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Determination of Surface Seed Distribution in the Different Seeding Methods of Maize

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ABSRACT

In this study, the quality of surface (horizontal) seeds distribution and the growing area of seeds was determined by carrying out laboratory tests at 4 different seeding methods (conventional and twin row) and 3 forward speeds of precision pneumatic seeder (3; 5 and 7 km h^{-1}). We compared the different seeding methods with the the average shape coefficient (r_{ort}) of growing area and determined the most optimal seeding method for maize. The coordinates (x, y) of each seed were measured and entered into the MATLAB software to generate the Voronoi polygons around each seed. These polygons were considered as the growing area of the seeds.

According to the results, the analysis of variance performed on shape coefficients values showed that the difference between seeding methods were significant ($P < 0.01$). The most optimal seeding method for corn is the twin row method 25 cm seeds spacing intra row because it had a better growing area for the seeds with a average shape coefficient closer to 1 (r_{ort}=0.87). In addition we found the twin row seeding method 16 cm seeds spacing intra row very interesting because it had a high coefficient of form (r_{ort}=0.81) and also allowed to seed more seeds in a same area than all the other seeding methods of our study. This is a method whose can be a good alternative for maize seeding.

1. Introduction

For centuries, agriculture occupies an important place in human life. Poor mastery of calendars and farming techniques caused massive production losses for many farmers. Thereafter men have understood that the most important steps in agricultural activity is planting or seeding because it largely determined the quality and quantity of production. The invention of seeder has revolutionized the work of seeding and significantly increased yields. Despite the factors that affect the distribution of seeds in the soil such as seeders setting, seed pipes, leads to seed, the physical properties of grain, soil conditions and so on, a seeder must be able to seed in order to have the proper output and an adequate growing area of the plant.

The seeding uniformity of a seeder is an important factor affecting field germination, development and consequently yield of crops. In the seeding process, the distribution of seeds in soil is expressed by horizontal and vertical distribution. Planting arrangements are effective in the first degree in ensuring a smooth horizontal seed distribution in the planting.

According to Karayel and Özmerzi (2008), the homogeneity of the distribution of plants in the field minimize competition among plants by allowing the use rate equal to the basic elements such as light, water and food, and will result in better plant output and sprouting. In order to minimize the competition among plants, it is necessary to provide suitable inter row and intra row spacing during seeding. In seeding of a single seed, the appropriate inter row and intra row spacing would provide the maximum effective area for each plant (Hudspeth and Wanjura, 1970).

Flavio H. da Silva et al. (2015) evaluated the effects of variability in the distribution of seeds along the planting row on corn production components. No interactions were observed for the analysed corn variables.

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Taken from the master's thesis

However, as the non-uniformity in seed distribution along the planting row increased, stalk diameter, hundred-grain weight, number of rows per ear, number of kernels per row and ear length decreased. Additionally, linear reductions were observed in corn grain yield with the increase in the coefficient of variation of the spatial distribution of seeds along the planting row.

Bozdogan (2006) evaluated the seeding uniformity of seeders, seed spacings using the methods (MISS, MULT, QFI and PREC). For $P < 0.01$, operating speed affected MISS and QFI values, and the within-row seed spacing affected MULT and PREC values. The best operating speed was 1.8 km h^{-1} because of the highest QFI value (88.5%). There was no difference between 1.8 and 3.6 km h^{-1}. The speeds, 1.8 and 3.6 km h^{-1}, were different from 5.4 and 7.2 km h^{-1}. The best within-row distance was 18 cm because the QFI value was higher than those of 14 and 20 cm, 86.9%, 82.0% and 81.8%, respectively. The best PREC value was obtained for 21 cm within-row distance (17.4%). PREC values were acceptable for precision seeding in all trials. In addition, Karayel and Özmerzi (2010) identified new approaches in seed distribution uniformity of the seeders in two dimensional evaluations. The seeds spacings and depths are measured and the seed distributions are evaluated linearly using these measurements. New methods (growing area and distribution areas in the vertical plane) are used to evaluate the two-dimensional (horizontal and vertical plane) seed distribution.

