# THE EFFECT OF SEED COATING THICKNESS ON SUGAR BEET (*Beta vulgaris* L.) YIELD AND QUALITY UNDER DIFFERENT IRRIGATION CONDITIONS

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**Abstract.** Sowing naked seeds is generally preferred in arid and semiarid regions. This research aimed to find the optimal dimensions for both pelleted and naked seeds based on seed distance in rows and field emergence irrigation setting in sugar beet (*Beta vulgaris* L.) cultivation under the environmental conditions of Central Anatolia in Turkey. For comparison, the research considered two field emergence irrigation conditions, namely, irrigated and non-irrigated, at 8 and 17 cm seed distances within rows for naked seeds of two dimensions: N3.25-Ø4.50 and N3.00-Ø3.50 mm and for pelleted seeds of five dimensions: P3.50-Ø3.75, P3.75-Ø4.00, P4.00-Ø4.25, P4.25-Ø4.50, and P4.50-Ø4.75 mm. The results showed that the highest beet yield and refined sugar content were 66.67 and 10.31 t ha$^{-1}$, respectively, obtained in the plot that was irrigated and drilled with N3.00-Ø3.50 mm seeds at 8 cm sowing distance. The lowest values were obtained from the non-irrigated plot that was drilled with P4.50-Ø4.75 mm seeds at 17 cm sowing distance in all conditions. In field emergence irrigation conditions, planting pelleted seeds from 3.50 to 4.25 mm in dimension or 0.25-0.75 mm in thickness at row distances of 8 and 17 cm can be concluded to be the optimum application.
**Keywords:** *sugar beet, seed pelleting, germination, field emergence irrigation, row space, quality indicators*

## Introduction

Decreasing the manual labor and increasing machinery operations by as much as possible are among the goals of sugar beet (*Beta vulgaris* L.) farming. In practice, considerable progress has been achieved with machinery operations except for thinning and singling. Reducing manual labor generally depends on three factors: uniform and healthy seedling rows, uniform seedling distribution, and adequate weed control (Draycott, 2006). Achieving a uniform seedling distribution and the optimum plant density depends on the seed specifications, proper cultivation, and sowing technique. The application of suitable mechanical and chemical weed control is also important to ensure a high yield and quality (SBGG, 2016).

Sugar beet is generally planted at 8 cm seed distance in a row and at 45 cm distance between rows by using precision drilling machines; a singling distance of 20-25 cm is applied in Turkey. In addition, planting at 45 cm row spacing and at the desired seed spacing within a row can be carried out with the use of pneumatic drilling machines. The optimum plant frequency to obtain the highest yield and quality has been determined to be between 70000 and 90000 plants ha$^{-1}$ (Hozayn et al., 2013; SBGG, 2016). The forward speed of the drilling machine is one of the major factors affecting the sowing quality; a forward speed of 4.5-5 km h$^{-1}$ seems to provide the most appropriate seed distribution. A high speed causes an irregular seed distribution, changing the depth settings and leaving


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the seeds on the soil surface. The planting depth is also a major factor in yield and quality. Sugar beet seeds must be sown at a depth of 2-4 cm and should be checked continuously during sowing. Further, proper planting facilitates the subsequent hoeing and harvesting process (Hozayn et al., 2013).

Spacing is the distance between two successive seeds in a row. Misses (voids) refer to the absence of a seed where there should be one theoretically, that is, where the spacing is more than 1.5 times the theoretical seed spacing. Multiples (doubles) refer to the presence of two or more seeds where there should only be one, that is, where the spacing is less than 0.5 times the theoretical seed spacing (Lammers et al., 2015). One seed within targeted rows and single seedling germination in each cell are desired in sugar beet cultivation. To achieve these goals, it is important to use precisely calibrated pelleted and naked seeds. The vast majority of sugar beet seeds sown in Turkey consist of naked genetic monogerm seeds. Genetically monogerm sugar beet seeds belonging to different varieties are processed and calibrated according to sizes of 3.25-Ø4.50 mm at the Turkish Sugar Factories Corporation seed processing plant. They are then delivered to farmers after being treated with one insecticide (imidacloprid or thiamethoxam), two fungicides (hymexazol and thiram) against disease and pests. The variety of seeds produced by private seed companies can be bought from the market and sown according to the preference of farmers (TSFAS, 2019).

