Yield and Yield Components at Maize under Different Row Spacing, Plant Population and Growing Conditions

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Abstract: - The yield components, respectively the elements which determine the yield, are influenced both by environmental and technological factors. Among the environmental factors, the water availability and soil conditions are ones of the most important. Among the technological factors, the row spacing, plant population, and the cultivated hybrid are of great importance.
The aim of the present paper is to present the results obtained in the year 2013 regarding yield components and grain yield at different maize hybrids studied under different row spacing and plant population in different locations (different soil and climatic conditions) from South Romania.
Researches were performed in field experiments 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 studied maize hybrids were the following: Cera 440, Cera 540, Flanker, ES Feria, PR35T36, and Janett. Each hybrid in the two locations was studied under three row spacing, respectively: 75 cm, 50 cm, and twin-rows of 75/45 cm. Also, each hybrid in the two locations was studied at three plant populations: 60,000, 70,000, and 80,000 plants ha^{-1}.

Key-Words: - maize, yield, yield components, row spacing, plant population, hybrid, growing conditions.

1 Introduction

Maize (*Zea mays* L.) 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.

In order to fully explore their capacity to transform solar radiation into grain production, it is necessary to understand how plants interact morphologically and physiologically in a community and to identify the management practices which allow them to maximize the use of growth resources [1].

The yielding capacity of plants is determined by the yield components, which are the components that are participating to the yield formation [2]. Yield components are very important because they form the basis for crop plant yield which is always the final variable or attribute used in evaluating any crop plant [3].

The yield components are influenced both by environmental and technological factors. Among the environmental factors, the water availability and soil conditions are ones of the most important. Among the technological factors, the row spacing, plant population, and the cultivated hybrid are of great importance.

Selecting an appropriate plant density and planting pattern is important in establishing the crop production system and many investigations have deal with crop responses to population density [4].

Planting at high plant densities is a technique which can be used to increase crop yield; while single-plant yield decreases with increased plant density total light interception by the canopy is increased [4]. This means that the decreased single-plant yield is associated with an increased yield per unit of cultivated surface (hectare).

Optimum population levels should be maintained to exploit maximum natural resources, such as nutrient, sunlight, soil moisture and to ensure satisfactory yield [5]. A plant population that is higher than the optimum level is increasing plant competition for growth resources which is

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conducting to a much too small single-plant yield, which is associated with a small yield ha^{-1}. Also, a plant population that is smaller than the optimum level is leading to an inefficient use of growth resources, which is associated with a high single-plant yield but a small yield ha^{-1}.

Many researches were conducted to determine optimum plant density and row spacing by different researchers in last decades; however, researches on twin row planting configurations are still new and needs further evaluation [6].

Reducing row width to provide a more equidistant planting pattern has the potential to increase maize yield and shift optimum plant population to a higher value depending on the interactions with management and environmental factors [1].

2 Materials and Methods

The aim of the present paper is to present the results regarding yield components and grain yield obtained at different maize hybrids studied under different row spacing and plant population in different locations (different soil and climatic conditions) from South Romania.

Researches were performed in field experiments in two locations from South Romania, respectively Fundulea (44^{o}28' N latitude and 26^{o}27' E longitude), Calarasi County, and Moara Domneasca (44^{o}29' N latitude and 26^{o}15' E longitude), Ilfov County.

The soil from Fundulea area is chernozem (cambic chernozem soil), which is characterised by loam to clay loam texture, pH between 6.4 and 6.8, and humus content between 2.8 and 3.2%. The soil from Moara Domneasca area is reddish preluvosoil, which is characterised by clay loam texture, pH between 6.2 and 6.6, and humus content between 2.2 and 2.8%.

Researches were performed in year 2013, which can be characterised from a climatic point of view for the period September 2012 - August 2013, as follows: for Fundulea area, the average temperature was of 12.0^{o}C and the sum of rainfall of 700.6 mm; for Moara Domneasca area the average temperature was of 12.6^{o}C and the sum of rainfall of 288.0 mm.

The studied maize hybrids in the field experiments from Fundulea area were the following: Cera 440 (FAO group 440), Cera 540 (FAO group 540), Flanker (FAO group 450), ES Feria (FAO group 550), PR35T36 (FAO group 500), and Janett (FAO group 550). In the field experiments from Moara Domneasca, the studied maize hybrids were the following: Cera 440, Cera 540, Flanker, ES Feria, and PR35T36.

Each hybrid in the two locations was studied under three row spacing, respectively: 75 cm, 50 cm, and twin-rows of 75/45 cm. Also, each hybrid in the two locations was studied at three plant populations: 60,000, 70,000, and 80,000 plants ha^{-1}.

The field experiments were performed in four replications. The number of variants was 54 at Fundulea location and 45 at Moara Domneasca. Each variant consisted in four lines with a length of 10 m. The sowing was performed on 17th of April at Fundulea and on 26th of April at Moara Domneasca.

The crop technology was the usual one for cultivating maize in South Romania under rainfed conditions. The preceding crop was sunflower. 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 and through one manual hoeing.