Jones (2010) showed that twin-row spacing as an alternative planting practice for corn silage production in the Shenandoah Valley leads to greater corn silage yields through greater water use efficiency and faster canopy development. Rusk and Sievers (2010) in the study of Comparison of Twin Row and 30-in. Row Corn reported that Statistical analysis showed a significant difference in the stand counts between the single row and twin rows at 32.000 seeds/acre. The twin row population was lower, which may be why the yield was numerically lower for twin row corn at 32.000 seeds/acre. There were no yield advantage was obtained planting corn in a twin row configuration compared with a single 30-in. row. Karlen et al., (1987) explained that narrow row spacing increased corn yield by 5-10%. But they not determined whether these yield increases are sufficient to warrant equipment changes necessary for reducing row spacing. An alternative twin-row planting configuration that can increase yields by improving intra-row plant spacing without-requiring major equipment changes is also evaluated and discussed. The average grain yield was also significantly greater for the twin-row configuration. This research demonstrated that twin-row planting may offer a more practical alternative to narrow rows because with the exception of planter units, conventional wide-row equipment can be used.

Griepentrog (1998) explained the quality of horizontal overall distribution is influenced by row width and longitudinal distribution and of course plant or seed density as a no-technical parameter. A method is presented to describe the arrangement of plants in row crops by allocating a polygonal area of ground to each plant. This method is able to operate completely in a two dimensional way. The analysis of polygon size and circumference is able to evaluate the longitudinal distribution of seeding machines in relation to the overall distribution and therefore to aspects of plant development. The method of utilizing polygon calculations is a general possibility of describing seed and plant overall distributions.

Karayel (2010) evaluated the seed distribution in the horizontal plane and plant growing area for row seeding using Voronoi polygons. The growing area of the each plant was calculated using Delaunay triangulation and Voronoi polygons to analyse the seed distribution uniformity after seeding. The results of the research showed that seed spacing and growing area ($r = 0.60$) evaluation criteria gave similar results for soybean and maize because of the larger row spacing of these seeds whose was not increased significaly from 0.7 to 1.5 m s^{-1}.

Nowadays precision seeding methods (single row (normal), narrow, twin row and others) of maize vary from one area to another with more or less mixed results in terms of yield. With the single row seeding (70cm x 16cm), we are increasingly developing the twin row seeding method (70cm x 25cm x 20cm) and sometimes a combination of these two methods.

The importance of the study is to study the principles and seed distribution surface in four different seeding methods, to highlight the most appropriate method for optimal growing area of plants and to share information with the stakeholders (manufacturer of agricultural machinery, farmers and others).

2. Materials and Methods

A precision vacuum seeder was general-purpose Sakalak seeder designed for row crops such as maize and soybean (Sakalak Company, Konya, Turkey). Seed plate operated in a vertical plane and required a vacuum of 3.5–8.0 kPa to select a seed. Air suction from the holes of the seed plate caused the seed to stick to holes 4.5 mm in diameter. Seed was released from the rotating plate by blocking air suction over the opener, which had no seed tube Each seeding unit was independently mounted on a four-bar parallel linkage equipped with joint springs to apply downward force on the seeding unit.

Maize (Zea mays L.) seed with a mean mass per seed of 235 mg were used for all treatments. The farmers in the region are seeding 7.500 to 14.000 seeds per decar in corn production.

The experiments were carried out in the research and application facilities of the Department of Agricultural Machinery and Engineering Technologies of Selçuk University. A test area was set up for the various tests. It is a rectangular surface of 3 m x 3 m of nylon film. This nylon film has been fixed to the ground using steel bars to prevent movement of the test surface during dispensing. According to the seeding patterns we applied to the nylon film of the mechanical grease (yellow-brown or white) to facilitate the fixation of the seed after distribution by the pneumatic seeder. This area is shown in Figure 1.

Figure 1

Test area

In experiments were conducted at 4 different seeding methods of maize and 3 forward speeds (V1:3, V2:5 and V3:7 km h^{-1}). These are seeding methods which are carried out using a precision seeder and consist in arranging the seeds one by one in line with a predetermined regular spacing.

Seeding Method (SM1): Single row or Normal seeding

This is traditional maize seeding on 4 rows (16 cm x 70 cm) with a spacing of 16 cm intra row and a spacing of 70 cm inter row (Figure 2). In this method, 8.930 seeds are seeded per decar..

