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A Study on Pelleting and Planting Sesame (*Sesamum indicum* L.) Seeds

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Abstract: This study was aimed to develop an alternative and sensitive sesame seed planting method instead of traditional broadcast seeding method. Muganli-57, Ozberk-82 and Golmarmara type sesame seeds were pelleted and prepared for planting with sensitive pneumatic spacing planter. Bare seeds were pelleted with a special pelleting mixture prepared with four different mixture rates, in a pelleting mechanism. Then, germination tests were done for each. Moreover, the physico-mechanical properties of pelleted sesame seeds are assessed. To accomplish this, properties of these three kinds of sesame seeds, such as length, width, thickness, sphericalness, rolling resistance coefficient on different surfaces, dissolution time in water, refraction resistances of pelleted seeds and the number of seeds in pellets are analyzed. The planting criteria were determined with the laboratory experiments, with a pneumatic spacing planter operated in four different speeds. Germination tests were done in the laboratory for bare and pelleted seeds of all three types. The pelleting mixture rate with highest germination was used for pelleting the seeds that were planted in the field trials. The bare seeds were planted with broadcast seeding method as the control group and the pelleted seeds were planted with a pneumatic spacing planter. The emergence rates of three types of sesame seeds in the field were measured. As a result, planting the pelleted seeds with a pneumatic spacing planter led to high emergence rates and smooth sowing. This study shows that using the pneumatic spacing planter with pelleted seeds leads to more favorable results than the broadcast seeding method under field conditions.

Key words: Sesame, pelleted seed, physico-mechanical properties, precision planting

INTRODUCTION

Sesame holds a special importance in the world's oil production due to its high quality. 40-60% of sesame seed is composed of oil. Although it is not commonly used in Turkish cuisine, it is mostly used in tahin and halva production[1]. The production rate is far below the need in Turkey. Therefore, Turkey imports sesame oil. According to FAO, in 2003, the reserved area for sesame planting in the world was 6.57 million ha, with the production rate of 3,096 million tones year^{-1} and the average yield of 471.2 kg ha^{-1}[2]. In Turkey, reserved area for sesame planting was 50,000 ha, the production rate was 22,000 tones year^{-1} and the yield was 440 kg ha^{-1} in the same period. Although the yield in Turkey is close to the world average, it is not satisfactory[3,4]. Planting sesame as a secondary crop, insufficient fertilizer usage and insufficient watering with broadcast seeding are the reasons of this unsatisfactory condition. In China, hybrid sesame varieties were produced and due to the usage of fertilizers, sprays, hormones, mulching and mechanization, the yield increased to 2.573,488 kg ha^{-1}[5]. Hence, sesame production will have an increasing popularity in oil industry in a few years[6].

In Turkey, the soil preparation for sesame cultivation starts in autumn following the former plant harvest. The field is tillaged in 20-25 cm depth with plough. When the soil is tilted in spring, it is tillaged with plough in order to preserve the tilth. Or better it is tillaged in 10-15 cm depth with duckfoot share cultivator or disc-harrow. Fertilizer is spread on soil by fertilizer broadcaster. Additionally, herbicide can be applied if necessary. The fertilizer and herbicide are mixed into soil with disc harrow and tooth harrow. Finally, the soil is ready for sowing after compacting it with float[7].

Sesame agriculture is conducted as the primary crop between April and May in the Aegean Region. In those areas where dry farming prevails, the sowing should be carried out in May in order to benefit the most from the tilth. The common sowing method is broadcast seeding, which involves the scattering of seed mixed with sand. The application of discharrow and float follows. If the sowing is with seed drill, the seeds should still be mixed with sand. The sowing depth is 2,5-4,0 cm. After sowing,

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the soil is compacted by float. If the sowing is done through broadcast seed, the application of disc harrow precedes the scrubbing. In broadcast seed, the sufficient amount of seed is 800-1000 g da^{-1}. with seed drill and 250-400 g da^{-1}. with drilled seed.

In those researches conducted in the Aegean Agriculture Research Institude, the sowing distance is 70 cm inter-row width and 15-20 cm distances on the row. The plant reaches 10-15 cm length with in 20-25 days after sowing. It is 30-35 cm tall after 35-40 days. A sesame plant flowers within 60-75 days and in 90-120 days it reaches its physiological maturity. Finally it is harvested 110-130 days after sowing[7].