In recent years, an increase has been observed in the number of producers sowing pelleted genetically monogerm seeds, called thin pelleted seeds, 3.50 to 4.00 mm in dimension. The smoother surface and more spherical structure of pelleted seeds result in a more precise seed distribution in a row, especially when precision sowing machines are used. Also, larger amounts of pesticide may be mixed into the coating material depending on the naked seeds, thus increasing the efficacy of pesticides against both pests and diseases. On the other hand, seed pelleting increases the costs and decreases the amount of field emergence in some regions where arid and semi-arid climate conditions prevail and during years of arid climate and with insufficient rainfall periods, especially just after drilling in spring. The germination rate of naked sugar beet seeds delivered to farmers by the Turkish Sugar is required to be at least 85% (TSFAS, 2019). Although the standard naked seeds satisfy this requirement, the rate may decrease to 68% after pelleting (Duan and Burris, 1997).

Pelleting of sugar beet seeds is done after polishing, dimension measurement, and separation by weight. To prepare the seeds for pelleting, one or all of these processes are carried out depending on the physical characteristics of the seed lot to be used. The pre-cleaning dimension of harvested seeds is generally between 3.25 and 6.00 mm. The seed size is decreased to 3.25-Ø3.50 mm by polishing before the pelleting process (Draycott, 2006). Polishing is the process of correcting the disk-shaped, jagged outer surface of beet seeds and obtaining the desired dimension by chipping the pre-pelleting of the seed outer surface (pericarp). Thinning of the pericarp by polishing increases the water intake and germination speed. After polishing, the seed units are passed through a multilevel sieve with round holes; seeds that are too small to be pelleted are removed, whereas those that are too large are polished again. Next, the seed units are passed through a sieve with oval holes, and those with multiple embryos are separated (Draycott, 2006). The remaining seeds are separated by weight and assessed by an X-ray test; those found to be 100% full are then sent to the pelleting units. Pellet sizes of 3.50-Ø4.75 and 3.75-Ø4.75 mm are widely preferred in Europe; only Finland and Sweden use pelleted seeds in the range of 4.00 to 5.00 mm. The thickness of the pelleting material increases


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the seed weight by an average of 180% (between 150 and 200%) or by 0.50-0.75 mm (Draycott, 2006). In Turkey, a pellet thickness of 0.50 mm is generally applied.

The pelleting process consists of four stages (*Fig. 1*). During seed pelleting, naked seeds are pelleted with a mixture of clay, wood flour, and adhesive. The process is done in rapidly rotating cylindrical boilers; inside the drums, water and the pelleting powder are sprayed onto the seeds. After that, the seeds are dried, and the water in the pelleting material is removed by evaporation, thus turning the pelleted seed into a hard pellet (KWS, 2020). Turkey has no domestic production of the sugar beet seed pelleting material, which is currently sourced from abroad.

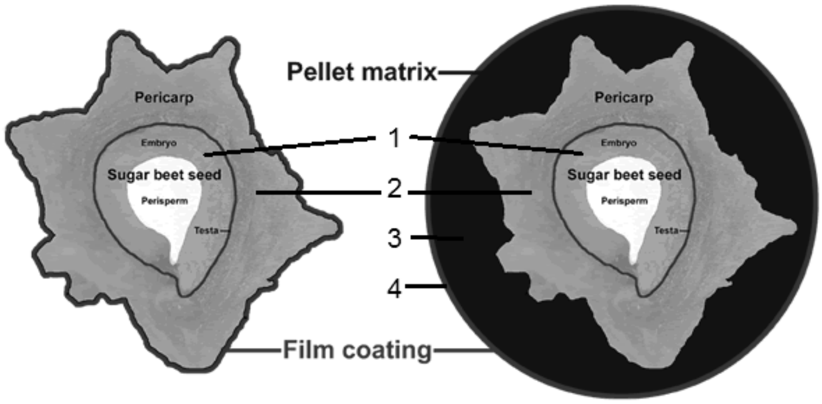


***Figure 1.*** *Sectional view of the pelleted seed*

In this study, it was aimed to determine the most suitable seed type and seed coating thickness for high yield and quality by comparing uncoated and coated sugar beet seeds under different of sowing distances and with and without emergence irrigation conditions.

## Materials and methods

This research was carried out at the Sugar Institute in the Eskişehir (39°47′N, 30°31′E), Etimesgut (39°56′45″N, 32°40′10″E), and Ilgın (38°16′45″N, 31°54′50″E) experimental stations over a three-year period from 2012 and 2014 in Turkey. The soil textures in the three locations were silty-clayey and clayey, and the regional climatic characteristics were arid and semi-arid. During the vegetation period of sugar beet, the total annual precipitation in April-August period is given in *Fig. 2* and the average temperature values by months are given in *Table 1*. Climate data (temperature, precipitation) in the test fields were taken hourly by the automatic climate station in the test regions. In the three-years period, the three regions had similar mean rainfall rates despite their different geographic locations. Although there are minor differences in regions, the temperature between June-August periods was 15-25°C that were desired for the development of sugar beet.