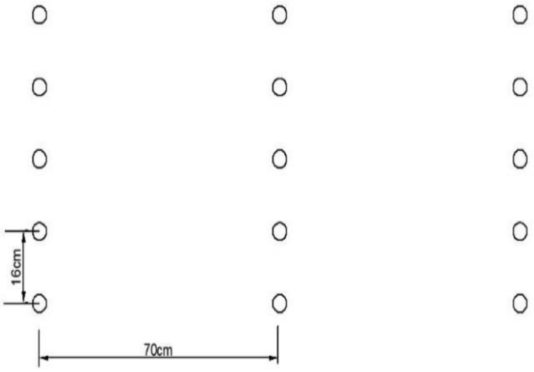


Figure 2

Single row seeding

Seeding Method (SM2): Single row or Normal seeding in staggered

This is a traditional corn seeding (16cm x 70cm) modified in a staggered manner, that is to say on 4 rows with a shift on the 2nd row of 8cm on the line compared to the first row as illustrated in the Figure 3. In this method, 8.930 seeds are seeded per decar.

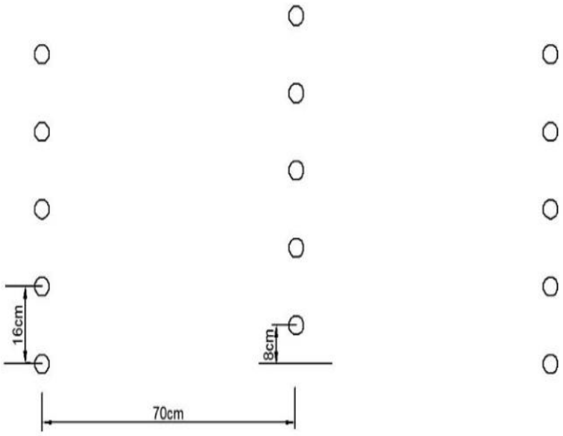


Figure 3

Single row seeding in staggered

Seeding Method (SM3): Twin-row seed of 25 cm

It is a technique of corn seeding in staggered of rows twinned (25 cm x 20 cm x 70 cm). It is presented on 8 rows including 4 row twinned. We have 70 cm between two row twinned, 20 cm between row twinned and 25 cm of seed intra rows spacing. This seeding method is illustrated in the Figure 4. In this method, 11.428 seeds are seeded per decar.

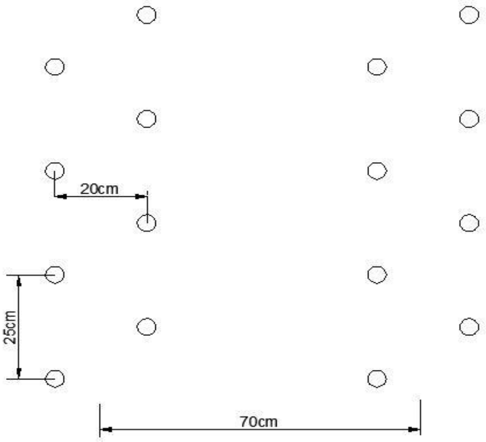


Figure 4

Twin-row seed of 25 cm

Seeding Method (SM4): Twin-row seed of 16cm

It is the same technique of corn seeding like method 3 but with 16cm of seed intra row spacing (16cm x 20cm x 70cm). In this method, 17.860 seeds are seeded per decar (Figure 5).

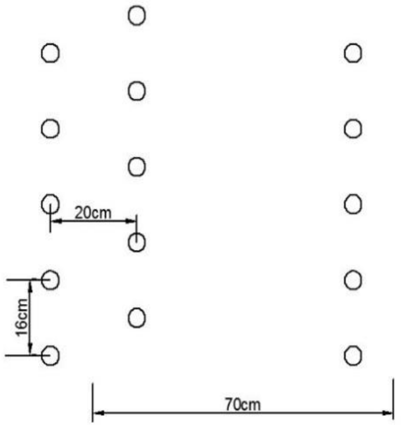


Figure 5
Twin-row seed of 16 cm

The settings of the machine used for seeding are made according to the settings that the company has already set before seed seeding. The experiments were carried out at constant vacuum pressure of 5 kPa and at the seed fall height of 58.5 cm.

The movement required for the seeder is provided on the mainframe and on the right side according to the direction of displacement. The movement from this wheel is transferred to a main shaft using chain-wheel system (Figure 6) and of these shafts to planting units. The movement from the wheel is transmitted to the main shaft using gears Z1 and Z2. These gears are stretched with tensioner in case of change.

