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Performance of a Metering Unit Equipped with a Fluted Roll for Seeding Coriander Seeds (*Coriandrum sativum* L.)

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A R T I C L E I N F O

Research Article

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A B S T R A C T

The objective of this study was to find out the performance of a seeding unit metering coriander seeds (*Coriandrum sativum* L.) with a fluted roll. As a first step for the determination of the performance of the metering unit, flow rate measurements were achieved at a combination of five roll lengths and ten different rpm values with three replications. The coefficient of variation (CV, %) was calculated and each CV value was used to characterize the flow evenness. The seed distributions were obtained at three seeding rates (15, 20 and 25 kg ha^{-1}) and three forward speeds (1.0, 1.5 and 2 ms^{-1}). The data obtained from the sticky belt test stand experiments; the seed distribution uniformity was evaluated based on two performance criterion. One of them was the variation factor (V_f) and the other one was the goodness criterion (λ). The CV (%) values of flow evenness were found to vary between 0.28 and 1.05%. On the other hand, the variation factor (V_f) values were found to range from 0.65 to 0.83 and these values indicated that the seeding can be characterized as precision seeding at all combinations of three seeding rate and three forward speeds. The goodness criterion (λ) values varied between 69 % and 77.3%. Based on the evaluation range of the goodness criterion (λ), the seeding at a seeding rate of 15 kg ha^{-1} and forward speed of 1.0 ms^{-1} along with the seeding rate of 20 and 25 kg ha^{-1} at a forward speed of 1.0 and 1.5 ms^{-1} was classified as very good. The rest of the four seeding rates and forward speeds combinations, the goodness criterion (λ) was evaluated to be good quality.

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Introduction

Medicinal and aromatic plants (MAPs) are such plants that are used as medicine in order to solve different health problems, maintain health and prevent diseases. They are also used in perfumery and cosmetics industry. Hence, they are of importance for the whole world and have a special commercial value. The main producing regions in the world are mainly India, Russia, Africa, Asia and Morocco (Deniz et al., 2018). In terms of trading, Turkey has also an important exporter of MAPS, especially thyme. According to Temel et al. (2018), there are twenty MAPs and they are grown around 0.13 million hectares in Turkey.

One of the MAPs is coriander. Coriander belongs to Apiaceae family and used for medicinal and nutritional purposes since 1500 BC (Deniz et al., 2018). It is mostly grown in Ankara, Antalya, Burdur, Eskişehir, and Konya. The production area of coriander in Turkey showed a significant increase especially in 2020 while the yield fluctuates from one year to another as shown in Figure 1.

Seed drills are usually used for seeding many crops seeds as well as MAPs seeds. The metering unit of seed drills are usually equipped with fluted or studded rolls and there are many studies concerning the flow rate and flow characteristics of different seeds from these types of rolls. The constructive properties of fluted rolls such as flute shape and dimensions, the volume of the flutes, the number of flutes, helical angle of the flutes contribute the flow rate and flow evenness. In addition to these, the dimensions of the seeds, sphericity, the friction coefficient of material on material and material with the fluted roll material are the factors that affect the flow.

Yıldırım et al. (2004) conducted a study with wheat and barley with semi-circular and trapezoidal shaped flutes and found that the semi-circular shaped flutes provided more uniform flow rate. Flow evenness values (CV, %) were found to be 2.92 and 3.93% for wheat and barley, respectively.

Yıldırım and Turgut (2007) investigated the flow of Alfalfa and sesame seeds from semi-circular, trapezoidal, triangle shaped fluted rolls. They found that the best flow was obtained with a fluted roll in the diameter of 56 mm with 22 semicircular flutes at 5-10 rpm at a roll length of 8 mm. Once they evaluated the results in terms of flow uniformity, the CV (%) as a flow evenness was found to range between 7 and 13% while the results for sesame seeds varied between 10 and 21%.

Güler (2005) studied the flow rate, flow evenness of sesame seeds from fluted rolls. The variables considered in the study was the flute diameter, active roll length and the rate of revolution. They used fluted diameter of 4, 6 and 8 mm at six different roll lengths. The CV values generally went down exponentially and ranged between 1.87 and 32.38%. Güler recommended that flute diameter of 6 and 8 mm and roll length of 15 and 25 mm at a roll speed of 20-40 rpm.