In each location and from each variant, the ears from one square meter were collected and analysed. The following determinations of the ear yield components were performed: ear length (cm), ear diameter (mm), number of kernel rows per ear, number of kernels per ear, number of kernels per kernel row, ear weight, kernel weight, kernel rate per ear, and weight of thousand seeds. Also, it was calculated the grain yield (kg ha^{-1}) which was reported at moisture content of 14%. The obtained data were statistically processed by analyses of variance.

3 Results and Discussions

3.1 Ear length

Under favourable growing conditions (chernozem soil under good climatic conditions of the year 2013 in Fundulea area), the ear length registered the highest value (20.5 cm) at the row spacing of 75 cm (Fig.1.a). The narrow rows reduced the ear length. On the contrary, under less favourable growing conditions (reddish preluvosoil under less rainfall in the year 2013 in Moara Domneasca area), the ear length registered the highest value (18.4 cm) at row spacing of 50 cm.

For favourable growing conditions, the obtained results are according to those obtained by Gardner and Tetio-Kagho (1988), who was saying that generally, with decreasing the row spacing and increasing in plant population, competition between plants for absorbing photosynthetically active radiation (PAR) is enhanced and ear length is reduced [7].

The increasing of plant population from 60,000 to 80,000 plants ha^{-1} decreased the ear length both on favourable and less favourable growing conditions (Fig.1.b). It is interesting to underline the fact that under less favourable growing conditions the increasing of plant populations determined a not so important decrease of ear length than those under favourable growing conditions.

Our results are according to Porter and Hicks (1997) who stated that an increase in plant density decreases the size of ears since the needed space for the plant is gradually reduced, the plant absorbs less nutrients and it proportionally transfers less assimilates to the ears which cause smaller ears [7]. Also, Gozubenli et al. [6] and Sharifi et al. [5] found that ear length decreased with increasing plant density.

Among the studied maize hybrids, the ear length registered the highest values at Flanker hybrid, while the smallest values were registered at Cera 540 hybrid, both on favourable and less favourable growing conditions (Fig.1.c).

In average for all the row spacing, plant population, and studied hybrids, the ear length under favourable growing conditions was of 20.3 cm, while under less favourable growing conditions it was of 18.1 cm, which represents about 89% from the ear length under favourable growing conditions.

3.2 Ear diameter

Ear diameter registered the highest values at twin-rows of 75/45 cm, while the smallest values were registered at row spacing of 50 cm, both on favourable and less favourable growing conditions (Fig.2.a).

Regarding the ear diameter at different plant population, the highest values were registered at 70,000 plants ha^{-1}, while the smallest values were registered at 80,000 plants ha^{-1}, both on favourable and less favourable growing conditions (Fig.2.b). The slight increasing of ear diameter from 60,000 to 70,000 plants per hectare seems to be a reaction of the maize plants to compensate the smaller length of the ear. The further increasing of plant population at 80,000 plants per hectare determined the smallest values of the ear length and diameter because of the strong competition of plants for growing factors.

At the studied maize hybrids, the ear diameter was influenced differently by the growing conditions (Fig.2.c). The highest ear diameter was registered at Janett hybrid (47.1 mm). Under favourable growing conditions, the smallest ear diameter was registered at Cera 440 hybrid (43.0 mm), while under less favourable growing conditions the smallest value was registered at Flanker hybrid (37.3 mm).