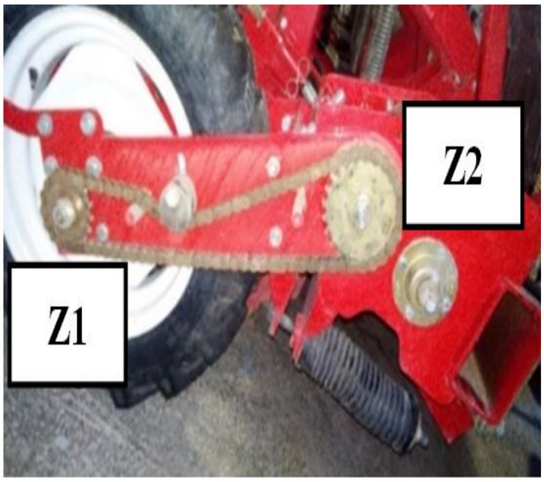


Figure 6
Chain-wheel system

As shown in Figure 7. the movement from the wheel is adjusted to the desired transmission ratio with the different gears in the motion transmission system and transmitted to the perforated vertical seed discs.

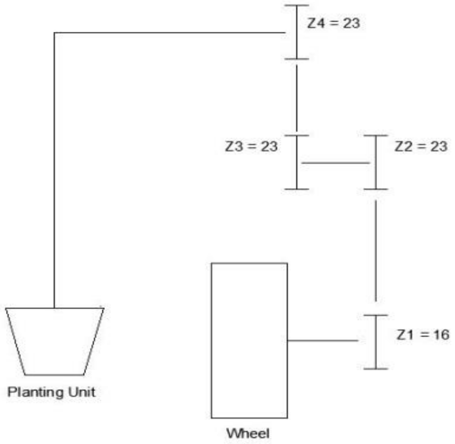


Figure 7
Transmission system

In our study we fixed the transmission system for all tests and the transmission ratio is i = nseed-disc / nwheel = 1 / 2.85 = 0.35

The peripheral speeds of the holes in the seed discs are one of the most important factors for keeping the seeds on the perforated seed discs side, are shown in Table 1 for the 24 and 36 holes plate used in the experiments.

Table 1
The peripheral speeds of the holes (Vp) in the seed discs

	V1	V2	V3
n (min^{-1})	10.45	15.67	20.90
Vp ($m\ s^{-1}$)	0.12	0.18	0.24

In fact to obtain the same speed of seed discs for each forward speed we used a fixed transmission system and used 2 disks (Figure 8) of the same diameter (22cm) one of 24 holes and the other of 36 holes.

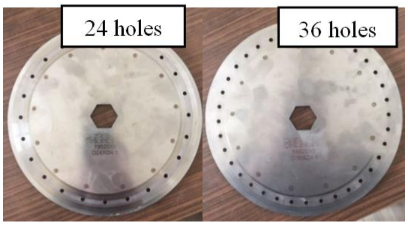


Figure 8
Seeding unit and seed discs

The movement taken from the wheel-chain system is transmitted to the planting unit shaft. The planting shaft provides motion transmission with the chain-to-gear system of the planting units. In the transmission of the motion between the wheel and the planting shaft, the seed row spacing and seeding norm are set in order by the changes in the number of teeth and the number of discs holes. The information about the number of teeth and the number of disc holes required to be used according to the seed range over the desired row is given by the manufacturer and is in a table on the machine.

After the distribution of the seeds on the test surface by the pneumatic seeder, we have defined an orthonormal landmark (abscissa and ordinate) with steel bars. The base of the abscissa of this landmark has been taken according to the direction of advance of the tractor. After this marker was established, the x and y coordinates of all seeds were measured for each test (seeding method and forward speed) (Figure 9). All of these measurements were made using a measuring instrument namely the tape measure and the caliper.

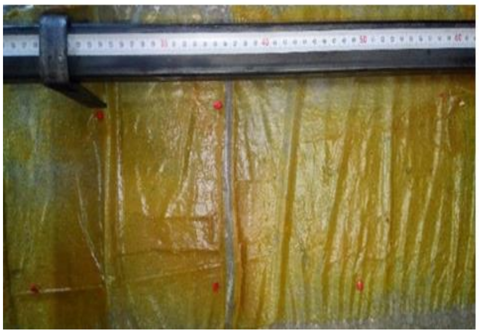


Figure 9

Seeds coordinate measurement

The seed distribution (Figure 10) data of the various experiments after seeder passage were entered into the computer.

