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# Influence of Row Spacing on Root Yield and Yield Components of Fodder Beet (*Beta vulgaris var. crassa* Mansf.) in the Black Sea Coastal Region

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**Abstract:** Effects of four row spacing (30, 40, 50 and 60 cm) on root yield and some yield components of fodder beet (*Beta vulgaris var. crassa* Mansf.) cultivar Ecdorot and cultivar Ecdogelb were evaluated in Çarşamba and Bafra plains, Turkey in the 2002 and 2003 growing seasons. The root yield, root dry matter rate, root dry matter yield, root diameter, root length, and sugar content were determined. Row spacing significantly affected most of the yield components determined in both locations. Root yield, root dry matter yield, root diameter, and root length increased along with increased of row spacing. However, root dry matter rate and sugar content were not greatly influenced by row spacing. The highest root dry matter was obtained from 50-60 cm row spacing for both cultivars and locations. Cultivar Ecdorat had higher yield data and this cultivar was also found more stable than cultivar Ecdogelb in the Black Sea costal region of Turkey.

**Key Words:** Fodder beet, row spacing, root yield, root dry matter yield

## Karadeniz Bölgesi Sahil Koşullarında Sıra Aralığının Yemlik Pancar (*Beta vulgaris var. crassa* Mansf.)'ın Yumru Verimi ve Verim Ögeleri Üzerine Etkisi

**Öz:** 2002 ve 2003 yılları yetiştirme peryodunda, Çarşamba ve Bafra ovalarında dört farklı sıra aralığı (30, 40, 50 ve 60 cm)'nın Ecdorot ve Ecdogelb yemlik pancar çeşitlerinin yumru verimi ve bazı verim ögelerine etkileri incelenmiştir. Araştırmada, yumru verimi, yumru kuru madde oranı, yumru kuru madde verimi, yumru boyu, yumru çapı ve yumru şeker oranı incelenmiştir. Sıra aralığının artmasıyla yumru verimi, yumru kuru madde verimi, yumru boyu ve yumru çapı artmıştır. Buna karşılık yumru kuru madde oranı ve şeker içeriği sıra aralığından fazla etkilenmemiştir. Her iki lokasyonda ve çeşitte en yüksek kuru madde verimi 50-60 cm sıra aralığında bulunmuştur. Karadeniz Bölgesi sahil koşullarında, Ecdorot çeşidi Ecdogelb çeşidine göre daha stabil ve daha yüksek verim değerlerine sahip olduğu belirlenmiştir.

**Anahtar Kelimeler:** Yemlik pancar, sıra aralığı, yumru verimi, yumru kuru madde verimi

### Introduction

Fodder beet is successively grown as a fodder crop in the coastal regions of many European countries. The plant is used as a valuable source of fodder for cattle (Niazi et al. 2000). Since fodder beet contains more water and sugar, it increases milk product and being suitable forage for dairy cows. The fodder beet is used by being chopped and by mixing with straw in European countries. It is also reported that the plant is suitable to make silage (Akyıldız 1983, Özen et al. 1993).

Including fodder beet in diet of cattle increases intake of dry matter that is quantitative and qualitative factors affecting intake of the basal diet. Vitamin and mineral supplements should be adjusted by increasing nitrogen supplements and decreasing energy from concentrate. Along with maize silage, 3 kg fodder beet with 5 kg hay per day is the optimum amount for cattle diet. It is also reported that milk contamination with butyric acid bacteria is lower when cows are fed with fodder beet compared to hay feed alone (Chenais 1994).

In the literature, various root yields of fodder beet are reported changing from 22.59 to 145.24 t $ha^{-1}$ (Buryakov 1994, Rzekanowski 1994, Stroller 1994, Koszanski et al. 1995, JuSam et al. 1995, Podstawka and Ceglarek 1995, Drashkov 1996, Grzes et al. 1996, Lukic and Vasilijevic 1996, Avcıoğlu et al. 1999, Soya et al. 1999). The possible reasons of different root yields might be different ecological conditions, soil structure, light duration, varieties and cultural treatments. Common view in all these reports is that there is a significant correlation between row spacing and root yield. Specifically, the most suitable row spacing reported was 40-60 cm (Manga et al. 1997, Avcıoğlu et al. 1999, Soya et al. 1999, Acar and Mülayim 2001).