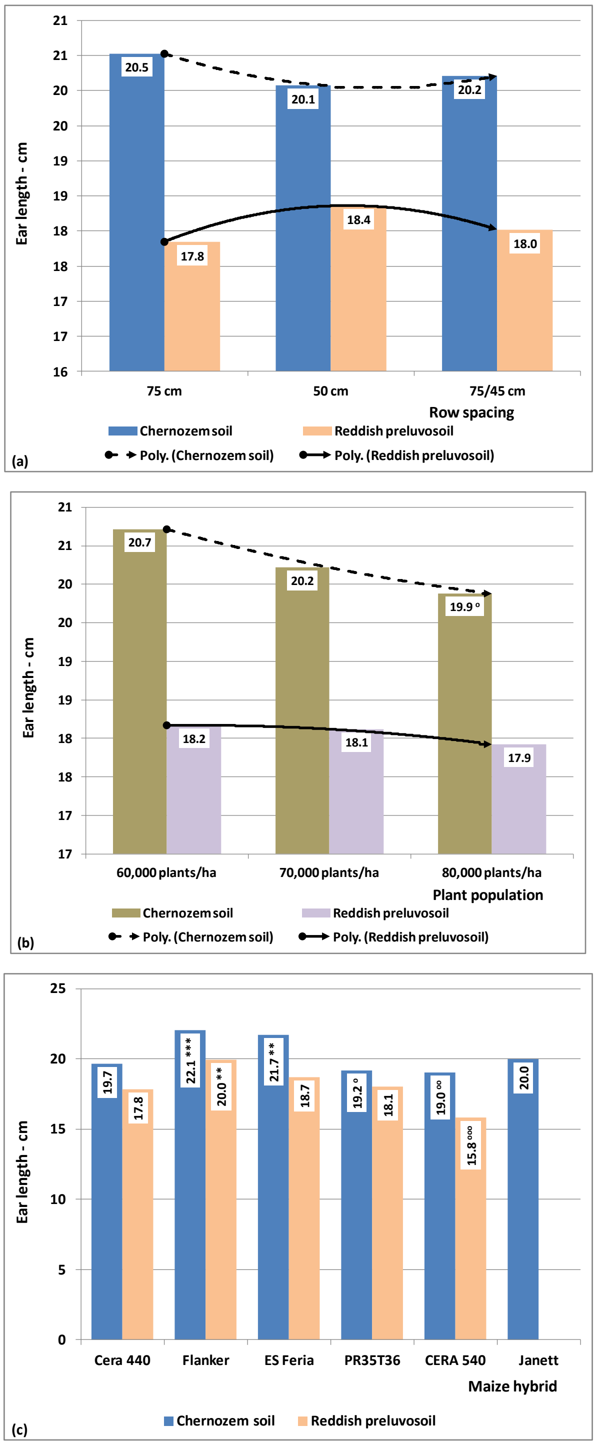

Figure 1. Ear length at different row spacing (a), plant population (b), maize hybrids (c), and on different soil and climatic conditions from South Romania

In average for all the row spacing, plant population, and studied hybrids, the ear diameter under favourable growing conditions was of 44.7 mm, while under less favourable growing conditions it was of 39.2 mm, which represents about 87.6% from the ear diameter under favourable growing conditions.

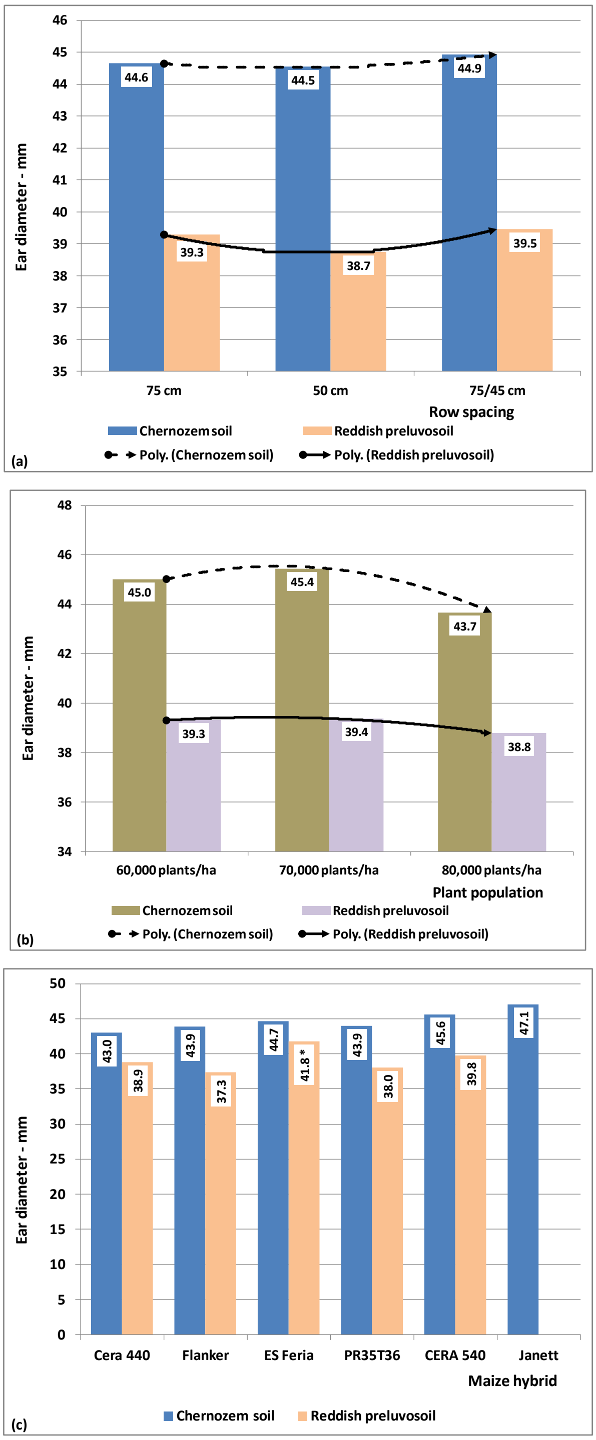

Figure 2. Ear diameter at different row spacing (a), plant population (b), maize hybrids (c), and on different soil and climatic conditions from South Romania

3.3 Number of kernel rows per ear

Under favourable growing conditions, the narrow rows decreased the number of kernel rows per ear, the smallest value being registered at twin-rows of 75/45 cm (Fig.3.a). On the contrary, under less favourable growing conditions, the narrow rows increased the number of kernel rows per ear, the highest value being registered at twin-rows of 75/45 cm.

Under favourable growing conditions, the increasing of plant population determined the decreasing of the number of kernel rows per ear (Fig.3.b). Under less favourable growing conditions, the highest number of kernel rows per ear was registered at 70, 000 plants per hectare.

Among the studied maize hybrids, the highest number of kernel rows per ear was registered at hybrids Cera 540 and Cera 440, while the smallest number of kernel rows per ear was registered at hybrids Flanker and ES Feria (Fig.3.c).

In average for all the row spacing, plant population, and studied hybrids, the number of kernel rows per ear under favourable growing conditions was of 16.0, while under less favourable growing conditions it was of 15.4, which represents about 96% from the number of kernel rows per ear under favourable growing conditions.