Figure 10

Seeds distribution on test area

The distribution of the seeds in the horizontal plane has determined using a new method of growing area.

In the evaluation made by using the growing area, the growing area of each seed whose the distance has been measured is determined. In order to determine the growing area, two-dimensional coordinates are determined on the test area surface for each seed. Delaunay triangulation and Voronoi polygon (polygon), which are a branch of computational geometry, were used in determining the growing area of the plants whose coordinates were determined (Karayel, 2010; Altikat and Gülbe, 2015)

The MATLAB Voronoi control was used to construct the growing area of plants whose (x,y) coordinates of the experiments results were determined. A m-file has been created for calculating the growing area including following command:

```
>> voronoi (x, y)
```

After generating distribution mode and growing area of seeds by Voronoi control in MATLAB, the polygons in the rows of the centre are selected to determine the value of the growing area. The selection of these polygons is done without taking into account doubles and miss. Only polygons from seeding with acceptable spacing can be selected. For precisely analyses, at least 20 polygons per test were selected in our study.

Each selected polygon or growing area is entered into the Paint software so that the interior of this polygon is completely painted in order to obtain a block of the same colour as shown in the Figure 11.

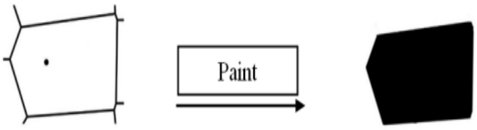
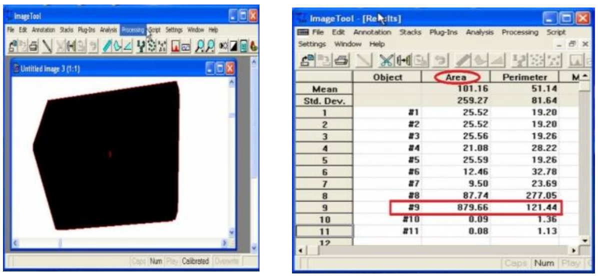


Figure 11

Polygon processing in Paint

The Image Tool was used to determine the value of the generated growing areas (Figure 12). Indeed the polygon block (interior of growing area painted black) is entered in the Image Tool program that will generate the surface and the perimeter of each polygon.



	Object	Area	Perimeter	M
Mean		101.16	51.14	
Std. Dev.		259.27	81.64	
1	#1	25.52	19.20	
2	#2	25.52	19.20	
3	#3	25.56	19.26	
4	#4	21.08	28.22	
5	#5	25.59	19.26	
6	#6	12.46	32.78	
7	#7	9.50	23.69	
8	#8	87.74	277.05	
9	#9	879.66	121.44	
10	#10	0.09	1.36	
11	#11	0.08	1.13	
12				

Figure 12

Polygon area processing in Image Tool

Theoretically, the ideal growing area of a plant is a circle. A coefficient called the shape coefficient is used to determine how closely the created growing spaces are geometrically close to the circle of the ideal growing space (Griepentrog 1998).

Approximately when the shape coefficient is close to 1 this indicates that the growing area is approaching a circle. The shape coefficient is the ratio of the circumference of the polygon calculated as the growing area of the plant and the circumference of the circle surrounding the growing area (Karayel, 2010).

