Grain yield and yield components at maize under different sowing and growing conditions

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ABSTRACT

The aim of the present paper is to present the grain yield and the yield components at different maize hybrids studied at different row spacing and plant densities and under the influence of different soil and climatic conditions from South Romania.

Maize (Zea mays L.) is the most important crop in Romania with a harvested area of 2.5 million ha in 2014. The largest cultivated surfaces are located in south of the country which has favourable conditions for growing maize, but with a different influence on the maize crop according to the soil from each location and climatic conditions of the year. In order to use the growing conditions in an efficient way the farmers are interested into the best row spacing and plant density of the maize crop. In this respect, we performed field experiments in the years 2013 and 2014, in two locations from South Romania, respectively Fundulea (44°28’ N latitude and 26°27’ E longitude) and Moara Domneasca (44°29’ N latitude and 26°15’ E longitude). The two years offered different climatic conditions and the two locations offered also different climatic conditions as well as different soil conditions, respectively chernozem and reddish preluvosoil. Within the field experiments a number of four maize hybrids were studied, respectively: Cera 450 (FAO precocity group 450), Flanker (FAO precocity group 450), PR35T36 (FAO precocity group 500), and ES Feria (FAO precocity group 550). The four maize hybrids were studied in each location and in each experimental year under three row spacing conditions (75 cm, 50 cm, and twin-rows of 75/45 cm) and at three plant density conditions (60,000, 70,000, and 80,000 plants.ha⁻¹). In each experimental variant, the cobs from one square meter were collected and determinations of yield components were performed, the grain yield being calculated and reported at moisture content of 14%.

Keyword: maize, grain yield, yield components, sowing conditions, growing conditions.
1. Introduction

Maize (*Zea mays* L.) is the most important crop in Romania with a harvested area of 2.5 million ha in 2014, but with a variation for the period after year 2000 between 2.09 million ha in 2010 and 3.19 million ha in 2004, and with a maximum of 4.32 million ha in 1947. The largest cultivated surfaces with maize are located in South Romania, this plain area offering favorable growing conditions for maize plants. However, the different soil and climatic conditions influence both the cultivated area and the level of the yields.

Maize has a high grain yield potential, which is determined by the genetics of the cultivated hybrid and is influenced by the environmental factors that are affecting the plant growth (Ion et al., 2014). The environmental factors are affecting the so-called yield components. The yield components represent the components that are participating to the yield formation (Ion et al., 2013). They form the basis for the crop yield (Adeyemi, 2011). Among the environmental factors with a significant influence on the yield components, respectively on the grain yield, there are counted the soil and climatic conditions.

Soil provides suitable media for plant growth and development during the whole crop life cycle (Javeed et al., 2013). Among the most important climatic factors, there are counted the water and temperature conditions. Rainfall has a greater positive influence than light and temperature on yield increase (Chen et al., 2012). Yield potential can be diminished as a consequence of insufficient water supply to meet crop water demand (Grassini et al., 2009). Temperature has also an important influence on the growth and development processes of the maize plant. For instance, the optimum temperature for maize plant in day and night times ranges from 22 to 32°C and 16.7 to 23.3°C, respectively (Naveed et al., 2014).

The yield components and respectively the yielding capacity of the crop are influenced also by the crop technology. Optimal cultivation techniques derived from intensive cultivation research are important in the efforts to increase yield and fully explore the yielding potential of the maize hybrids (Chen et al., 2012). Key planting factors influencing maize establishment include spacing of seed, uniform seed depth, seed quality, planter speed, insects, diseases, desired seed density (Lauer and Rankin, 2004). Among the cultivation techniques with a significant influence on the yield components, respectively on the yielding capacity of the plants are counted the row spacing and plant density.

Generally, maize is cultivated in wide spaced rows (Nik et al., 2011). Decreasing the distance between neighbor rows at any particular plant population has several potential advantages (Sango et al., 2001), among which of great importance is a better use of the growing factors.
Agronomic practices such as plant population are known to influence the yield and yield components (Sharifi et al., 2009). Parallel to the increasing of plant density the individual production of plants decreases but the yield per unit area increases, however to a certain limit (Murányi, 2015). Therefore, the optimum plant density according to growing conditions is a key element for obtaining high yields. In order to use the growing conditions in an efficient way the farmers are interested into the best row spacing and plant density of the maize crop. From this perspective, the aim of the present paper is to present the grain yield and the yield components at different maize hybrids studied at different row spacing and plant densities and under the influence of different soil and climatic conditions from South Romania.

