Development of a Vacuum Nozzle Seeder for Large Seeds in Cucurbitaceae

D. E. Kim, Y. S. Chang, J. K. Kim, H. H. Kim, D. H. Lee

Abstract: This study aimed to develop a seeder for sowing large seeds such as those of fruit vegetables used as rootstocks in grafting. It investigated how the nozzle diameter and the nozzle's vacuum pressure affected the seeding performance. This study found that a nozzle diameter of 1.5 mm was capable of sowing most of the seed sizes used in this study. The highest seeding rates for 'Chambak', 'Tuktozwa', and 'Hukjong' were 97.6%, 98.8%, and 97.6%, respectively. Lineup status after sowing was good. The working performance was 75.6 sheets/hr. An average seeding rate of 1 grain was 97.8%.

Keywords: Seeder, Raising Plug Seedlings, Vacuum, Agricultural Machinery

Introduction

Fruit vegetables such as cucumber, tomato, pepper, and watermelon were grown in the greenhouse. Most cultivated crops raised in the plug production greenhouse were grafted seedlings. Most of the seeds of the rootstock used for grafting were mainly sown by hand.

The elongation direction of the large seed's cortyledon was affected by the seed's sowing status. It was possible for a general seeder to sow mechanically with the same spacing but was difficult to sow in a lineup. A lineup seeder for cucurbitaceous seeds was developed, which sows large seeds in a unifying major axis direction and embryo position (Yamada 2004). The elongation direction of the cortyledon after germination was lined up in a row.

This study examined the suitable operating conditions to mechanize the sowing of large seeds such as those of fruit vegetables used as rootstocks in grafting. It aimed to develop a vacuum nozzle type seeder to sow large seeds in a row.

Materials and Methods

The experiment device tested the effects of the nozzle diameter, vacuum pressure, and vibration of seeds, among other things, to examine the factors affecting precise seeding. The seeder had a belt conveyor, seed supplement device with roller, sowing device, nozzle, vacuum ejector, and a control unit with a programmable logic controller (PLC).

The sowing device had a sowing hopper, a guide bar attached to a hopper, and a pneumatic cylinder. The supplement device had a roller for discharging the seeds, motor, and conveyor. The nozzle was joined with a sealed cylinder attached to the end of a pneumatic cylinder. Fig. 1. shows a schematic diagram of the vacuum nozzle seeder for large seeds.

The seeder's conveyor speed was adjustable from 1.0 to 5.5 m/min and its vacuum flow rate was 105 ℓ/min. The seeder was metered by suction and discharged with vacuum. It sowed seeds with its sowing hopper.

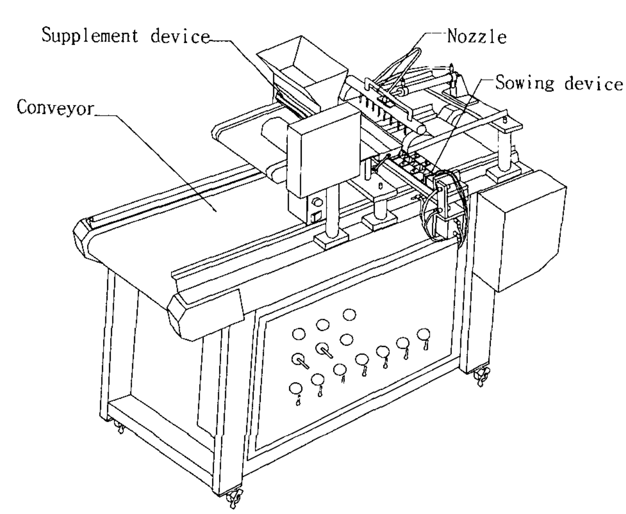

Fig. 1 Schematic diagram of the vacuum nozzle seeder for large seeds.

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The seeder was operated as follows: The conveyor moved a plug tray to a sowing hopper. The seed, attached to the nozzle by vacuum pressure, was moved to the sowing hopper by a pneumatic cylinder, and removing the vacuum discharged it. The sowing hopper went down to the press substrate in the tray. The sowing hopper opened, went up, and discharged a seed. The seed fell into a V shaped rectangular hopper and it lay on the hopper's face. The seed was sown in a row. Fig. 2 shows the operational flowchart of the seeder and Fig. 3 shows the seeder's pneumatic circuit.