The field used for sowing was prepared first by using a subsoiler, after which a disc harrow was used to clean the preplant wheat stubble in preparation for planting in autumn. The field was ploughed after the application of all the potassium fertilizer and two thirds of the phosphorus fertilizer according to the soil analysis. The seedbed was prepared with the combined use of a cultivator, harrow, and rotary harrow, which supplied the remaining one third of the phosphorus fertilizer and half of the nitrogen fertilizer in spring. The remaining half of the nitrogen fertilizer was applied before the first hoeing. According to


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the soil analysis, 120-170 kg ha$^{-1}$ of nitrogen, 50-100 kg ha$^{-1}$ of phosphorus, and 70-100 kg ha$^{-1}$ of potassium were present in the soil as pure substances at varying rates by region and year.

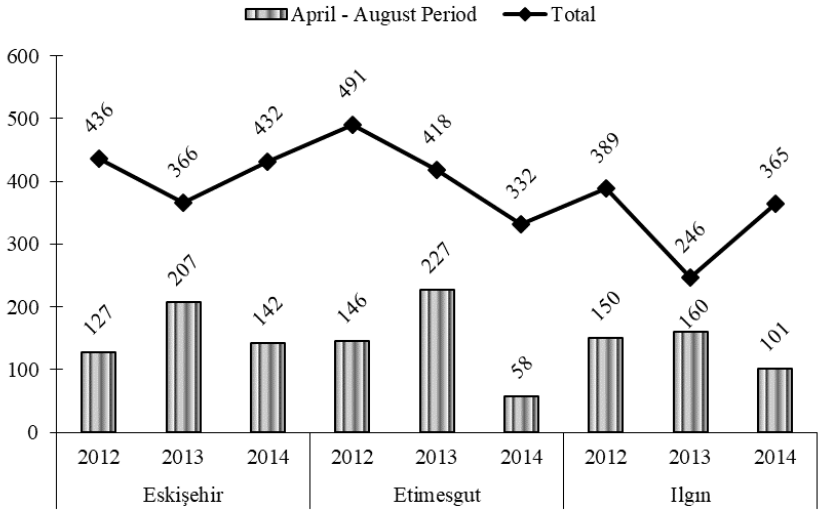


***Figure 2.*** *Precipitation status (mm)*

***Table 1.*** *Average temperature values of the regions by months*

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Dec | Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Etimesgut | | | | | | | | | | | | |
| 2012 | 2.6 | 4.1 | 6.6 | 9.9 | 15.1 | 21.2 | 24.8 | 27.0 | 20.5 | 13.0 | 11.0 | 4.1 |
| 2013 | 0.9 | 1.5 | 6.3 | 9.1 | 13.2 | 17.3 | 22.6 | 21.8 | 17.4 | 9.7 | 1.5 | 2.2 |
| 2014 | -3.0 | -5.9 | 1.2 | 12.0 | 15.2 | 20.5 | 23.7 | 21.7 | 19.9 | 14.7 | 7.8 | 2.4 |
| Eskişehir | | | | | | | | | | | | |
| 2012 | 2.7 | 6.1 | 7.0 | 10.0 | 15.4 | 19.4 | 22.1 | 25.0 | 19.2 | 11.1 | 10.5 | 5.6 |
| 2013 | 1.3 | 1.5 | 5.1 | 8.3 | 13.7 | 15.1 | 22.5 | 20.5 | 18.0 | 10.1 | 2.5 | 2.2 |
| 2014 | -2.1 | -4.2 | 2.6 | 12.6 | 15.9 | 21.1 | 23.5 | 21.2 | 19.1 | 15.7 | 8.3 | 3.6 |
| Ilgın | | | | | | | | | | | | |
| 2012 | 4.5 | 6.7 | 8.5 | 10.6 | 16.1 | 19.7 | 24.1 | 25.6 | 20.0 | 12.8 | 12.0 | 7.2 |
| 2013 | 3.6 | -1.4 | 5.8 | 9.8 | 13.7 | 18.3 | 23.6 | 21.7 | 18.0 | 10.5 | 2.6 | 3.1 |
| 2014 | -3.7 | -6.1 | 1.0 | 11.1 | 13.7 | 18.9 | 21.5 | 19.2 | 16.8 | 13.5 | 7.1 | 3.9 |