2. Materials and Methods

2.1. Experimental location

Researches performed for the elaboration of this paper were carried out in field experiments in the years 2013 and 2014. The field experiments were located in two places from South Romania, respectively: the experimental field belonging to Procera from Fundulea (44°28’ N latitude and 26°27’ E longitude) and the experimental field from Moara Domneasca Experimental Farm belonging to the University of Agronomic Sciences and Veterinary Medicine of Bucharest (44°29’ N latitude and 26°15’ E longitude).

2.2. Experimental design

In both experimental locations and in both experimental years a number of four maize hybrids were studied, respectively: Cera 450 (FAO precocity group 450), Flanker (FAO precocity group 450), PR35T36 (FAO precocity group 500), and ES Feria (FAO precocity group 550). Each hybrid in each location and in each experimental year was studied under three row spacing conditions (75 cm, 50 cm, and twin-rows of 75/45 cm) and at three plant density conditions (60,000, 70,000, and 80,000 plants.ha⁻¹). The field experiments were performed in four replications, and each variant consisted in four lines with a length of 10 m.

2.3. Crop management

The preceding crop was sunflower in both experimental locations and years. The fertilization was performed with 106 kg.ha⁻¹ of nitrogen and 40 kg.ha⁻¹ of phosphorus. The weed control was performed by the help of herbicides, respectively Dual Gold 960 EC (based on the active substance S-metolaclor 960 g/l) applied at a dose of 1.2 l.ha⁻¹ before seedbed preparation. The chemical control of weeds was completed by one manual hoeing. The field experiments were performed under rainfed conditions.

In 2013, the sowing was performed on 17th of April at Fundulea location and on 26th
of April at Moara Domneasca location, while in 2014, the sowing was performed on 8\textsuperscript{th} of May at Fundulea location and on 25\textsuperscript{th} of April at Moara Domneasca location. The sowing was performed manually with two seeds in the same place. The plant distances along the row were calculated for the three levels of plant population (60,000, 70,000, and 80,000 plants.ha\textsuperscript{-1}) and for each row spacing (75 cm, 50 cm, and twin-rows of 75/45 cm). Practically, the distances between plants along the row for each plant population and row spacing were marked on a rope that was stretched along the row and the seeds were sown next to these marks on the rope. In the growing stage of three leaves of the maize plants, the thinning operation was performed by snatching one plant there where two plants were in the same place.

2.4. Soil data
The specific soil from Fundulea area is chernozem (cambic chernozem), with a humus content between 2.8 and 3.2%, loam to clay loam texture, and pH between 6.4-6.8. The specific soil from Moara Domneasca area is reddish preluvosoil, with a humus content between 2.2 and 2.8%, clay loam texture, and pH between 6.2-6.6. Comparing the two soil conditions from the two locations, it can be said that Fundulea area offer better soil conditions for the maize crops.

2.5. Climatic data
For the growing period of maize (April-August) in Fundulea area, the average temperature was 20.1\textdegree C in 2013 and 18.9\textdegree C in 2014, while the multiannual average temperature is 18.6\textdegree C. The sum of rainfall for the same period was 381.1 mm in 2013 and 399.0 mm in 2014, while the multiannual rainfall is 327.9 mm.

Also for the growing period of maize (April-August) but in Moara Domneasca area, the average temperature was 20.5\textdegree C in 2013 and 18.8\textdegree C in 2014, while the multiannual average temperature is 18.5\textdegree C. The sum of rainfall for the same period was 115 mm in 2013 and 408 mm in 2014, while the multiannual rainfall is 313.2 mm.

Comparing the two climatic conditions from the two locations, it can be said that in both areas the temperatures were higher than the multiannual average value. It has to be emphasized that the year 2013 was warmer than the year 2014 and Moara Domneasca area was warmer than Fundulea area.