Kara et al. (2010) tested the performance of fluted rolls metering ammonium sulphate and diammonium phosphate. They used different rolls at different diameter, roll length and roll speed to investigate the flow evenness. The mean CV (%) values varied between 3.66 and 8.02 for the fluted rolls in the diameter at 10,12 and 14 mm while the values ranged between 3.23 and 7.66 for the rolls with a helical angle of 0, 10 and 20.

Altuntaş et al. (2007) conducted some experiments in the laboratory with wheat and vetch seeds and seed distribution was evaluated. The results obtained from the study indicated that forward speed and seeding rate should not be increased up to a certain level since this issue is of importance in order to obtain desired performance. They also indicated that improving seed distribution performance not only depends upon the metering unit but also forward speed and seeding rate.

In a latest study, Yazgı et al. (2017) studied the seed mixture flowing characteristics of a seed drill. Studded and fluted rolls used for the seed and fertilizer metering, respectively. The performance of the seed drill was tested for different vetch and barley mixtures. The flow evenness and seed distribution on a sticky belt result were evaluated based on the variation factor (V_f) and goodness criterion (λ).

These studies were mostly carried out with different crops rather than MAPs. Hence, a study was conducted and the objective of this study was to find out the performance of a metering unit equipped with fluted roll for seeding coriander seeds (*Coriandrum sativum* L.).

Materials and Methods

The coriander seeds were obtained from the market and the bulk density and the thousand seed mass was found to be 280 kg m^{-3} and 9.68 g, respectively. A special test unit designed and manufactured by Özdemir (2019) in order to obtain the volumetric efficiency of different crop seeds was used in this study. In this test stand, the roll in the diameter of 50 mm with 12 flutes (total cross section area of 579 mm^2) was used and driven by a step motor. A special software controlled the rotational speed of the roll with an accuracy of ± 0.1. The flow rate of the coriander seeds was obtained at different roll lengths and rpm values as a full factorial design (Table 1). Each test was carried out for one minute and triplicated.

The amount of seeds obtained in one minute was found by weighing seeds and a digital scale with the precision of ±0.01 g was used. The data obtained were then transferred to Microsoft Excel for further analysis in terms of flow rate, flow evenness and seed distribution calculations.

The flow rate data in terms of seed flow evenness were evaluated as CV (%) based on Önal (2011) as shown in Table 2.

The variation factor (V_f) in seed distribution was calculated using equation 1 while standard deviation was found using equation 2 (Griepentrog, 1994).

$$V_f = \frac{S^2}{\mu} \quad (1)$$

$$S^2 = \frac{\sum_{i=1}^{n} x_i^2 f_i - (x_i f_i)^2 / n}{n-1} \quad (2)$$

Where;

x_i: The expected number of seeds in the segment,

f_i: The segment ratio which is the percentage of the segments with different number of seeds

n: The total sample number.

Based on "V_f" values obtained from the experiments, the seed spacing was characterized and evaluated as tabulated in Table 3. The success in the quality of seed spacing was determined by goodness criterion (λ). This criterion is based on the percentages of segments with 1, 2, and 3 seeds and the results obtained are interpreted as tabulated in Table 4.

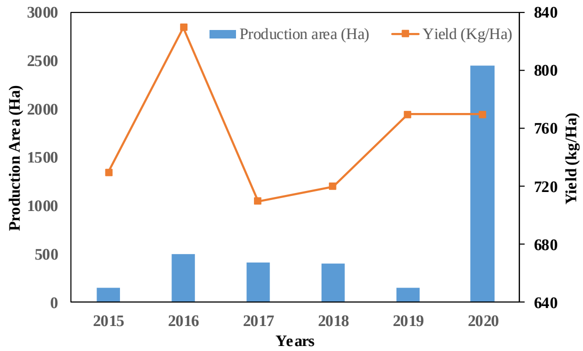

Figure 1. Production area and yield of coriander by years (TÜİK, 2021)

Table 1. Experimental design for the determination of flow rate of coriander seeds

Roll Length (mm)	Roll speed (rpm)
12,14,16,18,20	10,15,20,25,30,35,40,45,50,60

Table 2. Evaluation of seed flow evenness (Önal, 2011)

Seed flow evenness CV (%)	Evaluation
< 1	Very good
1-2	Good
2-3	Moderate
3-4	Sufficient
> 4	Insufficient

Table 3. Seed spacing uniformity criterion and its evaluation

Variation factor (V_f)	Distribution type
$V_f > 1.1$	Undesired misses and multiples in seed spacing
$0.9 < V_f < 1.1$	Poisson distribution
$V_f < 0.9$	Precision seeding

Table 4. Seed spacing Goodness criterion (λ) and its evaluation.