3.4 Number of kernels per ear

Under favourable growing conditions, the narrow rows decreased the number of kernels per ear, the smallest value being registered at twin-rows of 75/45 cm (Fig.4.a). Under less favourable growing conditions, the narrow rows increased the number of kernel per ear, the highest value being registered at row spacing of 50 cm.

The increasing of plant population from 60,000 to 80,000 plants ha^{-1} decreased the number of kernels per ear, both on favourable and less favourable growing conditions (Fig.4.b). The smallest values were obtained at 80,000 plants ha^{-1}.

Among the studied maize hybrids, the highest number of kernels per ear was obtained at ES Feria hybrid, both under favourable and less favourable growing conditions (Fig.4.c). The smallest number of kernels per ear was obtained at hybrids Flanker and PR35T36.

In average for all the row spacing, plant population, and studied hybrids, the number of kernels per ear under favourable growing conditions was of 630, while under less favourable growing conditions it was of 585, which represents about 92.8% from the number of kernels per ear under favourable growing conditions.

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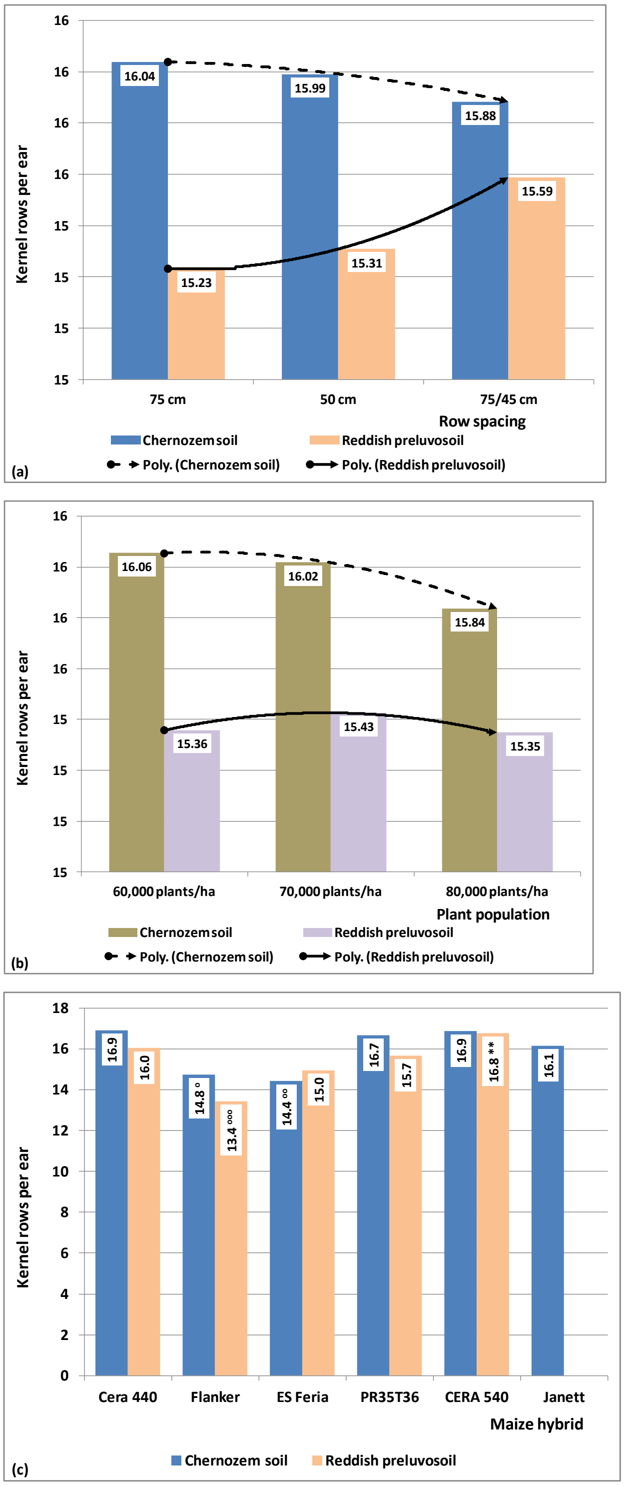

Figure 3. Number of kernel rows per ear at different row spacing (a), plant population (b), maize hybrids (c), and on different soil and climatic conditions from South Romania