Field tests were carried out by applying a randomized split plot design in four replications. The experimental plots were 10 m long and 4.5 m wide, and the seeds were planted in the plots at 10 rows each with 45 cm row spacing. The total trial area was 4977 m$^2$, the sowing plot was 45 m$^2$, and the harvest plot was 20 m$^2$. The main plots consisted of areas under field emergence irrigated and non-irrigated conditions, and the subplots were planted at 8 and 17 cm planting distances with naked seeds of two different dimensions: N3.25-Ø4.50 and N3.00-Ø3.50 mm pelleted seeds of five different dimensions: P3.50-Ø3.75, P3.75-Ø4.00, P4.00-Ø4.25, P4.25-Ø4.50 and P4.50-Ø4.75 mm. In the plots with a seed drilling distance of 8 cm, the beets were manually thinned to 20-25 cm at the 4-6 leaf stage. In the plots with a drilling distance of 17 cm, the beets were singled and but not thinned even if there were more than one seedling in the queue (*Fig. 3*).


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***Figure 3.*** *General view of the parcels and plants in the trial area*

In the study, 15 mm water was applied to the plots which will be applied emergence irrigation by sprinkler irrigation method immediately after sowing. According to the needs of sugar beet 6-7 irrigation was made and approximately 100-150 mm water applied in each irrigation during the vegetation period.

Genetic monogerm sugar beet seeds, called “Giraf,” from SESVanderhave (Belgium) were used in the study. A mechanical precision drilling machine manufactured by Turkish Sugar was used for sowing in the trial plots. The seed pelleting and classification processes were done at the BETA Agriculture and Trade Co. seed processing plant in Merzifon (*Fig. 4*). First, the raw seed dimension of 3.00-6.00 mm was decreased to 3.00-3.50 mm by polishing, after which the seeds were pelleted. Then, the pelleted seeds were passed through sieves with round holes of 4.50, 4.25, 4.00, 3.75, and 3.50 mm and divided into five groups. The pelleted seeds in these groups and the naked seeds were then sprayed with pesticide, painted with the company's promotional color, and packaged. *Table 2* shows the average mass of 1000 seeds according to the seed dimension.

***Figure 4.*** *Classification of seeds according to seed sizes in Beta Agriculture and Trade Co. seed processing plant*


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***Table 2.*** *Laboratory emergence values according to the seed dimension used in the research*

| Seed dimension | Coated thickness (mm) | Thousands of seed mass (g) | 14th day laboratory germination values | | |
|---|---|---|---|---|---|
| | | | 2012 | 2013 | 2014 |
| U 3.25 - Ø 4.50 mm | - | 11.4 | 98 | 99 | 99 |
| U 3.00 - Ø 3.50 mm | - | 12.6 | 96 | 96 | 97 |
| C 3.50 - Ø 3.75 mm | 0.25 | 17.9 | 93 | 99 | 99 |
| C 3.75 - Ø 4.00 mm | 0.50 | 21.1 | 99 | 99 | 100 |
| C 4.00 - Ø 4.25 mm | 0.75 | 22.6 | 97 | 99 | 100 |
| C 4.25 - Ø 4.50 mm | 1.00 | 23.5 | 99 | 100 | 99 |
| C 4.50 - Ø 4.75 mm | 1.25 | 33.4 | 99 | 100 | 100 |

U: uncoated seed, C: coated seed

Both pelleted and naked seeds were treated with thiram (3.2 g active ingredient/1 kg seed) and hymexazol (3.5 g active ingredient/1 kg seed) to protect against fungal disease and imidacloprid (9 g active ingredient/1 kg seed) to protect against underground pests (wireworms, springtails, and millipedes) and flea beetles (Kaya and Gürkan, 2011). Seed germination tests of all seed plots used in the trial were carried out in a laboratory (*Table 2*).

For the germination tests, at least 100 seeds from each test subject were placed in germination containers laid on a flat folded filter paper. Each container was sprayed with 40 ml of water in the application with four replications. The number of seeds germinated after 4$^{th}$ and 14$^{th}$ days was counted in a germination room kept at a constant temperature of 20-22°C under a 16 h light/8 h dark cycle (ISTA, 2019).

The duration of field emergence is usually 14 days from the date of sowing on. However, the counts were done weekly from the beginning to the completion of the field emergence. The plant emergence rate was determined as the proportion of the total number of plants counted after complete plant germination to the amount of seed thrown per unit area based on the sowing distance in a row and between rows (Lammers et al., 2015).