Using a syringe needle with a diameter of 0.65 mm, the preparation test showed a low level seeding rate. For the experiment, the nozzle sizes used were 1.0, 1.5, and 2.0 mm. Fig. 4 shows the schematic diagram of the nozzle and cylinder used in the experiment.

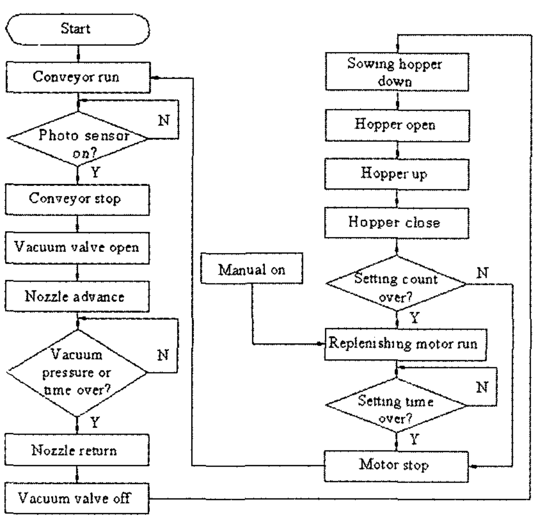

Fig. 2 Operational flowchart of the vacuum nozzle seeder.

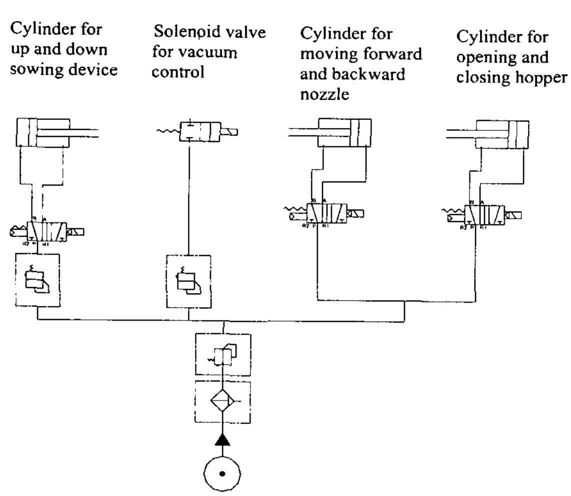

Fig. 3 Pneumatic circuit of the vacuum nozzle seeder.

The sowing device had a slider mounted hopper, V shaped hopper, pneumatic cylinder, and base. The hopper had a couple of hoppers and it opened and closed by the slider mounted hopper, sliding it from right to left. Fig. 5 shows the schematic diagram of the sowing device.

Table 1 dimensions of the seeds used in the experiment. Fig. 6 shows the samples of seeds used in the experiment.

The pick up distance between a nozzle and the seed was measured with digital a caliper (Mitsutoyo Co.), installed in support of the nozzle. The device measuring the pick up distance had a pneumatic regulator, nozzle, callipers, and solenoid valve, among other parts. The vacuum pressure in

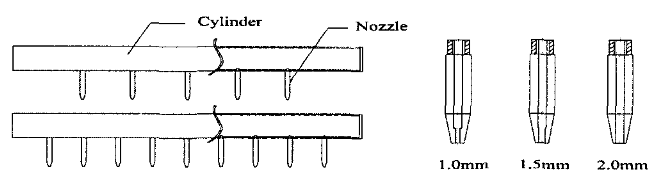

Fig. 4 Schematic diagram of nozzle and cylinder.

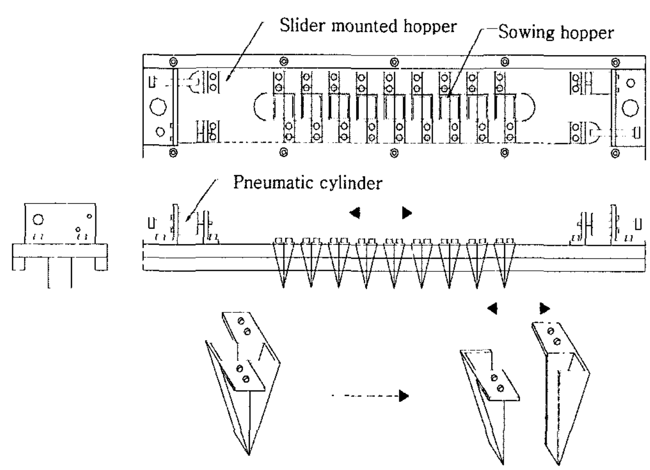

Fig. 5 Schematic diagram of the sowing device.