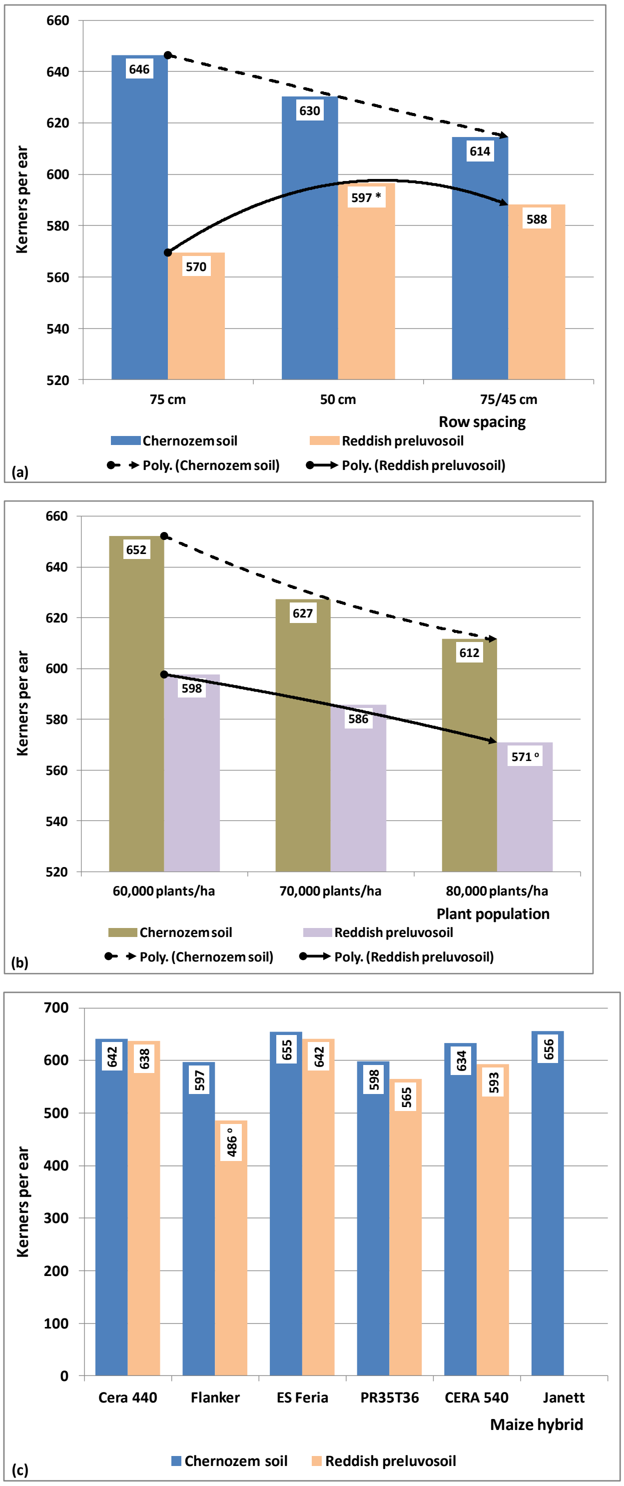

Figure 4. Number of kernels per ear at different row spacing (a), plant population (b), maize hybrids (c), and on different soil and climatic conditions from South Romania

3.5 Number of kernels per kernel row

The tendencies and correlations registered by the number of kernels per kernel row are similar to those registered by the number of kernels per ear at different row spacing, plant population and maize hybrids (Fig. 5.a, Fig. 5.b, Fig. 5.c).

In average for all the row spacing, plant population, and studied hybrids, the number of kernels per kernel row under favourable growing conditions was of 39.6, while under less favourable growing conditions it was of 37.9, which represents about 95.7% from the number of kernels per kernel row under favourable growing conditions.

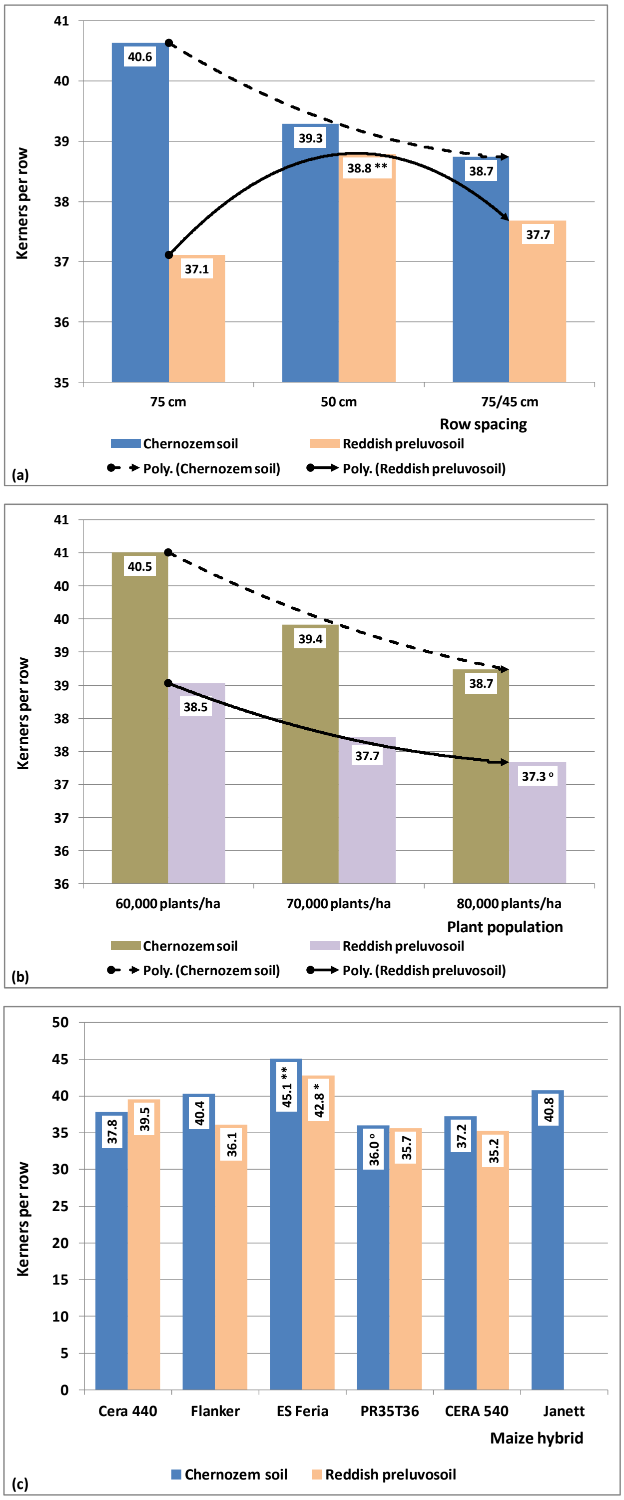

Figure 5. Number of kernels per kernel row at different row spacing (a), plant population (b), maize hybrids (c), and on different soil and climatic conditions from South Romania