The aim of this study is to determine the effect of different row spacings of two fodder beet cultivars on root yield and its components in Çarşamba and Bafra plains located in Black Sea Coastal Region of Turkey.

### Materials and Methods

Root yield and its components in fodder beet were examined in two different fodder beet cultivars at two locations in 2002 and 2003 in Turkey. Ecdorot and

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Ecdogelb are diploid fodder beet cultivars bred at Saaten Union, Germany in 1953. Fodder beet cultivars had production permission in 2002 in Turkey. Plants were grown under irrigated conditions in both locations. Sites are approximately 90 km apart. In the first experiment field located in Çarşamba, Samsun, the soil was clay loam, pH 7.1, 952 kg $ha^{-1}$ potassium, 230 kg $ha^{-1}$ phosphorus, and middle organic matter (2.42 %).

The monthly rainfall for March through September was 34.1, 61.9, 10.9, 53.8, 79.9, 14.3 and 34.6 mm in 2002 ( 289.5 mm total) and 73.5, 45.0, 54.7, 3.3, 37.2, 3.4 and 94.0 mm in 2003 (311.1 mm total) for Çarşamba location. It was 24.9, 44.9, 6.2, 95.3, 6.2, 115.1 and 69.9 mm in 2002 (370.6 mm total) and 66.1, 40.5, 52.1, 9.5, 49.7, 3.2 and 135.2 mm in 2003 (356.3 mm total) for Bafra location. Factorial arrangements of four-row spacing (30, 40, 50 and 60 cm) and two cultivars (Ecdorot and Ecdogelb) were evaluated in a randomized complete block design with three replications. Individual plot size was 2.4 x 5 m = 12 m² except 50 cm which was 12.5 m² . Sowing was done by hand on 24 and 28 March in 2002 and 2003 in Çarşamba, 25 and 29 March in 2002 and 2003 in Bafra, respectively. As a fertilizer, calcium ammonium nitrate of 100 kg $ha^{-1}$ after sowing and 75 kg $ha^{-1}$ in May was uniformly applied to all plots as. There were no problems with pests, diseases or weeds during the course of study.

Ten plants from each replication were taken at harvest stage for morphological measurements. Root diameter and root length were measured from individual plants. The plots were harvested by hand after the roots matured in September and the other parameters were determined at the same time. All statistical analyses were conducted using GLM producers of SAS (1998). Means were compared using Least Significant Differences (LSD) tests at the 0.05 probability level. Mean yield of fodder beet cultivars (x), regression coeffcient (r), deviation from regression ($s^2d$), determination coefficient ($r^2$), coefficient variation (CV), regression line intercept (a) were evaluated as stability parameters (Eberhart and Russell 1966).

## Results and Discussion

The root yields of cultivars and row spacing were significantly different in both locations. The highest root yield (115.46 t $ha^{-1}$) was obtained from Ecdorot with 50 cm row spacing in Çarşamba location, whereas the highest root yield (110.41 t $ha^{-1}$) was recorded from Ecdorot with 60 cm row spacing in Bafra (Table 1 and Table 2). As it

Table 1. Effects of row spacing on root yield and its components of fodder beet in Çarşamba location