As concerning the rainfall in Fundulea area, the rainfall was higher than the multiannual average value, the year 2014 being more humid than the year 2013. Regarding the rainfall in Moara Domneasca area, the year 2013 was affected by drought, especially in the second part of the growing period of the maize crops, the plants relying on the accumulated water in the soil during the cold season. The year 2014 in Moara Domneasca area was a humid one with more rainfall than multiannual average value and even more rainfall than in Fundulea area.
2.6. Determinations and data processing

In each location, in each experimental year, and from each experimental variant, the cobs from one square meter were collected in the fully ripe stage of the maize plants. The cobs were analyzed into laboratory in view to be determined the yield and yield components. The following determinations of the cob yield components were performed: cob length (cm); number of kernel rows on cob; number of kernels on cob; weight of cob (g); weight of kernels on cob (g); weight of thousand seeds (g). It was determined the moisture content of the kernels with a moisture analyzer and it was calculated the grain yield in tons.ha⁻¹, which was reported at moisture content of 14%. The obtained data were statistically processed by analysis of variance (ANOVA); for the row spacing, the control variant was used the variant on chernozem soil with 75 cm row spacing; for the plant density, the control variant was used the variant on chernozem soil with 60,000 plants.ha⁻¹. The yield and the yield components of the cob in this paper represent the average values of the four studied maize hybrids.

3. Results and Discussions

3.1. Cob Length

Cob length registered different tendencies according to row spacing and growing conditions (Figure 1). On reddish preluvosoil, there was registered a tendency for the cob length to increase at narrow rows, especially at 50 cm between rows (18.9 cm in 2013 and 17.3 cm in 2014). As regarding the situation registered on chernozem soil, a slight tendency of increasing the cob length at narrow rows was registered only in 2014, with the highest average value at twin-rows of 75/45 cm (16.8 cm), while in 2013 the highest cob length average value was registered at 75 cm between rows (21.0 cm).

Compared to control variants (chernozem soil and 75 cm row spacing), only in 2013 but for all row spacing conditions on reddish preluvosoil there were registered negative differences that were very significant. These negative differences statistically significant registered in 2013 on reddish preluvosoil were determined partially by soil conditions but especially by bad climatic conditions, respectively the drought manifested in this area in the second part of the growing period of the maize plants.

Cob length decreased with the increasing in plant density, especially in 2014. The smallest differences between the average values determined by the increasing of plant density were registered on reddish preluvosoil in 2013, the unfavorable growing conditions acting in a sense of unifying the values of the cob length (Figure 2). It has to be emphasized the fact that increasing in plant density reduced the limits of variations for the values of the cob length.

Compared to control variants (chernozem soil and 60,000 plants.ha⁻¹), in 2013 and on
reddish preluvosoil there were registered negative differences that were very significant for all the plant density conditions. In 2014, on chernozem soil only the plant density of 80,000 plants ha\(^{-1}\) determined a negative difference that was very significant, while on reddish preluvosoil the plant density of 80,000 plants ha\(^{-1}\) determined a negative difference that was distinct significant and the plant density of 70,000 plants ha\(^{-1}\) determined a negative difference that was significant.

Figure 1. Cob length under different row spacing and growing conditions

Figure 2. Cob length under different plant density and growing conditions
3.2. Number of Kernel Rows on Cob

The number of kernel rows on cob was influenced in different ways by the row spacing according to soil and climatic conditions of the year (Figure 3). As in the case of cob length, on reddish preluvosoil there was registered a tendency for the number of kernel rows on cob to increase at narrow rows. This tendency was also registered on chernozem soil in 2014. The wide row spacing (75 cm between rows) determined the highest value for the number of kernel rows on cob only on chernozem soil and only in 2013.

Compared to control variants, only in 2013 and for the row spacing of 75 and 50 cm on reddish preluvosoil there were registered negative differences that were significant. Increasing in plant density determined a slightly decrease of the number of kernel rows on cob (Figure 4). Compared to control variants, there were not registered any differences statistically significant.