3.6 Ear weight

Under favourable growing conditions, the narrow rows increased the ear weight, the highest value being registered at twin-rows of 75/45 cm (Fig.6.a).

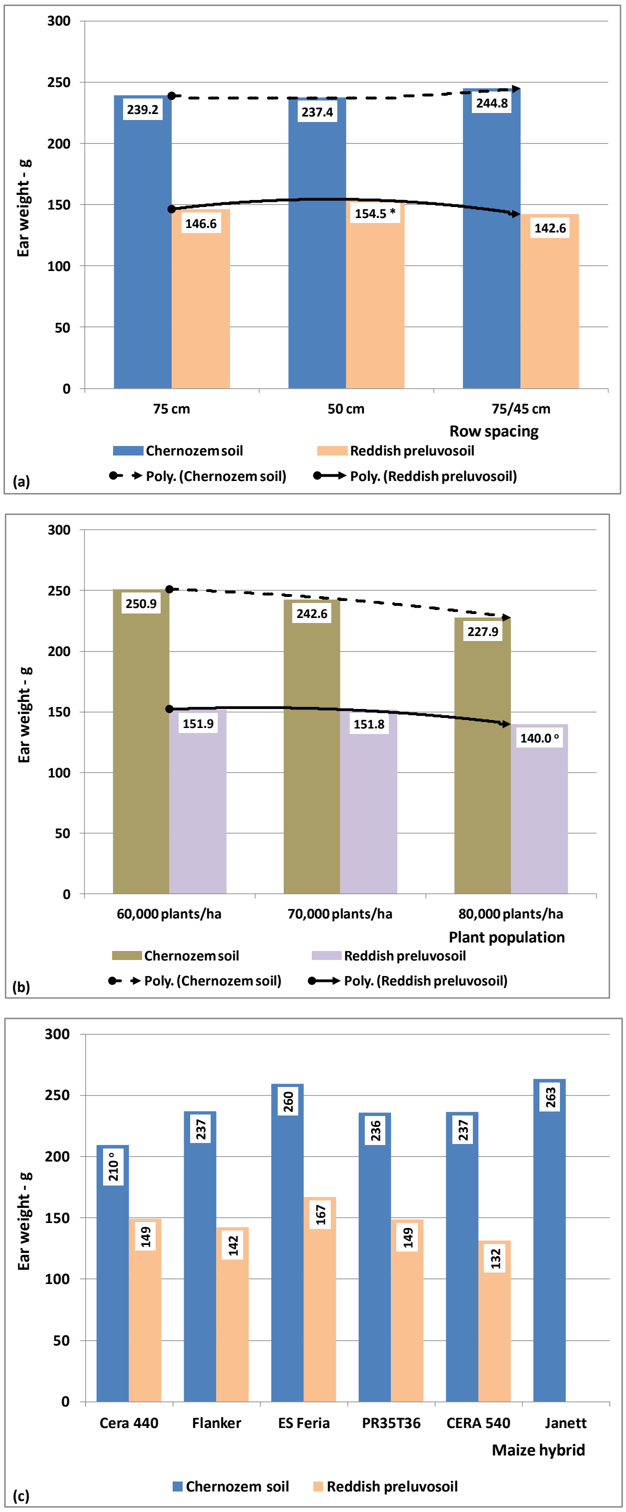

Figure 6. Ear weight at different row spacing (a), plant population (b), maize hybrids (c), and on different soil and climatic conditions from South Romania

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Under less favourable growing conditions, the highest value of the ear weight was registered at row spacing of 50 cm, while the smallest value of the ear weight was registered at twin-rows of 75/45 cm.

The increasing of plant population from 60,000 to 80,000 plants ha^{-1} decreased the ear weight, both on favourable and less favourable growing conditions (Fig.6.b). The smallest values were obtained at 80,000 plants per ha^{-1}.

Among the studied maize hybrids, the highest ear weight was obtained at hybrids ES Feria and Janett (Fig.6.c).

In average for all the row spacing, plant population, and studied hybrids, the ear weight under favourable growing conditions was of 240.46 g, while under less favourable growing conditions it was of 147.90 g, which represents about 61.5% from the ear weight under favourable growing conditions.

3.7 Kernel weight on ear

The tendencies and correlations registered by the kernel weight on ear are similar to those registered by the ear weight at different row spacing, plant population and maize hybrids (Fig.7.a, Fig.7.b, Fig.7.c).

