the gripper opened. The steckling was covered with soil by the covering device and a ridge was formed. A pair of press, wheels moving in an oblique position, followed the covering device and compressed the soil around the stecklings.

The field tests of the sugar-beet steckling transplanter were conducted in the Agriculture Machinery Test Center of the Republic of Azarbaijan in 1995. The transplanter was tested for it's suitability with regard to the agrotechnical requirements of the stecklings and the ergonomic and power requirement parameters were determined. The experiments were done in an experimental field measuring four hectares, with 4 replications. The experimental conditions are given in Table 1.

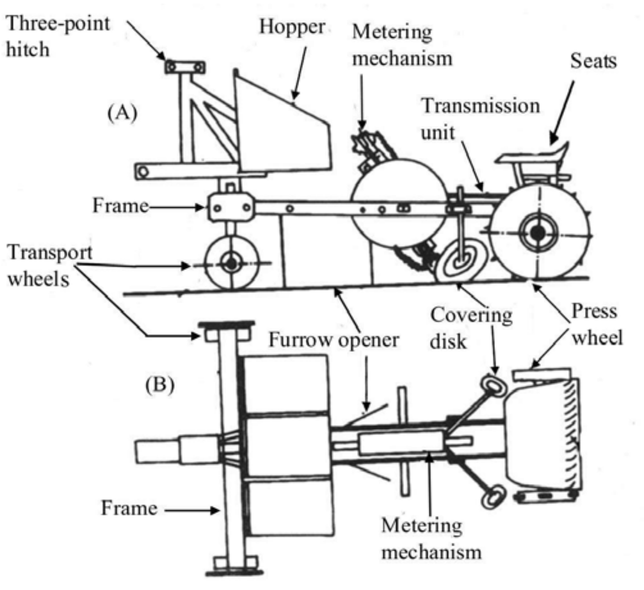

Figure 1. Semi-automatic sugar-beet steckling transplanter assembly: (A) Side view and (B) Plan view.

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Table 1. The experimental conditions.

Field	
Soil moisture % (dry basis)	1.3-15.1
Cone index (MPa)	1.5-4.3
Soil texture	Clay loam
Soil color	Brown
Field slope	Level
Tractor	
Model	M.T.Z.80
Gear	1-low
Transplanter	
Forward speed (km h^{-1})	0.716-0.730
Planting width (cm)	130
Planting depth (cm)	12-18
Steckling	
Length (cm)	12-14
Stem (cm)	2-6
Mass (g)	70-130
Moisture % (dry basis)	83

The values are the average of 100 observation.

Tests

Suitability of the Transplanter in Relation to the Agrotechnical Requirements of the Stecklings

An experiment was conducted for determination of row spacing, plant spacing along the row, planting depth, ridge height uniformity, deviation of steckling spacings along the row and in a direction perpendicular to the row. All measurements were based on the standards given by the International Organization for Standardization (ISO).

Determination of Power Requirement of the Transplanter

The required parameters, namely draft, transplanter forward speed, drawbar power and fuel consumption were measured by a mobile field laboratory. During transplanting operations, the mobile laboratory following the transplanter measured the factors being studied. Also measurement of the transplanter draft was checked by another method. In this method two MTZ 80 tractors were hitched face-to-face through a dynamometer, with the transplanter mounted to one of the tractors. The other tractor moved the one mounted with transplanter (Figure 3). In both tests, the tractor motion resistance and the force needed to pull the tractor and transplanter combination were measured. Then, the draft required to pull the transplanter and drawbar power were calculated. In the second test, as shown in Figure 3, the line of pull was not horizontal. Therefore, all the data measured in this method were multiplied by cos 17 to correct the draft values.

Figure 2. Determination of the energetic and ergonomic parameters of the designed transplanter using a mobile laboratory.

Determination of Ergonomic Parameters

Some of the ergonomic parameters were investigated by interviewing the operators, and some of them were measured using a mobile laboratory (Figure 2). The amount of dust raised during the transplanting operation, which may be harmful to the health of operators, was measured. Also, the number of stecklings that each operator could take out of the hopper and put into the gripper of transplanter was determined. The results obtained were compared with the ergonomic parameters of a semi-automatic potato planter.

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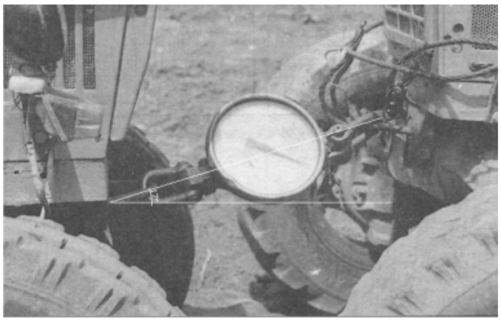

Figure 3. Method of determining required draft.