Goodness Criterion λ (%)	Evaluation
≥ 72	Very good
72-65	Good
65-55	Moderate
< 55	Insufficient

The evaluation of goodness criterion requires to determine the average of number of seeds per segment, μ. The segment length, a (cm), was calculated by using equation 3 (Önal, 2011) and for the evaluations, μ and row spacing (b) was assumed to be 2 and 20 cm.

$$a = \frac{100\,\mu\,\sigma}{b\,N} \qquad (3)$$

Where;

σ: Thousand seed mass (g)
b: Row spacing (cm)
N: Seeding rate (kg ha^{-1}).

The seed spacing uniformity tests were conducted on a sticky belt equipped with an electronic control for the speed and a laptop computer for data entry. The metering unit was placed on the sticky belt test stand and a seed tube was attached to it in order to deliver the seeds over the belt (Figure 2). The number of seeds on 300 segments were found for each test. An example seed distribution on sticky belt test and seeds on the segments are shown in Figure 3. As seen from the figure, the number of seeds on a segment was found by a simple device that consists of a long stick with dividers spaced at the segment length calculated.

The theoretical mass flow rate from fluted rolls can be written as in the following:

$$Q_{theo.} = \gamma .\ A.\ L.\ n \qquad (4)$$

Where;

Q_{theo}: Theoretical mass flow rate (g min^{-1})
γ: Bulk density of the material (g mm^{-3})
A: Cross sectional area of the roll (mm^2)
L: Roll length (mm)
n: Roll speed (rpm)

For a single crop and a fluted roll at a certain diameter, bulk density and the cross-sectional area of the roll will be constant. In this case, the theoretical flow rate will only be a function of roll length and roll speed and this can be written in theoretical form as in the following.

$$Q_{theo.} = f\,(L, n) \qquad (5)$$

Results and Discussion

The flow rate data obtained from the experiments as a function of roll speed (rpm) and roll length (mm) are depicted in Figure 4.

Figure 2. Closed view of metering unit with fluted roll (left) and setup on sticky belt test stand (Right)

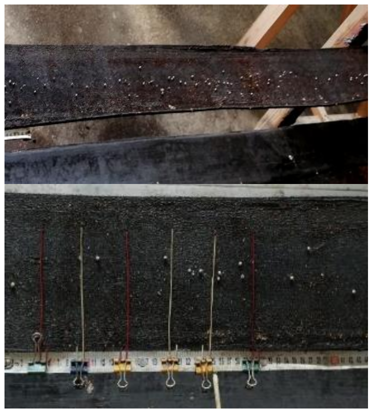

Figure 3. Distribution of corianders seeds on sticky belt test stand (Left) and seeds on the segments (Right).