Sesame seeds were pelleted with organic and inorganic materials to be able to use an integrated mechanization system and reduce labor costs in a study done in the National Honam Agricultural Experiment Station of Korea[8]. Traditionally, sesame sowing has been done manually in Korea. The system used in the study is more advanced than the traditional system which uses PE film mulcher and spot sower attached to the tractor. The mechanization system integrates ridge formation, P.E film mulching and sowing and reduces the labor hours by 80 to 95% compared to the conventional system. Diameter of the pelleted seeds were 3 mm and the average number of seeds per pellet was 1.9[8]. Mechanization system extends the emergence time but increases the number of capsules per plant as well. Plant height, first capsule set height and grain yield results are very close to the results of the conventional method. Overall, the integrated mechanization system improves the net income of the farmers by 11 to 20%.

As a hoeing plant, sesame has an important place in planting period. However, workforce and production costs increase considerably due to manual harvesting. Because of the small size of the seeds, planting mechanization is difficult in Turkey and hence broadcast seeding is common. In the areas of broadcast seeding where mechanization is not yet introduced into routine usage, yield and production costs are affected adversely from this condition. Moreover, manual harvesting increases labor costs. Therefore, introducing mechanization into sesame production and increasing the yield is a necessity. In this study, our aim was to increase the yield by making sesame seeds appropriate for planting with a pneumatic spacing planter by pelleting bare seeds with a special mixture produced with four different mixture rates. With our work, the first time in the world, the pelleted sesame seeds are implanted directly onto the soil (on the contrary of the technique utilized in Korea). Three kinds of registered sesame seeds (Muganli-57, Ozberk-82, Golmarmara) that are widely produced in Turkey were used in the experiments. Properties of these three kinds of sesame seeds (length, width, thickness, sphericalness, rolling resistance coefficient on four different surfaces, dissolution time in water and the radius and refraction resistance of pelleting seeds, the number of seeds per pellet) were examined.

MATERIALS AND METHODS

The seeds were pelleted with a special mixture produced with four different rates of two inorganic natural material (clay mineral and silicate compound) in a way that two different groups of pelleted seeds would emerge, which are below 3.5 mm (between 3 and 3.5 mm) and above 3.5 mm in diameter, in the Lab of the Agricultural Machinery Department in Agricultural Faculty in Adnan Menderes University. The pelleting mechanism consists of an electric motor, a tank, a reductor, a fan, a sprayer gun and a compressor. A cauldron that is made of hard rubber and installed to a shaft with a 30° inclination producing 40 rotations per minute and taking its' power from a d phase electric motor working with 380 V was used to produce pelleted seeds. In addition, a compressor and a spraying apparatus made of glass; helping the special mixture and seeds to stick on to each other and a fan to dry pelleted seeds were used[9,10].

Inclined surfaces consisting of plywood and rubber plates, stainless steel and galvanized metal sheets were used in order to measure the rolling resistance coefficient of the seeds[11,12]. Rolling resistance coefficient is determined by the tangent of the angle at which the seeds start rolling on the surface. In order to measure the rolling resistance coefficient of bare seeds, the bare seeds were placed upright, upside down and parallel to the surface on inclined surfaces. However, as pelleted seeds have spherical forms, the rolling resistance coefficients of pelleted seeds were measured by taking their forms into account.

During the experiments; all the variables were measured with three replications. The germination rates of these three kinds of sesame seeds, namely, Muganli-57, Ozberk-82 and Golmarmara (both bare seeds and pelleted seeds) were recorded in the lab. Germination tests were applied to the seed groups, diameters of which are less than 3.5 mm and more than 3.5 mm, with three replications in petri plates. Moisture of the setting was maintained around 33% in the germination period[13].

In measuring the refraction resistance of pelleted seeds, a Shimpo brand hand dynamometer with a 0.01 (N) sensitivity was used.

In order to fix the seed dispersion on the row, the grease belt test stand was used in the Lab of Agricultural

Machines in the Faculty of Agriculture in Ege University. Grease belt experiments were carried out at speeds of 0.5, 1.0, 1.5, 2 m s^{-1} providing 10 cm planting distances on the row.

In the laboratory, planting design is determined with grease belt experiments. Appropriate planting characteristics for seed dispersion on the row had to be determined in order to determine the efficiency of the mechanism on seed dispersion on the row[14].

In order to define the variation coefficient, which is one of the criteria for measuring the effect of the mechanism, average planting distance yielded by the distances between pelleting seeds falling down on grease belt was calculated along with the standard deviation[14].

The theoretical seed spacing that is desired during planting is defined as Z. Values between 0.5 and 1.5 Z are called acceptable seed spacing for seed dispersion on a row. In modern pneumatic spacing planters, the relative rate of acceptable seed spacing should be more than 80%. Moreover, the relative rate of seed spacing that is less than 0.5 Z and more than 1.5 Z should be less than 10%. The relative rates necessary for the evaluation were found with the help of the classification of seed spacing measured during grease belt experiments[15-17].

