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METERING UNIT PERFORMANCE OF A VACUUM TYPE PRECISION VEGETABLE PLANTER

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Abstract: The objective of this study was to determine the seeding performance of a precision vegetable planter with vacuum type metering unit at different seed spacings and forward speeds using onion and carrot seeds. The seeding performances were investigated and evaluated based on the seed distribution accuracy on sticky belt stand tests in laboratory conditions. The experiments were conducted at the forward speeds of 1.0, 1.5 and 2.0 m s^{-1}, and seed spacing of 25 and 50 mm for each seed. The vacuum plate of precision metering unit with 90 holes and hole diameter of 0.8 mm was used. The seed distribution accuracy was determined according to the factor of variation (V_f) and goodness criteria (λ) which are represented to be compatible with the Poisson distribution. The factors of variation were found in the range of 0.74-0.89 for carrot and 0.52-0.55 for onion. These values indicated that carrot and onion seeds can be planted in the character of precision seeding by a vacuum type vegetable planter. According to results of the experimental tests it was found that seed distribution accuracy of machine was in very good quality for carrot (λ = %78.42-%93.16) and onion (λ = %88.95-%94.11) seeds.

Key words*: carrot, onion, vacuum precision seeding, seed distribution accuracy*

INTRODUCTION

Precision seeding is the preferred method at present and the use of pneumatic precision planters has an increasing trend in the world since it provides more uniform single seed spacing without multiples and misses for row crops and vegetables. It is

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necessary to operate the planters at high performance for sowing of very small vegetable and oil seeds. Because in vegetable planting, seeding rate is very low and providing similar living space without eliminating competition among plants is difficult and seed costs are very high. there are limited number of studies on vegetable precision seeding in the literature even though many studies focused on precision seeding of row crops such as cotton, maize, sunflower, soybean etc.

One of the limited studies was conducted by [1] using belt type and vacuum type vegetable planters and they determined that a belt planter was as effective at singulating spherical seeds (cabbage) and nearly spherical seeds (onion) as the most precise vacuum planter, but seeding uniformity of all planters with elongated (carrot and cucumber) or angular (spinach) seeds was inadequate for precision seeding. The belt planter was also more effective than the vacuum planters at spacing the seeds uniformly within the target area when outliers (missed and multiple seed drops) were removed.

A low-cost pneumatic precision planter was developed and tested in the field by [2]. The evaluation of the precision planter based on the optimized design, and operational parameters revealed that quality of feed index more than 90% with a miss index of about 3-5% can be achieved. Plant spacing accuracy was affected by planter speed; higher planting speeds (>3.8 km h^{-1}) resulted in less accuracy than the slower speeds.

It was investigated by [3] that seed flow rate, seed flow evenness and in-row seed distribution uniformity of fluted rollers were examined in the laboratory experiments for the random seeding of uncoated onion, carrot, canola and coated canola seeds. They developed regression models that include the seed flow rate changes with “large scale fluted roller's active flute length, rates of revolution. They found that seeding unit was capable of sowing of uncoated onion and carrot seeds at “moderate” quality, and coated and uncoated canola seeds at “good” quality” from the point of λ goodness criteria and V_f factor of variation. In this study the seeding performance of the metering unit of a vacuum type precision vegetable planter was determined in carrot and onion seeding at different forward speeds and seed spacings. The seed spacings used in the experiments were chosen specially at very low distances for precision seeding and the response of metering unit was determined under this condition.

MATERIAL AND METHODS

The precision vegetable planter (Fig 1a) used in the experiments was a vacuum type metering unit (Fig 1b) consisting of a vertically operating plate where the pressure differential is supplied by creating vacuum on the side of the disc opposite the seeds. The vacuum plate with 90 holes, hole diameter of 0.8 mm was used. Besides positive pressure is applied to the disc for the hole cleaning after seeds are released. In the experiments, vacuum pressure of 4.0 kPa for carrot, 5.0 kPa for onion was applied while the positive pressure was set to 0.8 kPa was for hole cleaning. A ground-driven wheel transfers the motion to the seed plate with a combination of gears available that provides different seed spacings.

A greased belt stand was used for the tests and the vegetable planter was set to the theoretical seed spacing (Z) of 25 mm and 50 mm for both onion and carrot seeds. The physical properties of the seeds are tabulated in Tab. 1. The carrot seeds were calibrated before experiments using a sieve in the diameter of 1.5 mm.