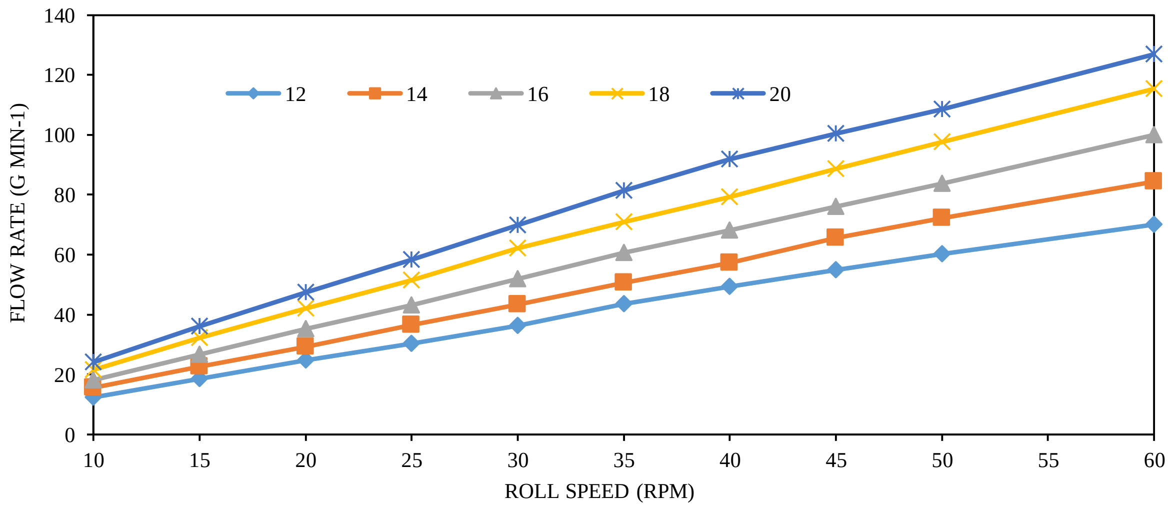

Figure 4. Flow rate as a function of roll speed at different roll lengths

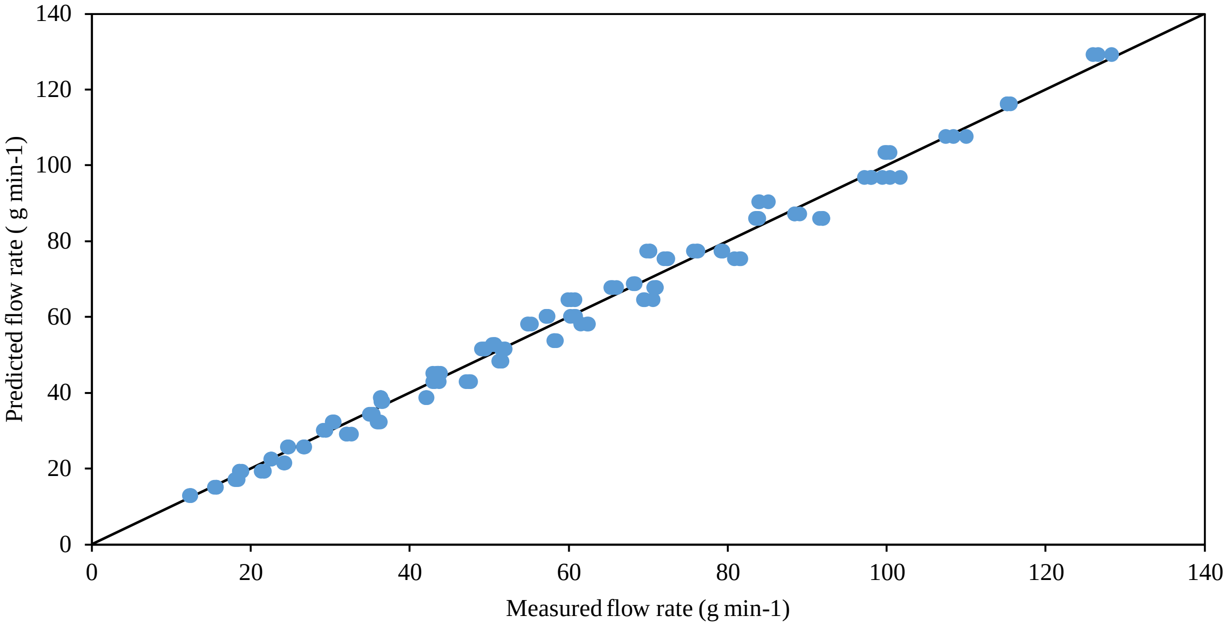

Figure 5. Comparison of measured and predicted flow rate

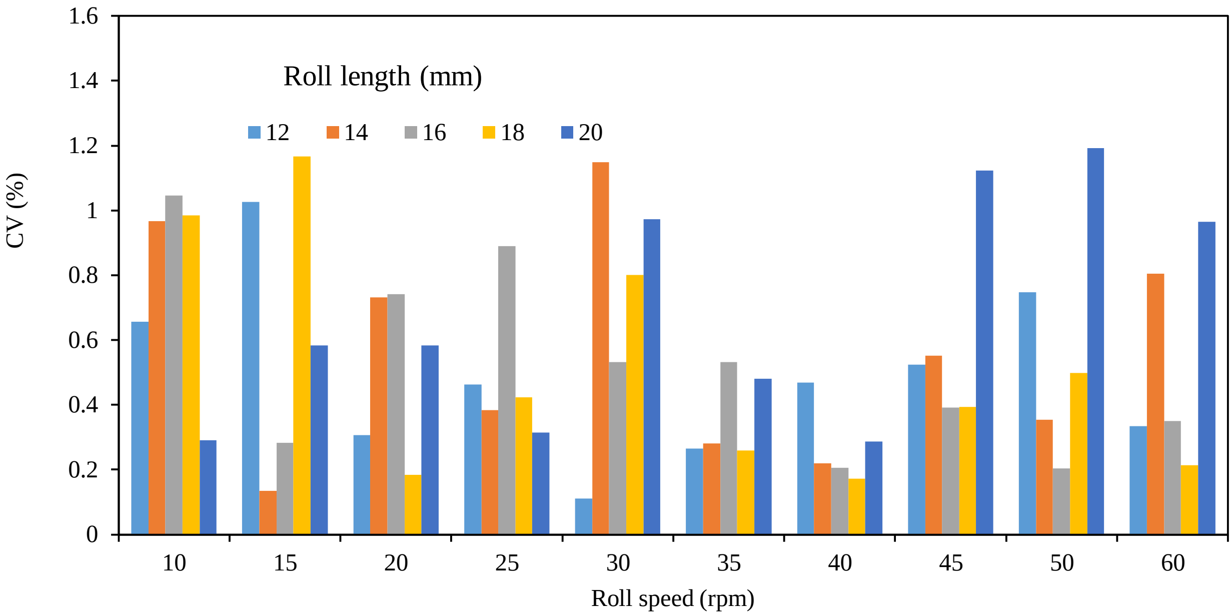

Figure 6. Seed flow evenness as a function of roll speeds and roll lengths

As seen from figure 4, an increase in roll speed and length increases the flow rate. Regression analysis to predict the flow rate was achieved using all combinations of roll speed and length with three replications (150 data points) in excel. The relationship given in theoretical form in Equation 5 was developed and the following prediction equation for the flow rate (Q_{pred}) was obtained with a coefficient of determination (R^2) of 0.997.

$$Q_{pred.}=0.107\ L.\ n \quad (6)$$

The comparison of measured and predicted flow rate is depicted in Figure 5. As seen from the figure, there is a good correlation (r=0.994) between the measured and predicted flow rate. The diagonal line in the figure represents the best fit and the data are expected to accumulate on or around this line.

The results obtained from the experiments for the evaluation of flow evenness as represented by CV (%) values are depicted in Figure 6. As seen from the figure, the CV (%) values are usually below 1% (classified as very good by Önal, 2011) except six cases. In general, the CV values varied between 0.11 and 1.19%. But it is interesting to observe that CV values at an rpm of 35 and 40 are comparable lower than the other flow evenness values at different rpm values. But there is no general trend such that the CV values decrease as the roll speed increases at a certain roll length. Kara et al. (2010), Güler (2005), Yıldırım and Turgut (2007) found an exponential reduction in flow evenness (CV, %) with an increased roll speed (rpm).