The mixture proportion of pelleted seed group, having the highest rates of emergence in the laboratory (first mixture prepared) was chosen for planting in the field and rates of emergence was recorded.

Field experiments were done in 2004, in the research and application plots of the Agricultural Faculty in Adnan Menderes University. The soil in the plots is alluvial soil, which is among Kademe series (Calcoric Fluvisol FAO; Oxaquic Xerofluvent USDA)[18].

For cultivating the soil, three body mounted tractor plough with a continental body was used. For preparing the seedbeds, a mounted tandem disc harrow and for maintaining the tilth of the soil a float were utilized. Under the conditions of main crop, bare seeds were planted with a sowing norm of 10 kg ha^{-1} according to the conventional method (broadcast seeding) and pelleted seeds were planted with a sowing norm of 0.6 kg ha^{-1} with a Hassia brand pneumatic spacing planter. After the broadcast seeding, the seeds were blended with the soil with the help of a mounted tandem disc harrow and then the soil was floated. The temperature of the soil was 24°C at the time of planting.

Pelleted seeds were planted with a Hassia brand pneumatic spacing planter at a speed of 0.5 m s^{-1}, leaving 10 cm between the pelleted seeds on a row and 70 cm between the rows. The planter consisted of a plate with a diameter of 220 mm and 30 holes on the plate each having a diameter of 3 mm so as to arrange suitable planting distances on the row.

In order to put forward the performance values of the planting methods, degrees of rate of emergence were observed under the field conditions[16,19,20].

RESULTS

Seed characteristics: The length of the sesame seeds used in the experiments are between 3.249 mm and 3.50 mm. Maximum and minimum values are 1.667 mm and 1.886 mm for width, 0.950 mm and 0.981 mm for thickness and 52.846 and 52.992% for sphericalness[16] (Table 1). Sphericalness values of the three kinds are close to each other. Diameters of the sesame seeds that are pelleted with a special mixture produced using four different mixture rates range between 3.019-3.179 mm for seeds with diameter less than 3.5 mm. For the ones with diameter bigger than 3.5 mm, they range between 3.892-4.578 mm (Table 2). Thousand kernel weights of bare sesame seeds are 4.16 g. 1000 $seed^{-1}$ for Muganli, 3.96 g.1000 $seed^{-1}$ for Ozberk and 3.80 g.1000 $seed^{-1}$ for Golmarmara (Table 3). Thousand kernel weights of the pelleted seeds vary between 33.14 and 103.57 g. 1000 $seed^{-1}$ depending on the diameter and mixture rate.

Table 4 shows the bare seeds' and pelleted seeds' rolling resistance coefficients which were calculated with the help of the inclined surfaces composed of either stainless steel, galvanized metal sheet, rubber or plywood plates. Pelleting decreased the rolling resistance coefficient of the seeds. For all mixture rates, minimum rolling resistance coefficient values are observed at stainless steel surfaces.

Refraction forces of the pelleted sesame seeds increase as the diameter increases (Table 5). Mixture rate also has an impact on the refraction force. Mixture rates with higher indexes have higher refraction forces (e.g. 4th rate is higher than 3rd rate) within each diameter group (smaller or bigger than 3.5 mm). Minimum refraction

Table 1: Some physical properties of bare sesame seeds used in the experiments

Samples	a	b	c	K
Muganli-57	3.500	1.886	0.981	52.924
Ozberk-82	3.249	1.667	0.950	52.846
Golmarmara	3.266	1.676	0.963	52.992

a: length (mm), b: width (mm), c: thickness(mm), K: sphericalness(%)

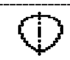
Table 2: Average diameters of pelleted seeds (mm)

	Mixture rates							
	1st		2nd		3rd		4th	
Samples	3.5<	3.5>	3.5<	3.5>	3.5<	3.5>	3.5<	3.5>
Muganli-57	3.094	3.892	3.034	4.195	3.028	4.396	3.105	4.331
Ozberk-82	3.099	3.903	3.019	4.304	3.049	4.157	3.038	4.110
Golmarmara	3.035	4.333	3.179	3.994	3.058	4.47	3.025	4.578

Table 3: Thousand kernel weights of bare seeds and pelleted seeds (1000 g seed^{-1})

		Pellets							
		1st rate		2nd rate		3rd rate		4th rate	
Sample	Bare	<3.5	>3.5	<3.5	>3.5	<3.5	>3.5	<3.5	>3.5
Muganli-57	4.16	41.92	50.35	33.14	60.95	47.78	103.57	44.13	73.66
Ozberk-82	3.96	40.72	53.88	39.85	62.57	37.71	62.50	44.21	59.50
Golmarmara	3.80	41.07	68.35	52.07	68.71	35.21	90.85	40.20	94.80