After the harvesting, the beets were washed, weighed, and sampled for laboratory analysis with the use of a fraise hob. The amount of dry matter was measured with the Anton Paar Abbemat 500 refractometer manufactured in Germany. The sugar content was considered as the percentage of polar sugar (P). The amount of polar sugar was determined by extracting 26 g of beet pulp with 178.2 ml of aluminum sulfate ($Al_2(SO_4)_3$) liquor, after which polar meter readings were taken. The amounts of sodium (Na), potassium (K), and α-N were determined by the Anton Paar Betalyser system applying flame photometry principles. The refined sugar content (RSC) and refined sugar yield (RSY) was obtained by calculations (Reinefeld et al., 1974).

Variance analysis and F-tests were applied to the results. No comparisons were made when the F-value was found to be non-significant. Duncan’s multiple comparison method was used when the F-values were significant.

## Results and discussion

### *Field emergence*

The germination power of the seed varieties was found to be 99% in laboratory conditions (*Table 2*). Water is one of the most important factors in the germination of all


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plants. After sowing, achieving rapid seed germination and plant emergence depends on having appropriate soil weathering during sowing and maintaining adequate moisture in the soil. Sugar beet is a plant which is extremely sensitive to water. It should be considered to obtain a high yield and quality of sugar beet during the sowing period from April to mid-September.

Based on the combined results over the three-year study period, higher field emergence was obtained from the irrigated plots than from the non-irrigated ones (*Table 3*). In particular, pelleted seeds of P3.50-Ø3.75, P3.75-Ø4.00, and P4.00-Ø4.25 mm showed a considerable advantage in field emergence under both irrigated and non-irrigated conditions. The total annual rainfall and the amount of precipitation showed a variation during the vegetation period (from April to August). The highest average rainfall in the period from April to August was measured in 2013 and the lowest in 2014 (*Fig. 2*). Therefore, field emergence irrigation may be necessary to ensure germination and field emergence exactly from year to year after sowing even if adequate rainfall is not being taken before sowing.

***Table 3.*** *Seedlings in the parcels after the field emergence is completed (means of 3 years and 3 locations, $10^3$ $ha^{-1}$)*

| **Subjects** | **2012** | | **2013** | | **2014** | |
|---|---|---|---|---|---|---|
| | **Irr** | **Non-irr** | **Irr** | **Non-irr** | **Irr** | **Non-irr** |
| 8cm, U3.25-4.50 mm | 143.4±19.2 | 109.8±7.1 | 148.7±44.2 | 132.5±30.8 | 150.8±11.8 | 101.5±6.7 |
| 8cm, U3.00-3.50 mm | 174.4±18.5 | 137.7±10.0 | 169.0±30.1 | 150.5±26.4 | 183.4±9.5 | 140.4±15.6 |
| 8cm, C3.50-3.75 mm | 203.4±22.2 | 183.7±4.5 | 185.6±36.1 | 142.5±23.7 | 224.5±17.9 | 160.7±24.8 |
| 8cm, C3.75-4.00 mm | 199.9±18.6 | 173.0±4.1 | 172.2±42.1 | 165.0±35.4 | 214.2±20.5 | 165.2±16.5 |
| 8cm, C4.00-4.25 mm | 190.7±16.7 | 150.7±10.3 | 174.6±40.0 | 163.3±30.3 | 205.2±17.0 | 138.7±22.9 |
| 8cm, C4.25-4.50 mm | 148.5±16.0 | 145.4±5.2 | 165.9±27.2 | 147.4±27.1 | 167.7±13.4 | 129.3±8.6 |
| 8cm, C4.50-4.75 mm | 65.6±7.9 | 63.5±9.4 | 85.7±19.9 | 69.1±14.7 | 63.8±7.2 | 67.0±10.8 |
| Subjects | 2012 | | 2013 | | 2014 | |
| | Irr | Non-irr | Irr | Non-irr | Irr | Non-irr |
| 17cm, U3.25-4.50 mm | 54.5±5.2 | 48.7±3.1 | 76.3±22.3 | 84.3±23.2 | 57.2±5.6 | 44.5±3.2 |
| 17cm, U3.00-3.50 mm | 58.6±6.8 | 52.8±1.3 | 76.6±27.4 | 75.8±19.2 | 63.3±2.7 | 50.3±2.1 |
| 17cm, C3.50-3.75 mm | 93.0±8.1 | 80.9±10.5 | 96.0±21.3 | 116.6±24.0 | 93.6±6.2 | 64.6±5.2 |
| 17cm, C3.75-4.00 mm | 89.7±10.4 | 75.1±12.3 | 97.3±8.1 | 102.1±22.5 | 84.8±9.4 | 66.4±7.7 |
| 17cm, C4.00-4.25 mm | 77.5±8.8 | 73.1±11.5 | 99.4±25.1 | 108.1±20.3 | 84.2±3.7 | 61.2±5.1 |
| 17cm, C4.25-4.50 mm | 73.5±12.2 | 54.0±5.6 | 88.4±19.6 | 96.4±20.3 | 68.6±11.7 | 46.8±6.9 |
| 17cm, C4.50-4.75 mm | 26.7±2.1 | 21.1±1.9 | 66.5±34.6 | 58.1±23.1 | 26.9±4.6 | 28.8±8.4 |