![Figure 3. Number of kernel rows on cob under different row spacing and growing conditions](image)

3.3. Number of Kernels on Cob

The number of kernels on cob decreased at narrow rows on chernozem soil in both climatic conditions, respectively in 2013 and 2014. In exchange, on reddish preluvosoil, the number of kernels on cob increased at narrow rows in both climatic conditions, the highest average values being registered at the row spacing of 50 cm, respectively in average 590 kernels on cob in 2013 and 599 kernels on cob in 2014 (Figure 5). Compared to control variants, only in 2014 and for the row spacing of 75 on reddish preluvosoil there were registered negative differences that were significant.
Figure 4. Number of kernel rows on cob under different plant density and growing conditions.

Increasing in plant density determined a decrease of the number of kernels on cob in all soil and climatic conditions, but the differences compared to control variants were not statistically significant (Figure 6).

Figure 5. Number of kernels on cob under different row spacing and growing conditions.
3.4. Weight of Cob

The highest values for the weight of cob were registered at narrow rows but differently according to soil conditions. Thus, the highest average values for the weight of cob on chernozem soil were registered at twin-rows of 75/45 cm, in both experimental years, respectively 240 g in the climatic conditions of the year 2013 and 147 g in the climatic conditions of the year 2014. On reddish preluvosoil, the highest average values for the weight of cob were registered at row spacing of 50 cm, in both experimental years, respectively 159 g in 2013 and 148 g in 2014 (Figure 7).

Compared to control variants, only in 2013 but for all row spacing conditions on reddish preluvosoil, there were registered negative differences that were very significant, these being explained by the drought manifested in the second part of the growing period of the maize plants in this year.

Increasing in plant density determined a decrease of the weight of cob in all soil and climatic conditions (Figure 8). Compared to control variants, in 2013 and for all the plant density conditions on reddish preluvosoil, there were registered negative differences that were very significant. In 2014, only the plant density of 80,000 plants.ha$^{-1}$ determined differences statistically significant on both soil conditions, which mean that for the specific climatic conditions of the year 2014, the plant density of 80,000 plants.ha$^{-1}$ were too much for the given climatic conditions.
3.5. Weight of Kernels on Cob

As in the case of the weight of cob, the highest values for the weight of kernels on cob were registered at narrow rows but differently according to soil conditions. Thus, the
highest average values for the weight of kernels on cob on chernozem soil were registered at twin-rows of 75/45 cm, in both experimental years (211 g in 2013 and 119 g in 2014), while on reddish preluvosoil, the highest average values for the weight of kernels on cob were registered at row spacing of 50 cm, in both experimental years, respectively 136 g in 2013 and 128 g in 2014 (Figure 9).

Compared to control variants, also as in the case of the weight of cob, only in 2013 but for all row spacing conditions on reddish preluvosoil, there were registered negative differences that were very significant.

![Figure 9. Weight of kernels on cob under different row spacing and growing conditions](image)

Increasing in plant density determined a decrease of the weight of kernels on cob in all soil and climatic conditions (Figure 10). Again as in the case of the weight of cob, compared to control variants, in 2013 and for all the plant density conditions on reddish preluvosoil, there were registered negative differences that were very significant. In 2014, only the plant density of 80,000 plants.ha⁻¹ determined negative differences statistically significant on chernozem soil.

### 3.6. Weight of Thousand Seeds

The weight of thousand seeds registered the same tendencies as in the case of the weight of cob and the weight of kernels on cob. Thus, the highest values for the weight of thousand seeds were registered at narrow rows but differently according to soil conditions, respectively: the highest average values for the weight of thousand
seeds on chernozem soil were registered at twin-rows of 75/45 cm, in both experimental years (348 g in 2013 and 212 g in 2014), while on reddish preluvosoil, the highest average values were registered at row spacing of 50 cm, in both experimental years, respectively 233 g in 2013 and 214 g in 2014 (Figure 11).

Figure 10. Weight of kernels on cob under different plant density and growing conditions

Figure 11. Weight of thousand seeds under different row spacing and growing conditions
Also as in the case of the weight of cob and the weight of kernels on cob, compared to control variants, only in 2013 but for all row spacing conditions on reddish preluvosoil, there were registered negative differences that were very significant. Increasing in plant density determined a decrease of the weight of thousand seeds in all soil and climatic conditions, except the situation registered at reddish preluvosoil and in 2013 (Figure 12). Again as in the case of the weight of cob and the weight of kernels on cob, compared to control variants, in 2013 and for all the plant density conditions on reddish preluvosoil, there were registered negative differences that were very significant. However, in 2014 there were not registered any differences statistically significant.