Table 4: The rolling resistance coefficient of the sesame seeds used in the experiments at different positions and different mixture rates

Seeds	Bare seeds			Pelleted seeds			
Position/Rate				1st rate	2nd rate	3rd rate	4th rate
Muganli-57	1.128	1.192	1.031	0.521	0.498	0.535	0.516
Ozberk-82	1.323	1.190	0.948	0.531	0.499	0.565	0.194
Golmarmara	0.931	1.540	1.159	0.537	0.491	0.664	0.438
Muganli-57	0.767	0.722	0.749	0.682	0.680	0.579	0.637
Ozberk-82	0.682	0.590	0.770	0.610	0.522	0.604	0.598
Golmarmara	0.704	0.700	0.767	0.586	0.598	0.570	0.645
Muganli-57	0.978	0.977	0.849	0.745	0.888	0.881	0.765
Ozberk-82	0.826	0.839	0.888	0.704	0.820	0.930	0.655
Golmarmara	1.013	1.146	0.999	0.669	0.736	0.816	0.606
Muganli-57	1.033	0.971	0.990	0.808	0.747	0.739	0.743
Ozberk-82	1.091	1.399	0.950	0.703	0.742	0.814	0.717
Golmarmara	1.195	1.087	1.017	0.763	0.706	0.777	0.823

1: Stainless steel, 2: Galvanized metal sheet, 3: Plywood, 4: Rubber

Table 5: Refraction forces of the sesame seeds used in the experiments (N)

	1st rate		2nd rate		3rd rate		4th rate	
Sample/ϕ(mm)	<3.5	>3.5	<3.5	>3.5	<3.5	>3.5	<3.5	>3.5
Muganli-57	163	231	170	210	199	233	280	311
Ozberk-82	218	242	250	261	285	363.5	297	380
Golmarmara	223	296	247	325	265	352	362	378

Table 6: The number of seeds per pellet

	1st rate		2nd rate		3rd rate		4th rate	
Sample/ϕ(mm)	<3.5	>3.5	<3.5	>3.5	<3.5	>3.5	<3.5	>3.5
Muganli-57	0.9	1.2	1	1	1.1	1	0.9	1.8
Ozberk-82	1	1.2	1	1.5	1	1	1	1.2
Golmarmara	1	1.4	1	0.9	0.9	1.3	0.9	0.9

force is 163 (N) and maximum is 380 (N). Number of seeds per pellet is another important criterion. As the diameter of the pelleted seeds increase, more seeds stick to it and number of seeds per pellet increase (Table 6). Although we found lower number of seeds per pellet in this study, number of seeds per pellet was satisfactory.

High dissolution rate in water is a desired characteristic of pelleted seeds. In Table 7, the dissolution rates of pelleted seed groups in water can be seen (below 3.5 mm and above 3.5 mm in diameter and with four different mixture rates). Pelleted seeds having bigger diameters had longer dissolution times in water related to the mixture rates used for pelleting. Especially, higher levels of aluminosilicate compound used in the pellets decrease the dissolution rate in water and increase the dissolution time. Longer dissolution time lags the absorption of moisture by the seed and inhibits germination.

Table 7: Dissolution times of pelleted seeds used in the experiments (sec)

	1st rate		2nd rate		3rd rate		4th rate	
Sample	<3.5	>3.5	<3.5	>3.5	<3.5	>3.5	<3.5	>3.5
Muganli-57	6.98	9.82	7.35	10.28	10.75	17.38	12,68	19.80
Ozberk-82	4.20	9.80	6.45	10.03	7.82	14.11	10.78	17.93
Golmarmara	5.30	7.36	6.13	10.96	7.44	19.06	12.76	25.35

Germination rates of bare seeds and pelleted seeds were measured at four different mixture rates with three replications (Table 8). The germination rates vary depending on the diameter of the pelleted seeds and mixture rates. It is not desirable to have germination rates that are dramatically smaller than 75%. Since the germination rates of the seeds with mixture rate 1 and diameters smaller than 3.5 mm are around 75% (Muganli kind 76.67%, Ozberk kind 69.00% and Golmarmara kind 78%), these seeds were used in field experiments.

The results of grease belt experiments: Table 9 shows the results of the grease belt experiments done with the pneumatic spacing planter in the lab. According to the table, as the speed goes up, plant spacing decreases and the variation coefficient increases.