In average for all the row spacing, plant population, and studied hybrids, the kernel weight on ear under favourable growing conditions was of 209.88 g, while under less favourable growing conditions it was of 125.68 g, which represents about 59.9% from the kernel weight on ear under favourable growing conditions.

3.8 Kernel rate per ear

Under favourable growing conditions, the narrow rows decreased the kernel rate per ear, the smallest value being registered at row spacing of 50 cm (Fig.8.a). On the contrary, under less favourable growing conditions, the highest value of kernel rate per ear was registered at row spacing of 50 cm, while the smallest value of kernel rate per ear was registered at row spacing of 75 cm.

Under favourable growing conditions, the plant population of 70,000 plants ha^{-1} determined the highest kernel rate per ear, while the increased plant population of 80,000 plants ha^{-1} determined the smallest kernel rate per ear (Fig.8.b). Under less favourable growing conditions, the increasing of plant population decreased the kernel rate per ear.

Among the studied maize hybrids, the highest kernel rate per ear was obtained at hybrids ES Feria and Janett, and the smallest values were obtained at Cera 440 hybrid, both under favourable and less favourable growing conditions (Fig.8.c).

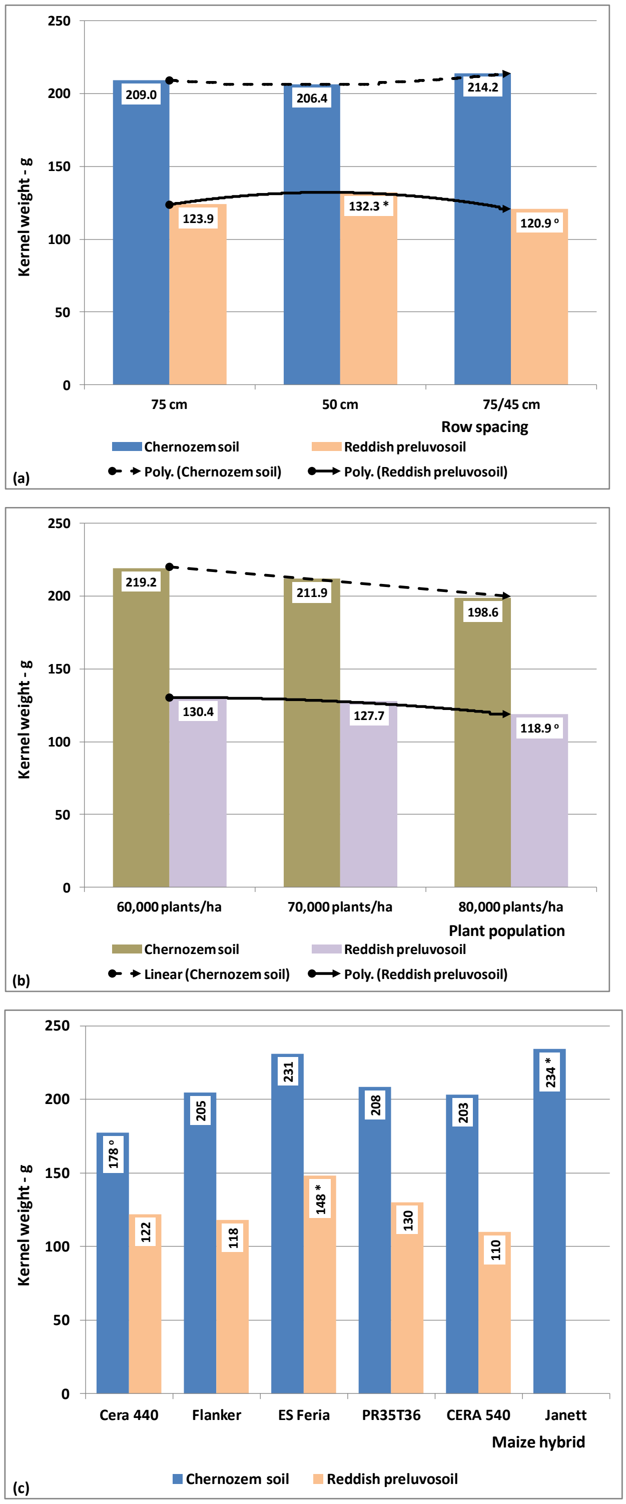

Figure 7. Kernel weight at different row spacing (a), plant population (b), maize hybrids (c), and on different soil and climatic conditions from South Romania

In average for all the row spacing, plant population, and studied hybrids, the kernel rate per

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ear under favourable growing conditions was of 87.1%, while under less favourable growing conditions it was of 84.5%, which represents about 97.0% from the kernel rate per ear under favourable growing conditions.