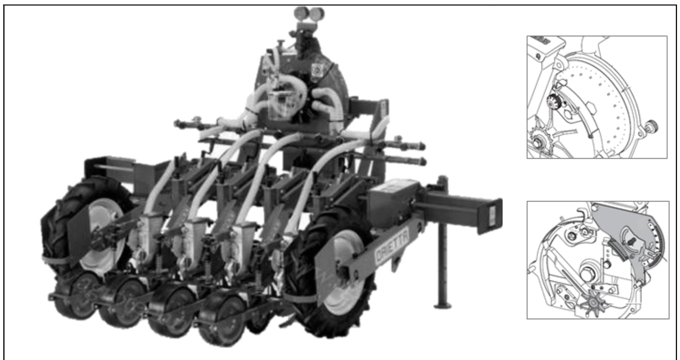

Figure 1. The precision vegetable planter (a) and vacuum type metering unit (b)

Table 1. The physical properties of carrot and onion seeds

Phsical property	Carrot		Onion	
	Mean	Standard Error	Mean	Standard Error
Length l, mm	2.28	0.103	2.93	0.069
Width w, mm	1.28	0.055	2.06	0.035
Thickness t, mm	0.65	0.023	1.41	0.050
Sphericity ,%	0.544	-	0.697	-
Thousand seed mass, g	1.2	0.006	4.1	0.002

The seed distribution accuracy was determined by conducting sticky belt stand tests in the controlled laboratory conditions from 300 seed bands at each forward speed and seed spacing for each seed. The seeding uniformity performance of the precision vegetable planter was evaluated based on the factor of variation (V_f) and goodness criteria (λ) which are represented to be compatible with the Poisson distribution. The V_f and λ values of seed distribution were calculated using the equations given below for the number of seeds in the 300 bands [4]. Experiments were conducted at the forward speeds of 1.0, 1.5 and 2.0 ms^{-1}.

$$V_f = \frac{S^2}{\mu} \tag{1}$$

$$S^2 = \frac{\sum X_i^2 . f_i - (X_i . f_i)^2 / n}{n-1} \tag{2}$$

Where, X_i ; expected value, f_i ; relative value and n; number of sample. The character of row seed distribution was determined according to V_f values as given in Tab. 2 and the evaluation quality of the in row seed distribution uniformity which depicts the percentage of the bands with 1, 2 and 3 seeds was revealed according to λ values are tabulated in Tab. 3 [5]. The average of the seeds in each band (μ) was assumed to be ≈2 for the evaluation of quality of row seed distribution uniformity.

The experimental data were measured with a computer aided measurement system while the forward speed was controlled by an electronic device.

Table 2. The character of the in row seed distribution as the compatibility to Poisson distribution

V_f	Evaluation	Trend of Seeding
Vf >1.1	Negative Binomial Distribution	Undesirable seeding type with unacceptable misses and multiples in seed distribution
0.9 < Vf < 1.1	Poisson Distribution	Character of random seeding
Vf < 0.9	Binomial Distribution	Character of precision seeding

Table 3. The quality of the in row seed distribution uniformity

Λ	Evaluation
≥ 72	Very good
> 65-72	Good
> 55-65	Moderate
< 55	Insufficient

RESULTS AND DISCUSSION

The experiments carried out in the laboratory at the theoretical seed spacing of 25 mm and 50 mm for carrot and onion seeds from 300 seed bands at the forward speeds of 1.0, 1.5, and 2.0 m s^{-1} are given in Tab. 4, Tab. 5, Fig. 2 and Fig. 3.

According to results of the experimental tests, it is clear that in precision carrot seeding at seed spacing of 25 and 50 mm the precision vegetable planter performance was in “very good” quality for each forward speed as the quality of in row seed spacing distribution based on the goodness criteria (Tab. 4). Once the performance of the planter is investigated as the compatibility to Poisson distribution of the seed spacing uniformity, it is seen from Tab. 4 that all V_f values are smaller than 0.9. Namely, the trend of seed distribution is binomial (V_f < 0.9). This means that the precision vegetable planter could incorporate carrot seeds into the soil in the character of precision seeding.