![Figure 12. Weight of thousand seeds under different plant density and growing conditions](image)

**3.7. Grain Yield**

Based on the fact that on chernozem soil the majority of the productivity elements of the cob registered the highest values at twin-rows of 75/45 cm, the highest yields were registered at twin-rows of 75/45 cm regardless of climatic conditions: the average value of the yield was of 15.36 tons.ha\(^{-1}\) in 2013 and 8.20 tons.ha\(^{-1}\) in 2014. Also based on the fact that on reddish preluvosoil the majority of the productivity elements of the cob registered the highest values at row spacing of 50 cm, the highest yields were registered at row spacing of 50 cm regardless of climatic conditions: the average value of the yield was of 10.06 tons.ha\(^{-1}\) in 2013 and 8.76 tons.ha\(^{-1}\) in 2014 (Figure 13).
It is interesting to underline the fact that in 2014, the highest average value of the yield registered on reddish preluvosoil at row spacing of 50 cm (8.76 tons.ha\(^{-1}\)) exceeded the highest average value of the yield registered on chernozem at twin-rows of 75/45 cm (8.20 tons.ha\(^{-1}\)). This means that the better climatic conditions, respectively the higher rainfall registered on reddish preluvosoil in 2014 counted more than the soil characteristics. Also, it has to be highlighted the idea that the narrow rows on reddish preluvosoil determined smaller variations of the yield, the situation being on the contrary on chernozem.

Compared to control variants, only in 2013 but for all row spacing conditions on reddish preluvosoil, there were registered negative differences that were very significant.

![Figure 13. Grain yield at 14% moisture content under different row spacing and growing conditions](image)

Despite the fact that the increasing of plant density decreased the values of the productivity elements of the cob, however the increasing of plant density increased the grain yield (Figure 14). The highest average values of the grain yield were registered at plant density of 80,000 plants.ha\(^{-1}\), except the situation registered on chernozem soil in 2014, when the highest average value of the grain yield was registered at plant density of 70,000 plants.ha\(^{-1}\). Also, it has to be noted that on reddish preluvosoil in 2013, the grain yields registered at plant density of 70,000 and 80,000 plants.ha\(^{-1}\) are very similar (9.99 tons.ha\(^{-1}\) at 70,000 plants.ha\(^{-1}\) and 10.01 tons.ha\(^{-1}\) at 80,000 plants.ha\(^{-1}\)). These findings sustain the idea according to which the
plant density has to be correlated to the growing conditions. Higher plant densities require better growing conditions; if this condition is not fulfilled then the high plant densities lead to the decreasing of the yields.

Compared to control variants, only in 2013 but for all plant density conditions on reddish preluvosoil, there were registered negative differences that were very significant.

![Figure 14. Grain yield at 14% moisture content under different plant density and growing conditions](image)

**4. Conclusion**

On reddish preluvosoil, the narrow rows increased the values of the cob length and of the so-called numerical productivity elements of the cob (number of kernel rows on cob and number of kernels on cob) regardless of climatic conditions. Generally, on chernozem soil, the same productivity elements registered smaller values at narrow rows compared to 75 cm between rows.

The so-called weight productivity elements (weight of cob, weight of kernels on cob, and weight of thousand seeds) registered the highest values at narrow rows, regardless of soil and climatic conditions. However, there are some differences determined by soil conditions. On reddish preluvosoil, the weight productivity elements registered the highest values at row spacing of 50 cm, while on chernozem soil, the same productivity elements registered the highest values at twin-rows of 75/45 cm. These productivity elements of the cob determined the same tendencies for the grain yield, respectively on reddish preluvosoil the highest yield were obtained at row spacing of...
50 cm, while on chernozem soil the highest yield were obtained at twin-rows of 75/45 cm.

Increasing of plant density from 60,000 to 70,000 and 80,000 plants ha\(^{-1}\) determined a decrease of all cob productivity elements. Despite this fact, the increasing of plant density increased the grain yield, except the situations associated with less favorable climate conditions. For good yields, the plant density has to be correlated with the growing conditions; higher yields need high plant density values but higher plant densities require better growing conditions to meet plants requirements.

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