$$C_{ideal} = 2\pi\sqrt{\frac{A_i}{\pi}}$$

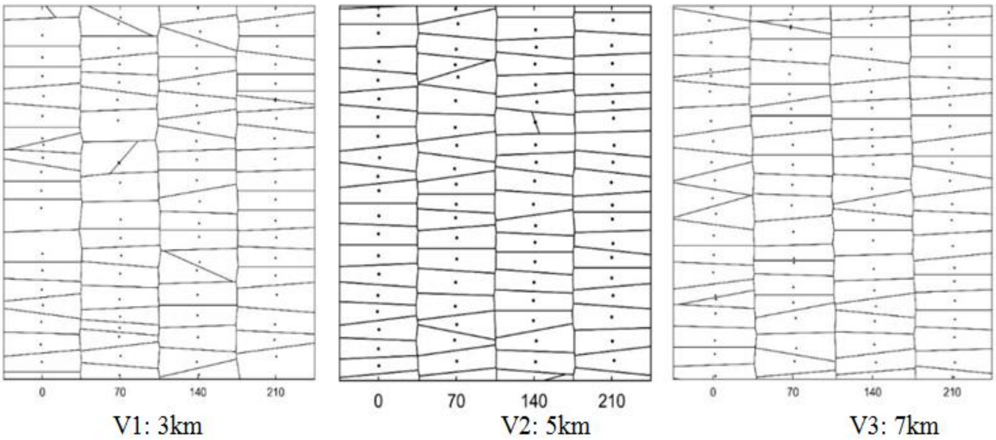
$$r = \frac{C_{ideal}}{C_{polygon}}$$

$$r_{ort} = \frac{1}{n}\sum_{i=1}^{n}\frac{C_{ideal}}{C_{polygon}}$$

Here: Cideal: ideal growing circumference; Ai: polygon area; Cpoligon: polygon circumference; r: shape coefficient; rort: Average shape coefficient and n: number of growing area calculated.

3. Results and Discussion

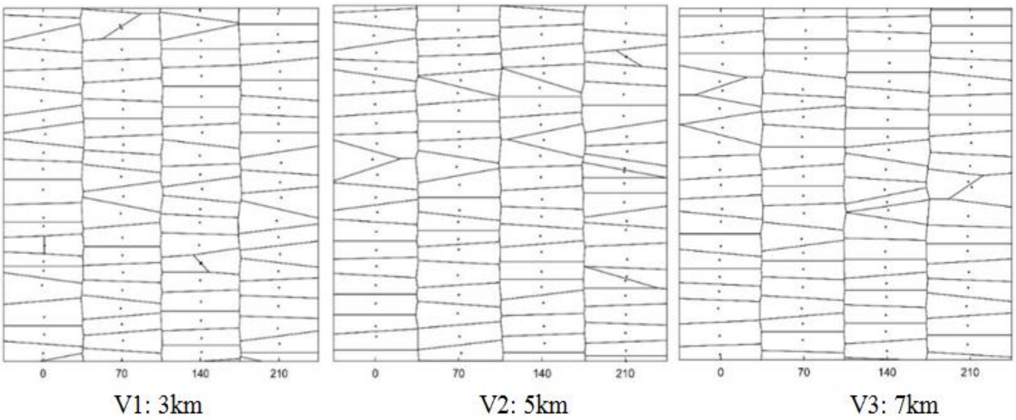
The distribution of the seeds after the pneumatics seeder as a function of the forward speed is presented in the surface plan for each seeding method used in our studies. The seeds are arranged in the horizontal plane according to their respective coordinates (x, y) and after processing in the Matlab software. The following visual results (Figure 13…16) are obtained:



V1: 3km V2: 5km V3: 7km

Figure 13

Distribution of seeds in single row seeding according to forward speeds



V1: 3km V2: 5km V3: 7km

Figure 14

Distribution of seeds in single row seeding in staggered according to forward speeds