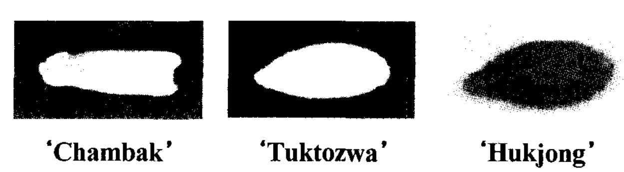

Fig. 6 Samples of the seeds used in the experiment.

Table 1 Dimensions of the seeds used in the experiment

Seed	Length (mm)	Width (mm)	Mass of 1,000 grains (g)
'Chambak'	14.39±1.0	6.84±0.3	146.4
'Tuktozwa'	16.21±0.8	9.37±0.3	189.9
'Hukjong'	17.66±1.3	0.78±1.0	197.2

the nozzle was measured with a vacuum gauge installed between the vacuum ejector and the sowing nozzle, under conditions without an attached seed. The vibration acceleration was measured with a pulse type 3560 of the Brüel & Kjaer Co.

The seeding performance according to the nozzle diameter, vacuum pressure, and vibration of the seed hopper was examined using the seeds of a calabash gourd, 'Chambak'; a gourd, 'Tuktozwa'; and a malaba gourd, 'Hukjong'. Experimental treatments were as follows: nozzle diameters were 1.0, 1.5, and 2.0 mm; vacuum pressures were from 0 to 13.3 kPa; and the the seed hopper's vibration accelerations were 39.3, 53.2, and 60.3 $m \cdot s^{-2}$. The developed seeder's performance was examined using 162 cell trays and the gourd, 'Tuktozwa'.

Results and Discussion

Experiment was carried out to investigate the distance between the nozzle and the seed as affected by the vacuum pressure and nozzle diameter. The pick up distance between the nozzle and the seed got wider when vacuum pressure went up. The pick up distances of the nozzles with 1.5 and 2.0 mm diameters, as affected by the vacuum pressure, were observed to be similar. However, the pick up distance for a 1.0 mm nozzle diameter was lower than those of the other two nozzles. The highest pick up distances achieved for nozzle diameters of 1.0, 1.5, 2.0 mm were 0.74, 1.7, 1.7 mm, respectively. Fig. 7 shows the pick up distance according to the nozzle diameter, as affected by the vacuum pressure.

The pick up distances according to the seed type were similar in all the nozzles. The highest distance in this experiment was about 1.5 mm. Fig. 8 shows the pick up distance according to the nozzle diameter, as affected by the

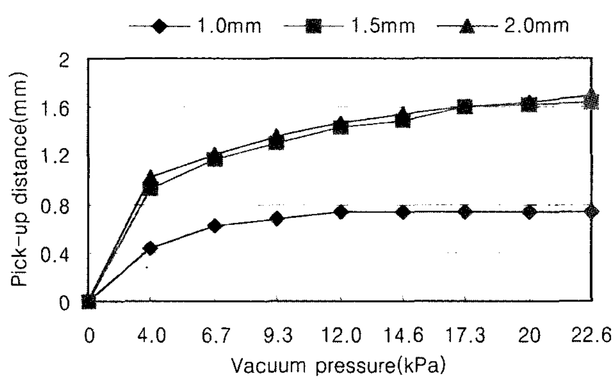

Fig. 7 The effect of the nozzle diameter on the pick up distance at different vacuum pressures.

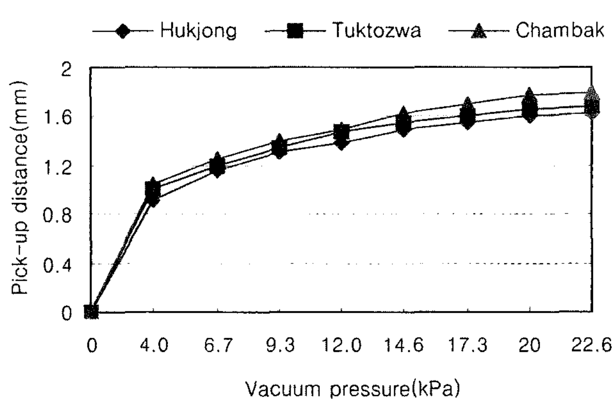

Fig. 8 The effect of the seed type on pick up distance at different vacuum pressures.