## *Beet yield*

Considering the mean values, a higher beet yield was obtained in the plots in which field emergence irrigation was applied. In the irrigated plots, better results were achieved at 8 cm sowing distance than at 17 cm; in the non-irrigated plots, similar yield values were obtained for both sowing distances. The average beet yield was 61.71 t $ha^{-1}$ in the irrigated plots, compared to 57.85 t $ha^{-1}$ in the non-irrigated ones (*Table 4*, *Fig. 5*). The difference between these yields was statistically significant ($P<0.01$).

Regarding the beet yield based on sowing distance in a row, a value of 60.67 t $ha^{-1}$ was obtained at 8 cm and 58.89 t $ha^{-1}$ at 17 cm. The difference between these yields was also statistically significant ($P<0.01$) (*Table 4*).

The differences in yield according to the dimension of the pelleted seeds, except for those P4.50-Ø4.75 mm, were not significant. When considering average values; the


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highest value was obtained as 61.22 t $ha^{-1}$ with P3.50-Ø3.75 mm seeds. However, the highest yield of 66.67 t $ha^{-1}$ was obtained in the irrigated plot sown with N3.00-3.50 mm seeds at 8 cm distance; the lowest value of 44.77 t $ha^{-1}$ was obtained in the non-irrigated plot sown with 4.50-4.75 mm seeds at 17 cm distance (*Fig. 5*).

***Table 4.*** *Statistical evaluation according to the data's*

| Subjects* | Beet yield (t $ha^{-1}$) | Sugar content (%) | Refined sugar yield (t $ha^{-1}$) |
|---|---|---|---|
| Non-irrigated | 57.85 | 17.49 | 8.64 |
| Irrigated | 61.71** | 17.72** | 9.38** |
| 8 cm | 60.67 | 17.63 | 9.15 |
| 17 cm | 58.89** | 17.58 | 8.87** |
| U3.25 - Ø 4.50 mm | 61.11 A | 17.50 C | 9.01 B |
| U3.00 - Ø 3.50 mm | 60.93 A | 17.63 C | 9.19 AB |
| C3.50 - Ø 3.75 mm | 61.22 A | 17.86 AB | 9.49 A |
| C3.75 - Ø 4.00 mm | 60.49 A | 17.98 A | 9.44 A |
| C4.00 - Ø 4.25 mm | 60.86 A | 17.85 AB | 9.40 AB |
| C4.25 - Ø 4.50 mm | 61.07 A | 17.68 BC | 9.26 AB |
| C4.50 - Ø 4.75 mm | 52.78 B | 16.73 D | 7.27 C |
| SEM | 59.78±8.890 | 17.61±0.12 | 9.01±1.729 |