RESULTS AND DISCUSSION

The results of experiments showed that the steckling transplanter planted the stecklings upright in the ridges with a 65 cm row spacing, a 50.38 cm plant spacing along the row and at a selected depth of 13 cm (Table 2). The row spacing was quite uniform, but the plant spacing along the row was higher than agronomical requirements of the steckling. This was due to the transplanter wheels slip page.

About 95% of the stecklings were planted vertically. Deviations in the steckling placements relative to their theoretical positions along the rows and in a direction perpendicular to the row were 4.5% and 3.6% respectively. Also these data proved that the steckling transplanter was suitable for the transplanting operation (Table 3). It has been demonstrated that the stecklings must be planted vertically in the soil at a correct depth, with the top of the crown covered with soil. For optimal seed yield, a plant population of 30,000 plants per hectare must be achieved with a row spacing of 65 cm and a plant spacing of 50 cm (Bornscheuer *et al*., 1993). The amounts of draft at different depths of planting are given in Table 4. As indicated in Figure 4, the relationship between the draft requirement and planting depth is linear. When the planting depth varies from 12 to 18 cm, the amount of draft changes from 2,600 to 4,050 N accordingly. When the working speed of the transplanter altered from 0.199 to 0.203 m/s, the drawbar power varied from 0.528 to 0.806 kW (Figure 5). For the maximum planting depth (18 cm) with full hopper of stecklings and two operators on the board, the maximum drawbar power was 0.8 kW (Figure 5). However, regardless of the type of tractor used, the forward speed during transplanter operations must not exceed 0.6 km/h. The Accord Land Machine Company (1963) and Ranjbar *et al*. (1996) indicated that the suitable speed for a

Table2. Transplanting accuracy data for the transplanter.

Replications	Parameters		
	Row spacing (cm)	Plant spacing (cm)	Planting depth (cm)
1	65	49.4	13
2	65	50.5	12.5
3	65	51	13.5
4	65	50.6	13
Mean	65	50.38	13

The values are the average of 30 observations.

Table 3. Deviation percent of the transplanted stecklings.

Replication	Side		Vertical line	
	Left (%)	Right (%)	Front (%)	Back (%)
1	5	6	4	4
2	4	4	4	3
3	5	4	3	4
4	3	5	4	3
Mean	4.25	4.75	3.78	3.5
Max deviation Angle	4°	5°	5°	4°

The values are the average of 30 observations.

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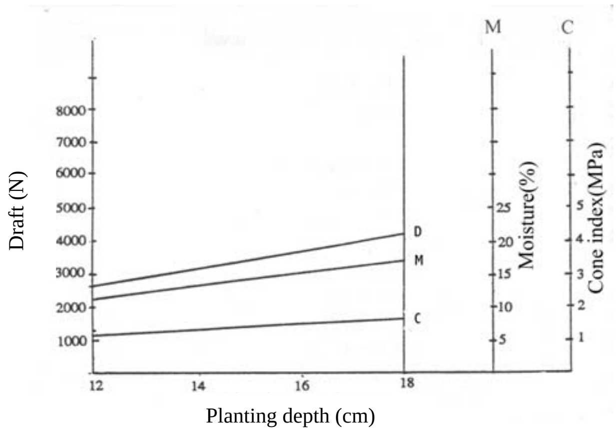

Figure 4. Variations in the draft (D), soil moisture content (M), and cone penetration resistance (C), vs. planting depth.

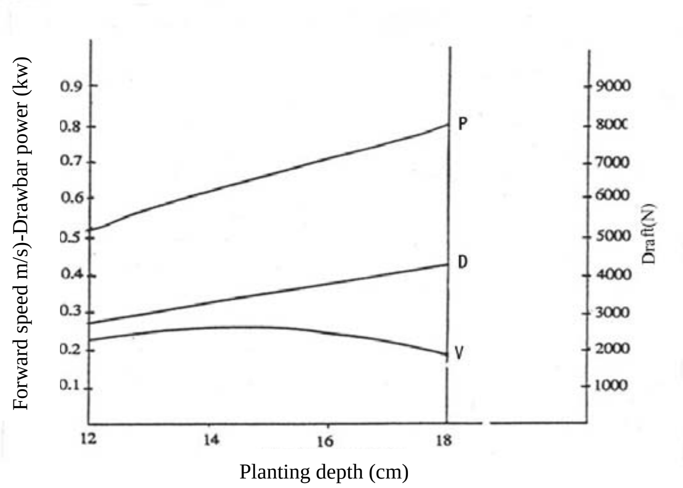

Figure 5. Variations in the tractive power (P), draft (D), and forward speed (V) vs. planting depth.

semi-automatic planter is 0.5 km/h. The fuel and energy consumption of the tractor for transplanting operation was 0.663 L/h and 0.410 kw/h, respectively (Table 5).