| Row spacing (cm) | 2002 | | | 2003 | | | average of 2 years | | |
|---|---|---|---|---|---|---|---|---|---|
| | ecdogelb | ecdorot | mean | ecdogelb | ecdorot | mean | ecdogelb | ecdorot | mean |
| | Root yield (t $ha^{-1}$) | | | | | | | | |
| **30** | 73.17 | 83.67 | 78.42 c | 85.95 | 90.30 | 88.12 b | 79.56 | 86.98 | 83.27 c |
| **40** | 80.48 | 96.11 | 88.30 b | 91.66 | 101.96 | 96.81 b | 86.07 | 99.04 | 92.55 b |
| **50** | 101.0 | 112.07 | 106.53 a | 109.74 | 118.85 | 114.29 a | 105.37 | 115.46 | 110.41 a |
| **60** | 93.53 | 107.17 | 100.35 a | 110.49 | 118.35 | 114.43 a | 102.01 | 112.76 | 107.39 a |
| **mean** | 87.05 b | 99.75 a | 93.40 b | 99.46 a | 107.37 a | 103.41 a | 93.25 b | 103.56 a | 98.41 |
| | Root dry matter content (%) | | | | | | | | |
| **30** | 13.52 | 12.26 | 12.89 | 11.55 | 12.45 | 12.00 b | 12.54 | 12.36 | 12.45 |
| **40** | 11.86 | 12.72 | 12.29 | 11.59 | 12.99 | 12.29 ab | 11.73 | 12.86 | 12.29 |
| **50** | 12.58 | 13.61 | 13.09 | 12.57 | 12.84 | 12.70 a | 12.58 | 13.23 | 12.90 |
| **60** | 11.37 | 12.88 | 12.13 | 12.20 | 12.21 | 12.21 ab | 11.79 | 12.55 | 12.17 |
| **mean** | 12.33 | 12.87 | 12.60 | 11.98 b | 12.62 a | 12.30 | 12.16 | 12.75 | 12.45 |
| | Root dry matter yield (t $ha^{-1}$) | | | | | | | | |
| **30** | 9.93 | 10.19 | 10.06 c | 9.93 | 11.41 | 10.67 b | 9.93 | 10.80 | 10.36 c |
| **40** | 9.46 | 12.19 | 10.82 bc | 10.63 | 13.24 | 11.93 b | 10.04 | 12.71 | 11.38 c |
| **50** | 12.54 | 15.25 | 13.89 a | 13.77 | 15.29 | 14.53 a | 13.16 | 15.27 | 14.21 a |
| **60** | 10.59 | 13.72 | 12.16 b | 13.50 | 14.47 | 13.99 a | 12.04 | 14.10 | 13.07 b |
| **mean** | 10.63 b | 12.84 a | 11.73 b | 11.96 b | 13.60 a | 12.78 a | 11.29 b | 13.22 a | 12.26 |
| | Root diameter (cm) | | | | | | | | |
| **30** | 8.28 | 8.66 | 8.47 c | 10.34 | 9.46 | 9.89 c | 9.31 | 9.06 | 9.18 d |
| **40** | 9.17 | 9.28 | 9.22 bc | 12.40 | 12.01 | 12.20 b | 10.79 | 10.64 | 10.71 c |
| **50** | 9.65 | 9.40 | 9.53 ab | 13.88 | 14.62 | 14.25 a | 11.77 | 12.01 | 11.89 b |
| **60** | 9.96 | 10.29 | 10.12 a | 14.39 | 15.69 | 15.04 a | 12.17 | 12.99 | 12.58 a |
| **mean** | 9.27 | 9.40 | 9.33 b | 12.75 | 12.94 | 12.85 a | 11.01 | 11.17 | 11.09 |
| | Root length (cm) | | | | | | | | |
| **30** | 13.40 | 13.00 | 13.20 c | 13.63 | 14.58 | 14.10 d | 13.51 | 13.79 | 13.63 c |
| **40** | 15.87 | 16.73 | 16.30 b | 17.39 | 18.50 | 17.94 c | 16.63 | 17.62 | 17.12 b |
| **50** | 18.13 | 17.33 | 17.73 ab | 18.53 | 19.94 | 19.24 b | 18.33 | 18.64 | 18.48 a |
| **60** | 19.13 | 17.07 | 18.10 a | 19.92 | 20.59 | 20.26 a | 19.53 | 18.83 | 19.18 a |
| **mean** | 16.63 | 16.03 | 16.33 b | 17.37 b | 18.40 a | 17.89 a | 17.00 | 17.22 | 17.11 |
| | Sugar content (%) | | | | | | | | |
| **30** | 6.24 | 6.44 | 6.34 | 5.48 | 5.76 | 5.62 | 5.86 | 6.10 | 5.98 ab |
| **40** | 5.57 | 6.84 | 6.21 | 6.04 | 6.22 | 6.13 | 5.81 | 6.53 | 6.17 a |
| **50** | 5.88 | 6.12 | 5.99 | 5.42 | 5.86 | 5.64 | 5.65 | 5.99 | 5.82 ab |
| **60** | 5.56 | 5.79 | 5.67 | 4.93 | 5.63 | 5.28 | 5.25 | 5.71 | 5.48 b |
| **mean** | 5.81 | 6.30 | 6.05 | 5.47 | 5.87 | 5.67 | 5.64 b | 6.08 a | 5.86 |

Means followed by the same letter(s) and column(s) are not significantly different at the p = 0.05 level.