For the sticky belt tests in order to find out the distribution quality at seeding rates of 15,20 and 25 kg ha^{-1} and three forward speeds, the theoretical flow rates were calculated (Table 5). Five out of nine flow rates were obtained during the full factorial design. As seen from the table, the flow rates at the seeding rate of 15 kg ha^{-1} at all speeds and 25 kg ha^{-1} at forward speed of 1 and 2 ms^{-1} were obtained during factorial experiments and met the required theoretical flow rates calculated. The required flow rates at a seeding rate of 20 kg ha^{-1} were calculated using equation 6 and then tested experimentally. Seed flow evenness for most of the cases were classified as very good while in two cases (15 kg ha^{-1} and at a forward speed of 1 ms^{-1} and 25 kg ha^{-1} and at a forward speed of 1.5 ms^{-1}), the flow evenness was evaluated to be in good quality.

The evaluations based on the goodness criterion are tabulated in Table 6. As seen from the table, the goodness criterion (λ) values varied between 69% and 77.3%. Based on the evaluation range of the goodness criterion (λ), at a seeding rate of 15 kg ha^{-1} and the forward speed of 1.0 ms^{-1} and the seeding rate of 20 and 25 kg ha^{-1} at a forward speed of 1.0 and 1.5 ms^{-1} was classified as very good. In order to obtain high field capacity (ha h^{-1}) in the field, the forward speed 1.5 ms^{-1} is recommended at a seeding rate of 20 and 25 kg ha^{-1} while the appropriate forward speed at a seeding rate of 15 kg ha^{-1} is 1 ms^{-1}.