The transplanting capacity of the machine was 14 stecklings per operator per minute. The ergonomic parameter results showed that when the forward speed of the transplanter varied from 0.199 to 0.203 m/s, the operators had sufficient time to take the stecklings out of the hopper and put them into the transplanter grippers. The planting rates of a semi-automatic planter reported by Nix and Hill, (1986) were in the range of 25-30 plant per operator per minute. However, 35-40 seedlings per operator per minute for a seedling transplanter and 15 plants per operator per minute for a tobacco transplanter have also been reported by Listopad (1986) and Suggs *et al*. (1986), respectively. The amount of dust raised during transplanting operations was 0.005 g/m^3 (Table 6). According to the report by Aliev and Eslamev (1999), the acceptable amount of poisonous dust and harmful molecules raised by animal and man in the work environment were 0.002-0.006 g/m^3. However, Doulin (1982) and Koloshin (1981) reported that it could range from 0.002 to 0.010 g/m^3.

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Table 4. Energetic parameters for transplanting of stecklings.

		Planting depth (cm)			
Parameters	R[a]	12	14	16	18
F[b]	1	2700	3200	3700	4100
V[c]		0.208	0.204	0.200	0.200
F	2	2600	3300	3800	4000
V		0.196	0.201	0.205	0.198
F	3	2500	3200	3700	4100
V		0.205	0.200	0.200	0.198
F	4	2600	3100	3600	4000
V		0.205	0.200	0.197	0.202
ATD [d]		2600	3200	3700	4050
ATFS[e]		0.203	0.201	0.200	0.199
ARDP[f]		0.528	0.643	0.740	0.806

[a] Replications.
[b] Draft (N).
[c] Transplanter forward speed (m/s).
[d] Average value for the transplanter draft (N).
[e] Average value for the transplanter forward speed (m/s).
[f] Average value for the required drawbar power (kW).

Table 5. Fuel consumption and tractor power.

Replications / Parameters	1	2	3	4	Mean
Fuel consumption (L h^{-1})	0.681	0.687	0.647	0.637	0.663
Drawbar power (kW)	0.406	0.406	0.419	0.412	0.410

The values are the average of 30 observations.

CONCLUSIONS

1. The steckling transplanter demonstrated a good suitability for the steckling transplanting operation. About 95% of the stecklings were planted in the ridges upright with a 65 cm row spacing, 50.38 cm plant spacing and at a selected depth of 13 cm.
2. At a forward speed of 0.199-0.203 m/s the required draft and drawbar power were 2.6-4.05 kN and 0.528- 0.806 kW, respectively. The fuel consumption and power required for the transplanting operation were 0.66 L/h and 0.410 kW, respectively.
3. Mechanical transplanting and mechanized inter–row cultivation, weeding and seed harvesting are possible.
4. In order to meet safety standards, the transmission chains need to be covered.

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Table 6. Comparison of ergonomic parameters of designed steckling transplanter with a semi-automatic potato planter.

Ergonomics parameters	Potato planter (based on ISO standards)	Designed steckling transplanter
Safety of machine during operation	Good	Good
Ease of maintenance	Good	Good
Ease of work	Good	Good
Number of plant per operator per minute	20-25	14
Quantity of raised dust during machine working ($g\ m^{-3}$)	0.010	0.005
Operators opinion	Positive	Positive

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تعیین مشخصات انرژتیکی و ارگونومیکی ماشین ریشچه‌کار چغندرقند

ک. کاظمین خواه

چکیده

کاشت دستی ریشچه چغندرقند از مراحل پر هزینه و زمان‌بر می‌باشد. برای افـزایش کـارآئی کـارگر و کـاهش هزینـه‌هـا، یکدسـتگاه ماشـین ریـشچه‌کـار نیمـه‌اتوماتیـک طراحـی و نمونـه‌سـازی شـد. نیازهـای آگروتکنیکی ریشچه مطالعـه و بـا ماشـین تطبیـق گردیـد و پارامترهـای اصـلی ظرفیـت مزرعـه‌ای (Field capacity) ارزیابی و اندازه‌گیری شدند. نتایج آزمایشات نشان داد که ماشین توانائی کاشت ریـشچه‌هـا را در فاصله بین ردیفی ۶۵ سانتیمتر، فاصله بین بوته‌ای ۵۰/۳۸ سـانتیمتر و عمـق کاشـت مناسـب ۱۳ سـانتیمتر داشت. انحرافات ریشچه‌ها نسبت به خـط کاشـت ۴/۵ درصـد و نـسبت بـه خـط قـائم ۳/۵ درصـد بودنـد. هنگامی که ماشین با عمق کاشت بیبشینه ۱۳ سانتیمتر و بـا سـرعت پـیش‌روی ۶/ کیلـومتر در سـاعت کـار می‌کرد ،توان مورد نیاز ماشین ۴/۰۵ کیلو نیوتن محاسبه گردید.

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