Table 2. Effects of row spacing on root yield and its components of fodder beet in Bafra location

| Row spacing (cm) | 2002 | | | 2003 | | | average of 2 years | | |
|---|---|---|---|---|---|---|---|---|---|
| | ecdogelb | ecdorot | mean | ecdogelb | ecdorot | mean | ecdogelb | ecdorot | mean |
| | Root yield (t ha$^{-1}$) | | | | | | | | |
| **30** | 63.26 | 66.94 | 65.10 c | 71.55 | 80.01 | 75.78 c | 67.41 | 73.48 | 70.44 c |
| **40** | 75.22 | 79.29 | 77.26 b | 88.40 | 93.20 | 90.80 b | 81.81 | 86.24 | 84.03 b |
| **50** | 92.03 | 102.15 | 97.09 a | 103.71 | 114.11 | 108.91 a | 97.87 | 108.13 | 103.0 a |
| **60** | 90.49 | 105.41 | 97.95 a | 111.48 | 115.41 | 113.45 a | 100.98 | 110.41 | 105.70 a |
| **mean** | 80.25 b | 88.45 a | 84.35 b | 93.79 b | 100.68 a | 97.23 a | 87.02 b | 94.57 a | 90.79 |
| | Root dry matter content (%) | | | | | | | | |
| **30** | 10.59 | 11.19 | 10.89 b | 11.82 | 12.29 | 12.05 | 11.20 | 11.74 | 11.47 b |
| **40** | 10.88 | 11.15 | 11.02 ab | 12.64 | 13.99 | 12.23 | 11.76 | 12.57 | 12.17 ab |
| **50** | 10.79 | 12.45 | 11.62 a | 11.68 | 14.36 | 13.02 | 11.24 | 13.41 | 12.32 a |
| **60** | 11.06 | 12.35 | 11.71 a | 12.78 | 11.69 | 13.32 | 11.92 | 12.02 | 11.97 ab |
| **mean** | 10.83 b | 11.79 a | 11.31 b | 12.23 | 13.08 | 12.66 a | 11.53 b | 12.43 a | 11.98 |
| | Root dry matter yield (t ha$^{-1}$) | | | | | | | | |
| **30** | 6.69 | 7.49 | 7.09 c | 8.45 | 9.79 | 9.12 c | 7.57 | 8.64 | 8.11 c |
| **40** | 8.18 | 8.85 | 8.52 b | 11.19 | 13.07 | 12.13 b | 9.68 | 10.96 | 10.32 b |
| **50** | 9.93 | 12.72 | 11.32 a | 12.09 | 16.34 | 14.22 a | 11.01 | 14.53 | 12.77 a |
| **60** | 10.01 | 13.01 | 11.51 a | 14.23 | 13.49 | 13.86 ab | 12.12 | 13.25 | 12.69 a |
| **mean** | 8.70 b | 10.52 a | 9.61 b | 11.49 b | 13.17 a | 12.33 a | 10.10 b | 11.85 a | 10.97 |
| | Root diameter (cm) | | | | | | | | |
| **30** | 8.97 | 9.24 | 9.10 b | 9.65 | 9.12 | 9.39 b | 9.31 | 9.18 | 9.25 b |
| **40** | 8.50 | 10.74 | 9.62 b | 9.85 | 10.16 | 10.01 b | 9.17 | 10.45 | 9.81 b |
| **50** | 10.11 | 11.30 | 10.71 ab | 11.73 | 12.09 | 11.91 a | 10.92 | 11.70 | 11.31 a |
| **60** | 12.27 | 12.08 | 12.18 a | 12.05 | 13.08 | 12.57 a | 12.16 | 12.58 | 12.37 a |
| **mean** | 9.96 | 10.84 | 10.40 | 10.83 | 11.11 | 10.97 | 10.39 | 10.98 | 10.68 |
| | Root length (cm) | | | | | | | | |
| **30** | 13.57 | 14.49 | 14.03 b | 14.26 | 13.86 | 14.06 b | 13.91 | 14.17 | 14.04 b |
| **40** | 15.67 | 17.44 | 16.56 ab | 15.79 | 17.21 | 16.50 a | 15.73 | 17.33 | 16.53 a |
| **50** | 17.42 | 17.35 | 17.39 a | 16.93 | 17.99 | 17.46 a | 17.18 | 17.67 | 17.42 a |
| **60** | 18.99 | 17.26 | 18.13 a | 18.71 | 17.82 | 18.26 a | 18.85 | 17.54 | 18.20 a |
| **mean** | 16.41 | 16.64 | 16.53 | 16.42 | 16.72 | 16.57 | 16.42 | 16.68 | 16.55 |
| | Sugar content (%) | | | | | | | | |
| **30** | 5.24 | 5.84 | 5.54 | 5.13 | 6.43 | 5.78 | 5.19 | 6.14 | 5.66 |
| **40** | 5.37 | 5.54 | 5.46 | 5.71 | 7.15 | 6.43 | 5.54 | 6.35 | 5.94 |
| **50** | 5.38 | 5.72 | 5.55 | 6.17 | 6.85 | 6.51 | 5.78 | 6.29 | 6.03 |
| **60** | 5.16 | 5.70 | 5.43 | 5.64 | 6.18 | 5.91 | 5.40 | 5.94 | 5.67 |
| **mean** | 5.29 b | 5.70 a | 5.49 b | 5.66 b | 6.65 a | 6.16 a | 5.48 b | 6.18 a | 5.83 |