Table 4. Seed distribution uniformity results obtained for seeding carrot seeds

Seed spacing (mm)	Forward speed (m s^{-1})	μ	λ	Evaluation of seeding quality	V_f	Evaluation of seeding character
25	1.0	2.12	92.63	Very good	0.79	Precision seeding
	1.5	1.96	84.74	Very good	0.78	Precision seeding
	2.0	1.92	78.42	Very good	0.74	Precision seeding
50	1.0	2.10	93.16	Very good	0.79	Precision seeding
	1.5	2.01	87.89	Very good	0.85	Precision seeding
	2.0	1.96	85.26	Very good	0.89	Precision seeding

While goodness criteria (λ) value is affected by the increase in forward speed negatively, V_f values are about the same. Negative effect of forward speed occurred at a seed spacing of 25 mm. Moreover forward speed has negative effects on the relative ratio of seeds number in the band. While the forward speed increases, the relative ratio goes down in the precision carrot seeding at both, 25 mm and 50 mm seed spacing (Fig. 2).

Table 5. Seed distribution uniformity results obtained for seeding onion seeds

Seed spacing (mm)	*Forward speed ($m\ s^{-1}$)*	μ	λ	*Evaluation of seeding quality*	V_f	*Evaluation of seeding character*
25	*1.0*	*1.96*	*93.68*	*Very good*	*0.52*	*Precision seeding*
	1.5	*1.95*	*91.05*	*Very good*	*0.55*	*Precision seeding*
	2.0	-	-	-	-	-
50	*1.0*	*2.02*	*94.11*	*Very good*	*0.52*	*Precision seeding*
	1.5	*1.98*	*92.05*	*Very good*	*0.55*	*Precision seeding*
	2.0	*1.96*	*88.95*	*Very good*	*0.53*	*Precision seeding*

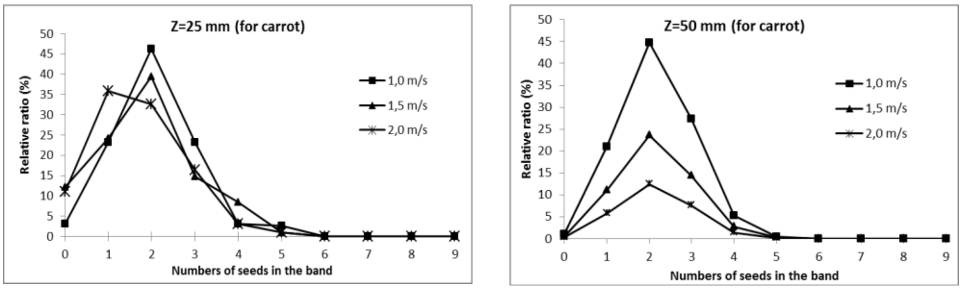

Figure 2. Relative ratio of the bands for carrot seeds

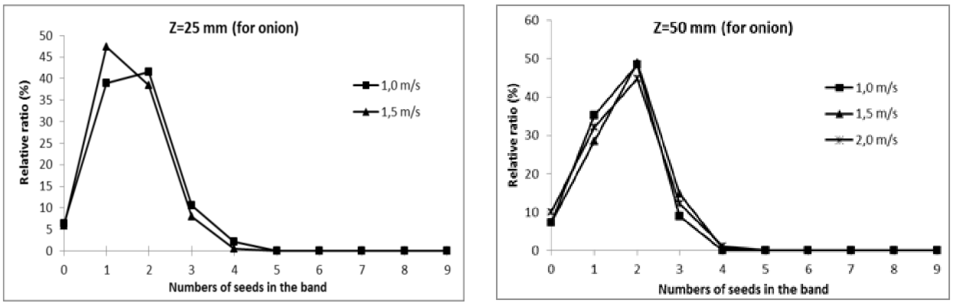

Figure 3. Relative ratio of the bands for onion seeds

As seen from Tab. 5, the onion seeding is in the character of precision seeding and seeding quality is in "very good" quality based on the V_f and λ values respectively, at all forward speeds for the seed spacing of 50 mm. This situation is also valid for the seed spacing of 25 mm, except the forward speed of 2.0 m s^{-1}. As the seed spacing decreases, the seed releasing frequency and the peripheral speed of the seed plate increase. This could be attributed to the fact that catching the seeds on the seed plate hole by vacuum becomes more difficult.