As the speed goes up, the percentage miss indices gaps decline. The performance of the machine has an inverse relationship with the miss index and multiple indexes. The machine shows its performance at up most level at the speeds of 0.5 and 1 m s^{-1} and at a plant spacing of Z = 10 cm.

Moreover, it has been found that the average planting distance values are very close to the plant

Table 8: The germination rates of bare seeds and pelleted seeds at four different mixture rates (%)

		1st rate		2nd rate		3rd rate		4th rate	
Sample	Bare	<3.5	>3.5	<3.5	>3.5	<3.5	>3.5	<3.5	>3.5
Muganli-57	100	76.67	37.33	42.67	17.33	26.66	12.00	21.33	2.67
Ozberk-82	100	69.00	48.00	46.33	20.69	42.00	18.00	16.00	9.34
Golmarmara	100	78.00	44.00	60.00	25.33	42.67	09.33	14.68	1.30

Table 9: The results of the experiments done with a pneumatic spacing planter

Vm (m s^{1})	CV	X (cm)	<0.5 Z (%)	(0.5-1.5) Z (%)	1.5 Z> (%)
0.5	34.126	10.253	4.95	83.11	11.92
1.0	39.804	10.400	3.41	80.57	16.02
1.5	41.463	9.713	7.71	81.06	11.22
2.0	45.983	8.950	12.56	77.18	10.25

Vm: speed of the machine, CV: variation coefficient,
X: average planting distance, z: plant spacing

Table 10: Germination rates of the sesame seeds

Sample	Traditional seeding (%)	Pelleted seed planting (%)
Muganli-57	61.15	73.3
Ozberk-82	63.14	75.8
Golmarmara	52.44	83.3

spacing values. The best results are obtained with the first three speeds (0.5, 1.0 and 1.5 m s^{-1}). As it is obvious in the table, as the speed diminishes, the distance between the seeds at plant spacing increases. Theoretically, the rate of acceptable planting distance should not be less than 80%. However, at a speed of 2 m s^{-1}, plant spacing could not be maintained. The intensifications in relative rates seen in plant spacing introduce the positive side of the method.

As a result, the best results were obtained at speeds of 0.5 and 1 m s^{-1} and plant spacing of Z = 10 cm at the end of the grease belt experiments. In field tests, the speed of 0.5 m s^{-1} was used as a planting speed.

Rates of emergence in the field: The rates of emergence in the field vary depending on the planting method (broadcast seeding method and planting pelleted seeds with a pneumatic spacing planter) and the seed kind (Table 10). In general, planting pelleted seeds with a pneumatic spacing planter leads to highest rates of emergence. Ozberk kind seeds have the highest rate of emergence at broadcast seeding (63.14%). Even though this is the maximum rate for bare seeds, it is still lower than the minimum rate for pelleted seeds (73.3% for Muganli). Other kinds of seeds have higher rates of emergence: 75.8% for Ozberk and 83.3% for Golmarmara.

In broadcast seeding, low emergence rates resulted from the planting method. When the bare seed planting and pelleted seed planting are compared to one another, planting pelleted seeds with a pneumatic spacing planter is obviously superior to using bare seeds.

DISCUSSION

It was observed that rolling resistance coefficient was decreased by pelleting the seeds. The average number of the seeds per pellet was at satisfactory levels. Due to their bigger diameters, pelleted seeds had longer dissolution times in water, depending on the mixture rates used for pelleting. The dissolution times of pelleted seeds showed a positive correlation with the pellets' diameter and the mixture rates of clay and aluminosilicate compound used for pelleting. The diameter after pelleting and the clay/aluminosilicate ratio used in pelleting mixture significantly affected the germination rates.

The part of research, dealing with the improvement of germination rate, is still in progress. In the grease belt experiments, best results were obtained with a speed of 0.5-1.0 m s^{-1} and a planting space value of 10 cm. Therefore our planting speed was 0.5 m s^{-1} in the arable field trials.

With the direct propagation of pelleted sesame seeds with pneumatic spacing planter on the field, the highest rate of emergence was obtained. Also, this method improved the planting norm significantly and hence decreased the production cost.

In brief, it is well known that the traditional broadcast seeding method has disadvantages such as irregular seeding in the field, difficulties in cultivating the soil and low rates of emergence and consequent increase in the amount of wasted seeds. On the other hand, pelleted seeds eliminate these disadvantages since seeding is more regular due to the utilization of pneumatic spacing planter, cultivation of soil is easier, rates of emergence are higher and consequently amount of wasted seeds is lower. This study shows that it is feasible to mechanize sesame planting using pelleted sesame seeds and eliminate the disadvantages related to traditional broadcast seeding.

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