Means followed by the same letter(s) and column(s) are not significantly different at the p = 0.05 level.

was indicated before, the root yield range from 22.59 to 145.24 t ha$^{-1}$ in fodder beet (Buryakov 1994, Rzekanowski 1994, Stroller, 1994, Koszanski et al. 1995, JuSam et al. 1995, Podstawka and Ceglarek 1995, Drashkov 1996, Grzes et al. 1996, Lukic and Vasilijevic 1996, Avcıoğlu et al. 1999, Soya et al. 1999). Fodder beet when grown under suitable conditions, can produce 150-200 t ha$^{-1}$ root yield (Açıkgöz 1991, Adıyaman 1996).

As row spacing widens, life area of plants increases. So using of nutrition matter, including water, light etc. per plant also increases. Increased photosynthetic activity leads to increase in root yield by increasing root diameter, root length, and carbohydrate storage (Salisbury and Rose 1992, Avcıoğlu 1995). The lowest average dry matters of roots were 12.17 % with 60 cm and 11.47 % with 30 cm row spacing in Çarşamba and Bafra, respectively. Previous results indicated that there was a negative correlation between root yield and rate of root dry matter in fodder beet (Langer and Hill 1991, Adıyaman 1996, Geren and Avcıoğlu 1996, Öz and Avcıoğlu 1997, Soya et al. 1997). It is also stated that there might be slight changes in root dry matter contents, as row spacing widens (Avcıoğlu et al. 1999, Soya et al. 1999). Although there were no statistically significant differences among the rates of root dry matter, it was relatively lower in wide row spacing than narrow row spacing. Ecdorot gave a higher dry matter rate than Ecdogelb in both locations (Table 1 and Table 2). It was previously reported that rates of dry matter in fodder beet might change from 11.82 % to 18.60 % (Rzekonowski 1994, Lukic and Vasilijevic 1996, Avcıoğlu et al. 1999, Soya et al. 1999).

The highest dry matter yield was obtained from cultivar Ecdorot (15.25 and 15.29 t ha$^{-1}$, respectively) in both years in 50 cm row spacing at Çarşamba location. At Bafra location, in the first year, while the highest root dry matter yield was obtained from cultivar Ecdorot (13.01 t ha$^{-1}$) in 60 cm row spacing. In the second year, cultivar Ecdorot had the highest yield (16.34 t ha$^{-1}$) in 50 cm row spacing (Table 1 and Table 2).

The root dry matter yields in the second year were higher than yields of the first year in both locations. These differences might be caused by the ecological conditions, such as precipitation and temperature recorded during the vegetative growth cycle. Avcıoğlu et al. (1999) showed that the variation seen in dry matter rates of fodder beet is also one of the reasons for the variation seen in root dry matter yield. In addition, several researches indicated that in contrast to root yield increase, both dry matter rate and root dry matter yield are decreased with a wide row space application (Geren and Avcıoğlu 1996, Öz and Avcıoğlu 1997, Soya et al. 1999, Acar and Mülayim 2001). Avcıoğlu et al. (1999) reported that increasing row spacing increased dry matter yield. Our results are similar to Avcıoğlu et al. (1999).