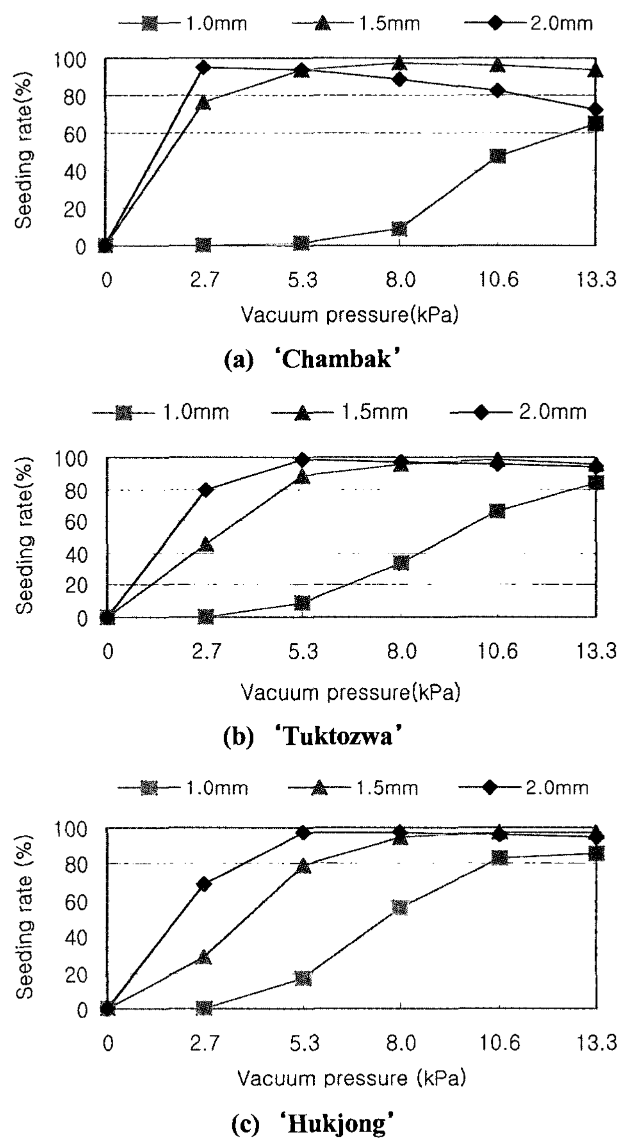

Fig. 9 The seeding rate of the nozzle diameters, according to the seed type, as affected by the vacuum pressure.

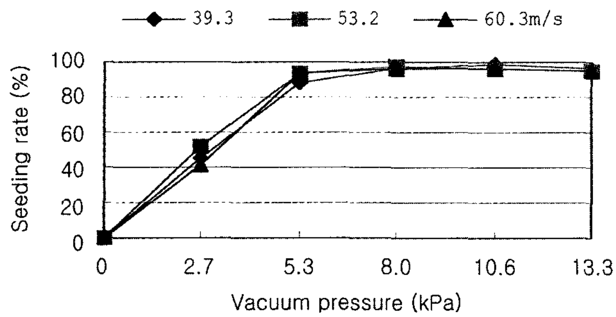

Fig. 10 The effect of vibration acceleration on the seeding rates at different vacuum pressures.

seed type.

With the 1.0 mm nozzle diameter, a seeding rate of 1 grain increased continuously little by little as vacuum pressure went up. With the 1.5 and 2.0 mm nozzle diameters, a seeding rate of 1 grain increased rapidly until an optimal vacuum pressure and decreased at its more. The 1.5 mm nozzle diameter's highest seeding rates were achieved for 'Chambak', 'Tuktozwa', and 'Hukjong' at vacuum pressures of 8.0 kPa, 10.6 kPa, and 13.3 kPa, respectively; for the 2.0 mm nozzle diameter, highest seeding rates were achieved at vacuum pressures of 2.7 kPa, 5.5 kPa, and 5.3 kPa for 'Chambak', 'Tuktozwa', and 'Hukjong', respectively. As seed is heavy, the vacuum pressure revealed the highest seeding rate is higher. Fig. 9 shows the seeding rate of the different nozzle diameters, according to the seed type, as affected by the vacuum pressure.