Another reason for the lower performance could be inappropriate use of hole diameter during the experiments. The use of vacuum plate with 1.0 mm hole diameter instead of 0.8 mm at higher forward speeds may result in increased performance. As seen from the overlapped graphs depicted in figure 3, the relative ratio of seed numbers for onion precision seeding is not affected by the variation of forward speed at all seed spacings and seed spacing contrary to carrot seeding.

For a quality sowing, single seed should be in each band and should not be more three. According to increasing ratio of bands without seed or with more than three seeds, the quality of sowing decreases. In carrot precision seeding the bands include two seeds for seed spacing of 25 mm and 50 mm, generally. But while there are some bands without seeds at all forward speed for 25 mm, but this did not happen for a seed spacing of 50 mm. This means that an increase in seed spacing affects the seed distribution accuracy positively.

Similarly, some bands include four and five seeds for 25 mm, but maximum four seeds in the bands for 50 mm. The numbers of bands with one or three seeds are in similar ratio and they are lower than number of bands with two seeds for both 25 mm and 50 mm. Only, for forward speed of 2.0 m s^{-1}, the number of bands with one seed is more than the others (Tab. 5). Because of this high level forward speed, the quality of seeding is found at the lowest value (λ = 78.42).

In onion precision seeding, the bands include two seeds as similar as carrot seeding, generally. Different from carrot seeding, the numbers of bands with one seed are higher than with three seeds for seed spacing of 25 mm and 50 mm (Fig. 2 and Fig. 3). The number of bands with one seed at forward speed of 1.5 m s^{-1} is higher than at 1.0 m s^{-1} for 25 mm. It can be said that the problem of holding seeds by vacuum on the seed plate started to occur at a forward speed of 1.5 m s^{-1}.

The metering unit of precision vegetable planter can seed onion seeds more precisely than carrot seeds. While V_f values of onion seeding were found within the range of 0.52-0.55. These same values for seeding carrot were found to be between 0.74 and 0.89. The variety of λ values were within the range of λ_{carrot}=78.42-93.16 and λ_{onion}=88.95-94.11 for carrot and onion seeds, respectively.

CONCLUSIONS

The results obtained from experiments indicated that carrot and onion seeds can be planted in the character of precision seeding by the same vacuum type vegetable planter in the "very good" quality. Onion seeding can be achieved more precisely than carrot seeding, but at higher forward speed affects the number of seed in the band at the low seed spacing.

Forward speed is an important variable for the relative ratio of the seed in the bands for carrot especially. The numbers of bands with one or three seeds are in similar ratio for carrot seeding, the numbers of bands with one seed are higher than with three seeds for onion seeding.

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PERFORMANSE MERNE JEDINICE VAKUUMSKE SADILICE ZA PRECIZNU SADNJU POVRĆA

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Sažetak: Cil ovog ispitivanja bio je da odredi performanse rada sadilice za preciznu sadnju povrća sa vakuumskim mernim uređajem pri različitim rastojanjima sadnje i brzinama pri sadnji semena luka i šargarepe. Radne performance su bile ispitivane i ocenjene na osnovu tačnosti distribucije semena na testovima sa lepljivim kaišem u laboratorijskim uslovima. Ogledi su izvođeni pri brzinama od 1.0, 1.5 i 2.0 m s^{-1}, i rastojanjima sadnje od 25 i 50 mm. Korišćena je vakuumska ploča preciznog mernog uređaja sa 90 otvora i prečnikom otvora od 0.8 mm. Tačnost distribucije semena bila je određena prema koeficijentu varijacije (V_f) i kriterijumu uklapanja (λ) koji su predstavljeni kao kompatibilni sa Poisson rasporedom. Koeficijenti varijacije bili su u opsegu od 0.74 do 0.89 za šargarepu i 0.52 do 0.55 za luk. Ove vrednosti pokazuju da semena šargarepe i luka mogu precizno da se seju vakuumskim tipom sadilice za povrće. Prema rezultatima testova tačnost distribucije semena bila je veoma dobra i za semena šargarepe (λ=%78.42-%93.16) i za semena luka (λ=%88.95-%94.11).

Ključne reči: *šargarepa, luk, vakuum precizna sadnja, tačnost dustribucije semena*

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