As row spacing widen, root diameter is also increased in cultivars Ecdorot and Ecdogelb in both locations (Table 1 and Table 2). Moreover, as the plant area widens, plant diameter is also getting increase. Since high plant density limits nutrition uptake and photosynthesis activity, plants are not able to store enough nutrition to root due to competition. Therefore, root development is restricted (Avcıoğlu et al. 1999; Soya et al. 1999; Geren and Avcıoğlu 1996; Sağlamtimur and Tansı, 1989). On the other hand, Sağlamtimur et al. (1989) reported a negative correlation between root diameter and plant density.

As row spacing is widening, root length is also increased in both cultivars in both locations, just like the root diameter (Table 1 and Table 2). Avcıoğlu et al. (1999) and Soya et al. (1999) indicated that root length was increased as the row spacing widen.

The lowest average sugar content was obtained from 60 and 30 cm row spacing in Çarşamba (5.48 %) and Bafra locations (5.66 %), respectively. Tayşi and Demir, (1979) reported that there was a negative correlation between sugar content and root yield, whereas root dry matter rate is positively correlated with sugar content.

If genotypes’ regression coeffcient (r) is close to 1, regression line intercept (a) is possitive, determination coefficient ($r^2$) is close to 1, deviation from regression ($s^2d$) is close to 0, coefficient variation (CV) is low, genotypes are stable in all this conditions (Eberhart and Russell 1966). According to this literature, cultivar Ecdorot is more stable than cultivar Ecdogelb (Table 3 and Figure 1).

According to the research investigated different row spacing on root yield and yield components of fodder beet (*Beta vulgaris var. crassa* Mansf.) cultivars having production permission in 2002 in Turkey in Çarşamba and Bafra plains located Blacksea Coastal Region in Turkey, the highest root dry matter was obtained from 50-60 cm row spacing for both cultivars and locations. Cultivar Ecdorat had higher yield data and this cultivar was found more stable than cultivar Ecdogelb too.

Table 3. Stability parameters for root dry matter yields

| Cultivars | x | b | a | $r^2$ | CV | $S^2d$ |
|---|---|---|---|---|---|---|
| **Ecdogelb** | 10.69 | 1.03 | -1.25 | 0.996 | 0.66 | 0.005 |
| **Ecdorot** | 12.53 | 0.93 | 1.739 | 0.991 | 0.78 | 0.01 |

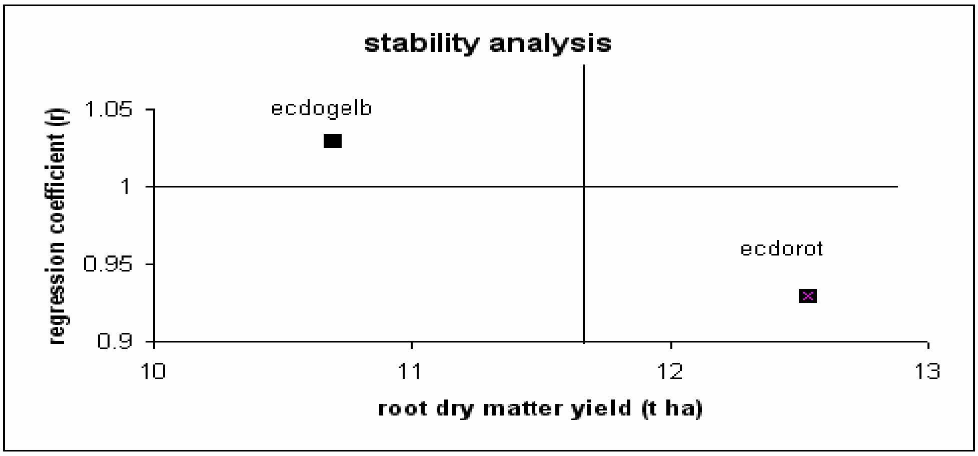


Figure 1. Stability situation of fodder beet cultivars according to root dry matter yield and regression coefficient

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