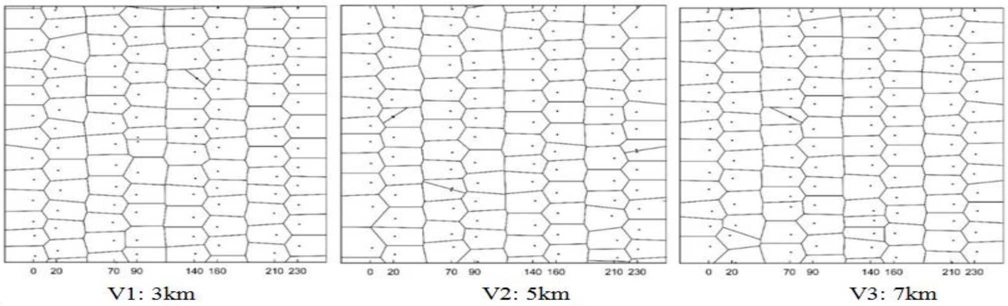


Figure 15

Distribution of seeds in Twin-row seeding 25cm according to forward speeds

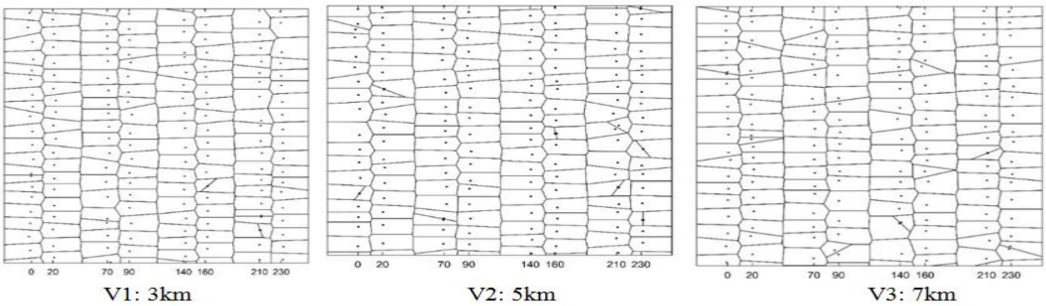


Figure 16

Distribution of seeds in Twin-row seeding 16cm according to forward speeds

All the results of the average shape coefficients obtained after calculation for each test and seeding method are presented in the Table 2. Average shape coefficients values were varied 0.66 to 0.87. The analysis of variance performed on average shape coefficients values showed that the difference between seeding methods were significant ($P < 0.01$). LSD test on averages showed that the difference between SM1 and SM2 from the conventional seeding methods were not significant (Table 3). The effect of forward speeds on average shape coefficients values were not found significantly. Karayel (2010) found that the effect on average shape coefficients values of forward speed were not significant for corn and soybean experiments.

Table 2

Average shape coefficients values

Seeding method	Forward velocity (km h^{-1})	Average shape coefficient
Single row seeding	3	0.66 ± 0.024
	5	0.68 ± 0.020
	7	0.66 ± 0.025
Single row seeding in staggered	3	0.67 ± 0.021
	5	0.67 ± 0.019
	7	0.67 ± 0.023
Twin-row seeding of 25cm	3	0.86 ± 0.009
	5	0.87 ± 0.012
	7	0.87 ± 0.006
Twin-row seeding of 16cm	3	0.81 ± 0.015
	5	0.81 ± 0.017
	7	0.79 ± 0.017

Table 3

Summary of average shape coefficients according to seeding methods

Seeding Method	Average Shape coefficient (r_{ort})
(SM1) Single row	0,66a
(SM2) Single row in staggered	0,67a
(SM3) Twin row 25cm	0,87b
(SM4) Twin row 16cm	0,81c
LSD (5%)	0,018

It can be seen that for each seeding method the shape coefficient remains virtually constant whatever the speed of advancement. The average shape coefficients closer to 1 are those of the twin-row seeding method 16cm (r_{ort} = 0.81) and 25cm (r_{ort} = 0.87). The reason of this; in these methods growing area is approaching a circle due to the narrower inter row spacing. According to the literature (Karayel, 2010; Griepentrog, 1998), the best growing area for plants is the closest to the circle In theory we can say that these seeding methods are the most ideal of the seeding methods of our study because the growing areas are closer to a circle. However, by comparing the average shape coefficients of these two seeding methods one can deduce that the most ideal method for corn is the twin-row seeding method 25 cm. We can also deduce that the least ideal seeding methods of the seeding methods studied are the both of single seeding methods that have no significant differences between their average shape coefficients (r_{ort} = 0.67). This means that the two methods (single seeding and single seeding in staggered) are identical in terms of growing area for the plant. In addition, similar results were obtained with the literature (Karayel, 2010) regarding the average shape coefficients in these two methods.

4. Conclusion

The seeding method presenting a better growing area for the seeds or plants is the twin-row seeding of 25 cm spacing intra rows. It was also found that the twin-row seeding 16 cm intra row seeds spacing had a average shape coefficient close to 1 (0.81) and was therefore also an advantage seeding method for the plant. In addition it's possible to seed a much larger number of seeds (on the same area) than all the other seeding methods used in our study. Single row seeding and single row seeding in staggered although having different distribution systems, show no difference in terms of growing area for the plant (r_{ort} = 0.67). We can therefore deduce that these two methods are identical because they do not bring any significant differences.

We can affirm on the basis of laboratory tests, accurate calculations and results obtained in terms of average shape coefficient and growing area as the most advantageous maize seeding method for seeds or plants in general are the twin row seeding methods and in particular the twin row seeding method 25cm.

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