* U: uncoated seed, C: coated seed

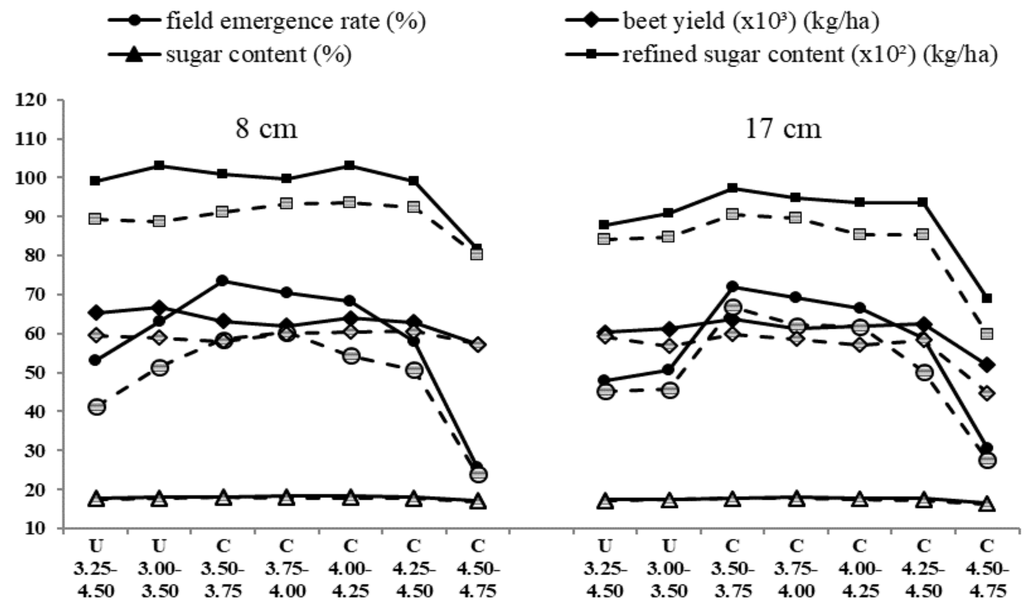


***Figure 5.*** *Quality data's obtained from plots (means of 3 years and 3 locations, dashed is non irrigated values)*

## *Sugar content*

Higher sugar content was obtained in the irrigated plots and at a sowing distance of 8 cm compared with the other plots (*Fig. 5*). The average sugar contents were determined as 17.72% in the irrigated plots and 17.49% in the non-irrigated ones. The difference between these values was found to be statistically significant (P<0.01).


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Regarding the sugar content by sowing distance in a row, 17.63% was obtained at 8 cm and 17.58% at 17 cm. The difference between these values was not statistically significant (*Table 4*).

The highest sugar content obtained based on seed dimension was 17.98% for P3.75-Ø4.00 mm seeds. Although the differences in sugar content between the seeds P3.50-Ø3.75, P3.75-Ø4.00, and P4.00-Ø4.25 mm in dimension were not significant, the differences between these subjects and the others were significant ($P<0.01$). The highest sugar content of 18.31% was obtained in the irrigated plot sown with P3.75-Ø4.00 mm seeds at 8 cm distance, whereas the lowest value of 16.32% was achieved in the non-irrigated plot sown with P4.50-4.75 mm seeds at 17 cm distance (*Table 4, Fig. 5*).

## *Refined sugar content*

Similarly to the beet yield and sugar content, a higher refined sugar content was obtained in the irrigated plots and at 8 cm sowing distance compared to the other plots (*Table 4, Fig. 5*). The average refined sugar content in the irrigated plots was 9.38 t $ha^{-1}$, compared to 8.64 t $ha^{-1}$ in the non-irrigated ones. The difference between these values was statistically significant ($P<0.01$).

Regarding the refined sugar content by sowing distance in a row, a value of 9.15 t $ha^{-1}$ was obtained at 8 cm and 8.87 t $ha^{-1}$ at 17 cm. The difference between these values was statistically significant ($P<0.01$).

The highest refined sugar contents were 9.49 and 9.44 t $ha^{-1}$, respectively, for the seeds P3.50-Ø3.75 and P3.75-Ø4.00 mm in dimension. The differences between seeds based on pelleting thickness were not significant. The highest refined sugar content was 10.31 t $ha^{-1}$, obtained in the irrigated plot sown with N3.25-3.50 mm seeds at 8 cm distance; the lowest value was 5.98 t $ha^{-1}$, achieved in the non-irrigated plot sown with P4.50-4.75 mm seeds at 17 cm distance (*Table 4, Fig. 5*).

In the statistical evaluations carried out in the three years of the research, location and year interactions were found. In essence, it is normal to have this type of interaction because the location and years differ in properties. However, since the results obtained in three years and three locations are parallel to the applied methods, the methods were evaluated over the averages.

Although it is not statistically significant in these three years, better results were observed comparing the irrigated plots to the non-irrigated ones with 8 cm sowing distance to 17 cm all of the three locations and years. A significant difference between irrigated and non-irrigated plots was found in the beet yield at Ilgın in 2014 ($P<0.05$), the sugar content at Etimesgut in 2012 ($P<0.05$), and the refined sugar content at Ilgın in 2012 ($P<0.05$) and 2014 ($P<0.01$) (*Table 5*). The difference between sowing distances of 8 and 17 cm was not significant in all the years and locations.

Regarding the difference between seed pelleting thicknesses by year and location, seeds P3.50-Ø3.75, P3.75-Ø4.00, and P4.00-Ø4.25 mm in dimension showed better results in all locations. The difference between the seeds P3.50-Ø3.75, P4.00-Ø4.25 mm in dimension and the other treatments were significant in terms of beet yield, sugar content, and refined sugar content ($P<0.05$, $P<0.01$) (*Table 5*).