It should be stated that the goodness criterion (λ) values that makes the seeding quality to be classified as good are very close to 72 as seen from Table 6. For example, the goodness criteria for 15 kg ha^{-1} seeding rate and a forward speed of 1.5 and 2 ms^{-1} is 70 and 71.7%, respectively. Similarly, at a seeding rate of 20 and 25 kg ha^{-1} and at a forward speed of 2 ms^{-1}, the goodness criterion is 69 and 70.3%.

Comparing the results found in this study with the one conducted by Yazgı et al. (2017). It can be stated that the prototype metering unit designed and manufactured by Özdemir (2019) performed better even with small seeds such as coriander seeds (thousand seed mass 9.68 g). Yazgı et al. (2017) found that the seed flow evenness for barley with fluted roll at three forward speeds and ranged between 1.4 and 2.6 and classified as either good or moderate. For the vetch seeds, the flow evenness varied between 1.1 and 2.3% and with these results the classification was either good or moderate just like barley. Goodness criterion (λ, %) at a seeding rate of 100 kg ha^{-1} at forward speeds of 1.0, 1.5 and 2.0 ms^{-1} were found to be 63.6, 67.2 and 71.2, respectively. Based on the Goodness criterion, the distribution with these values was classified to be moderate and good while based on the variation factor, the seeding was characterized to be Poisson distribution.

The average number of seeds per segments varied between 1.74 and 2.15 (Table 6) even though it was assumed to be 2 for the theoretical calculations. As an example of seed distribution, at 25 kg ha^{-1} and a segment length of 3.87 cm is depicted in Figure 7 at a forward speed of 1 and 2 ms^{-1}.

Table 5. Seed flow rate evenness and its evaluation as a function of fluted roll length and speed at different seeding rates.

Seeding rate	Forward speed	Roll length	Roll speed	Theoretical flow rate	MEFR	Seed Flow Evenness	Evaluation
(kg ha^{-1})	(ms^{-1})	(mm)	(rpm)	(g min^{-1})Ψ	(g min^{-1})ж	CV (%)	
15	1	16	10	18	18.18	1.05	Good
	1.5	16	15	27	26.69	0.28	Very Good
	2	16	20	36	35.13	0.74	Very Good
20	1	15¥	15¥	24	26.52	0.85	Very Good
	1.5	15¥	22.5¥	36	37.11	0.93	Very Good
	2	15¥	30¥	48	49.75	0.13	Very Good
25	1	12	25	30	30.38	0.46	Very Good
	1.5	12ξ	37.5ξ	45	46.23	1.04	Good
	2	12	50	60	60.29	0.75	Very Good

Ψ: Flow rate values calculated at a row spacing of 20 cm to obtained desired seeding rate, ¥: Calculated from the flow rate model (Equ.6) in order to achieve the desired seeding rate, ξ: Tested experimentally since it was not included in flow rate measurements in factorial design, ж: Average of three replications, MEFR: Mean experimental Flow rate.

Table 6. Performance of the fluted roll metering unit in terms of goodness criterion (λ; %) and its evaluation

Seeding rate	Segment length	Forward speed	Roll length	Roll speed	NSRB	ANSS	Goodness Criterion	Seeding Quality
(kg ha^{-1})	(cm)χ	(ms^{-1})	(mm)	(rpm)		μ	λ (%)	
5	6.45	1	16	10	600	2	72.2	Very good
		1.5	16	15	581	1.93	70	Good
		2	16	20	544	1.81	71.7	Good
0	4.84	1	15	15	625	2.08	72.3	Very good
		1.5	15	22.5	574	1.91	72	Very good
		2	15	30	591	1.97	69	Good
5	3.87	1	12	25	645	2.15	77.3	Very good
		1.5	12	37.5	550	1.83	74.7	Very Good
		2	12	50	524	1.74	70.3	Good

χ: Calculated using equation 3 by assuming μ=2, ANSS: Average Number of Seeds per Segment, NSRB: Number of seeds released on to belt.