Fig. 10 shows the seeding rate at different vacuum pressures, as affected by the vibration acceleration of the seed hopper. For 'Tuktozwa', a seeding rate of 1 grain increased at 8.0~10.6 kPa, but decreased more by vibration acceleration. Differences in seeding rates among the seed types, as affected by vibration acceleration, were minimal.

The optimal conditions for 'Chambak' are a nozzle diameter of 1.5 mm at a vacuum pressure of 8.0 kPa; for 'Tuktozwa', a nozzle diameter of 1.5 mm at a vacuum pressure of 10.6 kPa, as well as a nozzle diameter of 2.0 mm at a vacuum pressure of 5.3 kPa; for 'Hukjong'. a nozzle diameter of 1.5 mm at a vacuum pressure of 13.3 kPa, as well as a nozzle diameter of 2.0 mm at a vacuum pressure of 5.3 kPa. At these optimal conditions, the seeding rate of the vacuum nozzle seeder achieved 97%. Table 2 shows the optimal conditions of the vacuum nozzle seeder and the highest seeding rates of the seed types.

Table 3 shows the sown seeds' lineup status. A good lineup status after sowing was achieved for 'Chambak', 'Tuktozwa', and 'Hukjong' at 89.4%, 96.4%, and 95.2%, respectively. 'Chambak' had a lower lineup status that the other two because its shape had a corner. View of sowing status of 'Tuktozwa' seed is shown in Fig. 11.

Table 4 shows the performance of the developed seeder. The seeder's working eficiency was 75.6 sheets/hr and its seeding rate of 1 grain was 97.8%.

Table 2 Optimal conditions of the vacuum nozzle seeder and the highest seeding rates of the seed types

Seed	Diameter of nozzle (mm)	Vacuum pressure (kPa)	Seeding rate (%)
'Chambak'	1.5	8.0	97.6
'Tuktozwa'	1.5	10.6	98.8
	2.0	5.3	98.8
'Hukjong'	1.5	13.3	97.2
	2.0	5.3	97.6

Table 3 Lineup status after sowing with the vacuum nozzle seeder

Seed	Good (%)	Fair (%)	Bad (%)
'Chambak'	95.2	3.2	1.6
'Tuktozwa'	96.4	1.6	2.0
'Hukjong'	89.4	5.2	5.4

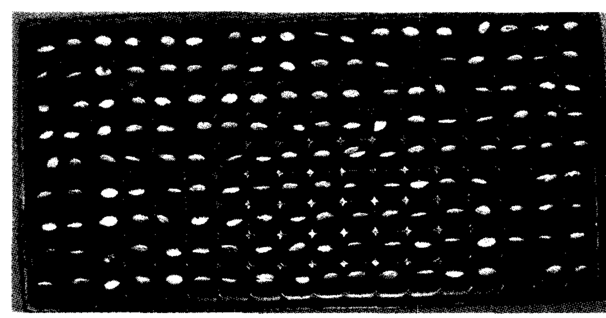

Fig. 11 The seeder sown seeds.

Table 4 Performance of the vacuum nozzle seeder

Item		Performance
Working efficiency (sheet/hr)		75.6
Seeding rate (%)	1 grain	97.8
	more than 2 grains	2.2

Conclusions

The experimental research aimed to identify the optimal conditions for mechanically sowing large seeds such as those of fruit vegetables used as rootstocks in grafting. A vacuum nozzle type seeder was developed on the basis of the experimental results and was tested for its performance.

The developed seeder had a belt conveyor, seed supplement device with roller, sowing device, nozzle, vacuum ejector, and control unit with PLC. The sowing device had a slider mounted hopper, V shaped hopper, pneumatic cylinder, and base. The hopper had a couple of hoppers and it opened and closed by sliding the slider mounted hopper from right to left.

Optimal conditions for precision seeding were determined by experimenting on the nozzle diameter, vacuum pressure, and seed hopper vibration. Results showed that the heavier the seed, the higher the optimal vacuum pressure. Differences in seeding rates as affected by the vibration acceleration were minimal. A nozzle diameter of 1.5 mm and a vacuum pressure of 8.0 kPa and over were ideal for the seeds used in this study. The seeding rate for the three seed types in this experiment was 97% and over.

The lineup status after sowing for 'Chambak', 'Tuktozwa', and 'Hukjong' was 89.4%, 96.4%, and 95.2%, respectively. The developed seeder's working efficiency was 75.6 sheet/hr and its seeding rate of 1 grain was 97.8%.

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