Seed germination is controlled by environmental factors (light, temperature, water). The field emergence rates of the seed variety and in the specific region have to be known to determine the optimal sowing distance in a row. In this research, the average field germination rates at three different experimental stations was determined as 58% in irrigated plots and 50% in non-irrigated plots. These values are representative of the


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Central Anatolian Region and show the average levels in Turkey. This rate is lower than the level of 76% in the United Kingdom (BBRO, 2020). The data indicate that sowing at a distance of up to 17 cm can be done in similar circumstances. Larger sowing distances are discouraged because they present a higher risk under climate conditions of arid and semi-arid countries as well as Turkey. On the other hand, sowing sugar beet seeds at 8 cm distance in a row and adjusting to 20-25 cm by thinning and singling ensure a high yield and quality despite the lower field emergence in Central Anatolia, where sugar beet is cultivated intensively (Çakmakçı and Oral, 1995; Tuğrul et al., 2012). The 8 cm sowing distance also provided the best results in this study. However, in many areas, farmers do not carry out the necessary thinning and singling because they think it will decrease the number of plants in the field. Eventually, more frequent seedlings prevent the development of sugar beets (Draycott, 2006).

***Table 5.*** *Interaction table according to location, year and subject*

| Location / Subject | 2012 | | | 2013 | | | 2014 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Beet yield | Sugar content | Refined sugar content | Beet yield | Sugar content | Refined sugar content | Beet yield | Sugar content | Refined sugar content |
| Etimesgut | | | | | | | | | |
| A1 - A2 | ns | + | ns | ns | ns | ns | ns | ++ | ns |
| B1 - B2 | ns | ns | ns | ns | ns | ns | ns | ns | ns |
| C1 - C5 | ++ | ns | ++ | ++ | ++ | ++ | ++ | ++ | ++ |
| Eskişehir | | | | | | | | | |
| A1 - A2 | ns | ns | ns | ns | ns | ns | ns | ns | ns |
| B1 - B2 | ns | ns | ns | ns | ns | ns | ns | ns | ns |
| C1 - C5 | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ |
| Ilgın | | | | | | | | | |
| A1 - A2 | ns | ns | + | ns | ns | ns | + | ns | ++ |
| B1 - B2 | ns | ns | ns | ns | ns | ns | ns | ns | ns |
| C1 - C5 | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ns |

ns: no significant, +: P<0.05, ++: P<0.01

## Conclusions

In this study, field emergence irrigation was shown to significantly increase the beet yield and quality in the conditions of Central Anatolian Region which has arid and semi-arid climate in Turkey. Thus, taking into account the climatic conditions after sowing, proper irrigation scheduling would be beneficial to the level of 15-20 mm in the soil condition of the absence of enough moisture. In particular, field emergence irrigation is of great importance in ensuring sufficient emergence when sowing pelleted seeds.

In conclusion, frequent beet rows fail to achieve adequate growth and cause yield loss to the farmers. On the other hand, labor costs also seem to be a growing problem every year. Considering these reasons, if the field and seedbed preparation is carried out at the right time by the appropriate technical quality, and the climatic conditions are suitable, beets can be sown at 12 and 17 cm distances. Increasing seed pelleting thickness reduces remarkably the field emergence, yield and quality. In this case, the seeds P4.50-Ø4.75 mm in dimension, which have the thickest pellet, are not suitable in similar arid and semi-arid climatic conditions. The P4.25-Ø4.50 mm seeds, which have the second thickest pellet, provided better results for C5; however, pelleting with this thickness is considered to be risky. Besides their high field emergence, the seeds pelleted


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P3.50-Ø3.75, P3.75-Ø4.00 and P4.00-Ø4.25 mm in dimension provided a high yield and quality due to their advantages of allowing uniform and high-dose pesticide application. The seeds pelleted 3.50 to 4.25 mm in size were considered to be of the appropriate thickness to obtain the best results. The results indicate that, given the regional climatic conditions, besides planting naked seeds at 8 and 17 cm sowing distances, the best results are obtained by sowing seeds pelleted 3.50 to 4.25 mm in dimension and 0.25-0.75 mm in thickness under irrigated conditions.

Nowadays due to global warming, many regions where sugar beet is grown are under the problem of drought in the spring season or the problem of obtaining sufficient water with rainfall or both. For this reason, continuing trials with thinly coated or uncoated seeds are among the important issues, especially in areas where the water required for germination of seeds and sprouts of the plants to reach the soil surface cannot be adequately met with rains.

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