Table 7. Performance of the fluted roll metering unit in terms of variation factor (V_f) and seeding characterization

Seeding rate (kg ha^{-1})	Segment length a (cm)	Forward speed (ms^{-1})	Roll length (mm)	Roll speed (rpm)	Variation factor V_f	Seeding Characterization
15	6.45	1	16	10	0.77	Precision Seeding
		1.5	16	15	0.78	Precision Seeding
		2	16	20	0.68	Precision Seeding
20	4.84	1	15	15	0.83	Precision Seeding
		1.5	15	22.5	0.71	Precision Seeding
		2	15	30	0.76	Precision Seeding
25	3.87	1	12	25	0.82	Precision Seeding
		1.5	12	37.5	0.66	Precision Seeding
		2	12	50	0.65	Precision Seeding

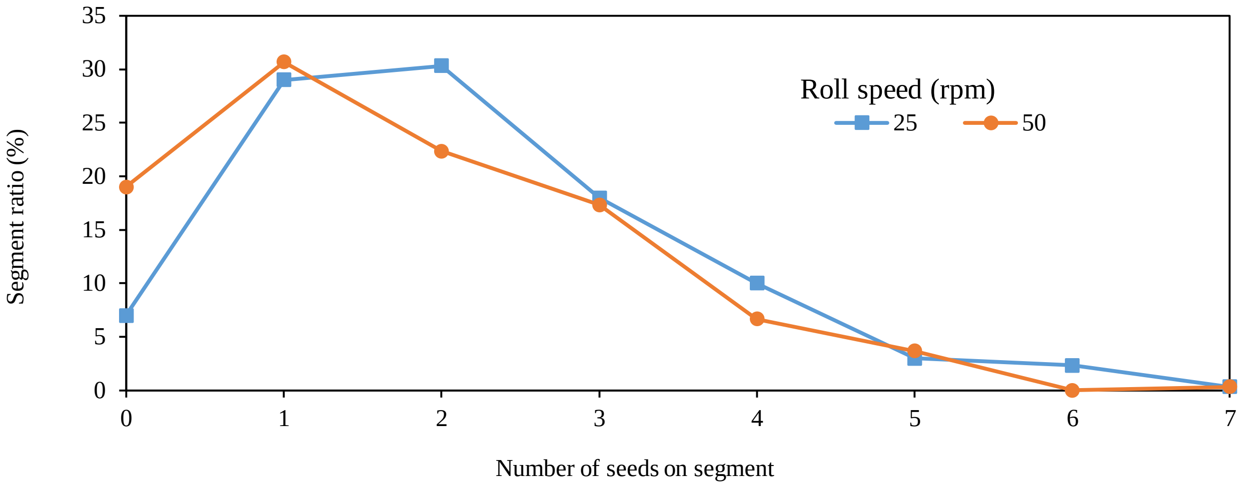

Figure 7. Number of seeds on segment and segment ratio relationship at a roll speed of 25 rpm (forward speed of 1.0 m s^{-1}) and 50 rpm (forward speed of 2.0 ms^{-1}) at a segment length of 3.87 cm for a seeding rate of 25 kg ha^{-1}.

The evaluations based on the evaluation factor (V_f) are tabulated in Table 7. As seen from the table, seed spacing uniformity can be characterized as "precision seeding" at all seeding rates, forward speeds and segment lengths since V_f values were smaller than 0.9 in all cases.

The evaluations based on the evaluation factor (V_f) indicated that the seed spacing uniformity can be characterized as "precision seeding" at all seeding rates, forward speeds and segment lengths.

Conclusions

The following conclusions were drawn from the study conducted:

- The coefficient of variation as an indicator of the flow evenness (CV; %) at a combination of five roll lengths and ten roll speeds ranged between 0.11 and 1.19%. The CV values obtained in this study for coriander seeds are significantly lower than the ones as found in the literature for different crop seeds.
- The goodness criterion (λ) values as one of the two performance criterion varied between 69% and 77.3%.
- Based on the evaluation range of the goodness criterion (λ), at a seeding rate of 15 kg ha^{-1} and the forward speed of 1.0 ms^{-1} and the seeding rate of 20 and 25 kg ha^{-1} at a forward speed of 1.0 and 1.5 ms^{-1} was classified as very good. In order to obtain high field capacity (ha h^{-1}) in the field, the forward speed 1.5 ms^{-1} is recommended at a seeding rate of 20 and 25 kg ha^{-1} while the appropriate forward speed at a seeding rate of 15 kg ha^{-1} is 1 ms^{-1}.

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