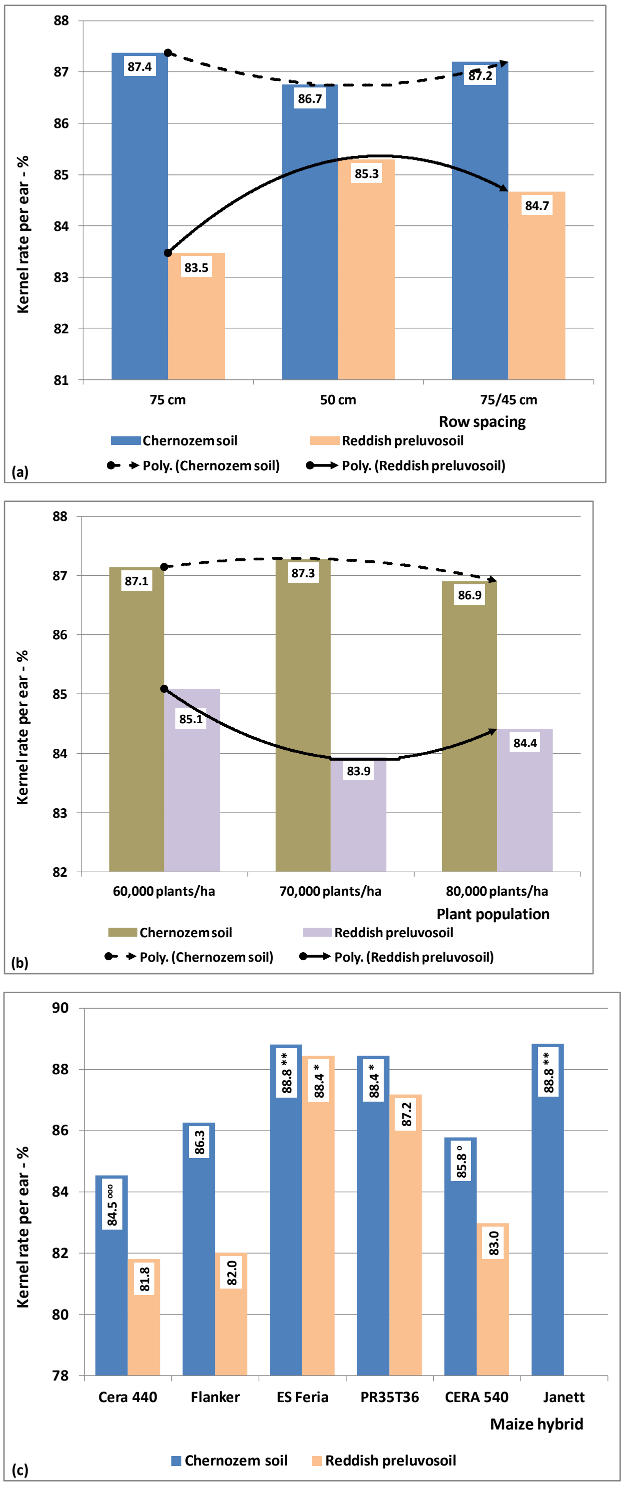

Figure 8. Kernel rate per ear at different row spacing (a), plant population (b), maize hybrids (c), and on different soil and climatic conditions from South Romania

3.9 Weight of thousand seeds

Under favourable growing conditions, the narrow rows increased the weight of thousand seeds, the highest value being registered at twin-rows of 75/45 cm (Fig.9.a). Under less favourable growing conditions, the highest value was registered at row spacing of 50 cm.

Plant population of 70,000 plants ha^{-1} determined the highest values for the weight of thousand seeds, while the increasing of plant population up to 80,000 plants ha^{-1} determined the smallest values for the weight of thousand seeds, both under favourable and less favourable growing conditions (Fig.9.b).

Among the studied maize hybrids, under favourable growing conditions, the highest values were registered at hybrids Janett and ES Feria, while the smallest value was registered at Cera 440 hybrid (Fig.9.c). Under less favourable growing conditions, the highest value was registered at Flanker hybrid and the smallest value was registered at Cera 540 hybrid.

In average for all the row spacing, plant population, and studied hybrids, the weight of thousand seeds under favourable growing conditions was of 335.1 g, while under less favourable growing conditions it was of 215.2 g, which represents about 64.2% from the weight of thousand seeds under favourable growing conditions.

3.10 Grain yield at 14% moisture

Grain yield is the main aim of growing maize crop, as well as for all other crops grown by farmers. Under favourable growing conditions, the narrow rows increased the yield, the highest value being registered at twin-rows of 75/45 cm, with 16.76 tons/ha (Fig.10.a). Under less favourable growing conditions, the narrow rows increased the yield, but the highest value was registered at row spacing of 50 cm (10.04 tons ha^{-1}).

Increasing of plant population increased the grain yield, both under favourable and less favourable growing conditions (Fig.9.b). A similar trend was found by Gozubenli et al. [6].

The highest yield was obtained at 80,000 plants ha^{-1}, respectively 16.85 tons ha^{-1} under favourable growing conditions, and 9.85 tons ha^{-1} under less favourable growing conditions.

Among the studied maize hybrids, under favourable growing conditions, the highest grain yield was registered at ES Feria hybrid, with 16.98 tons ha^{-1}, while the smallest value was registered at Cera 440 hybrid, with 12.74 tons ha^{-1} (Fig. 9.c). Under less favourable growing conditions, the highest value was registered at hybrid PR35T36

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(10.92 tons ha^{-1}) and the smallest value was registered at hybrid Flanker (8.52 tons ha^{-1}).

In average for all the row spacing, plant population, and studied hybrids, the yield under favourable growing conditions (Fundulea area on chernozem soil) was of 15.42 tons ha^{-1}, while under less favourable growing conditions (Moara Domneasca area on reddish preluvosoil) it was of 9.46 tons ha^{-1}, which represents about 61.3% from the yield under favourable growing conditions.

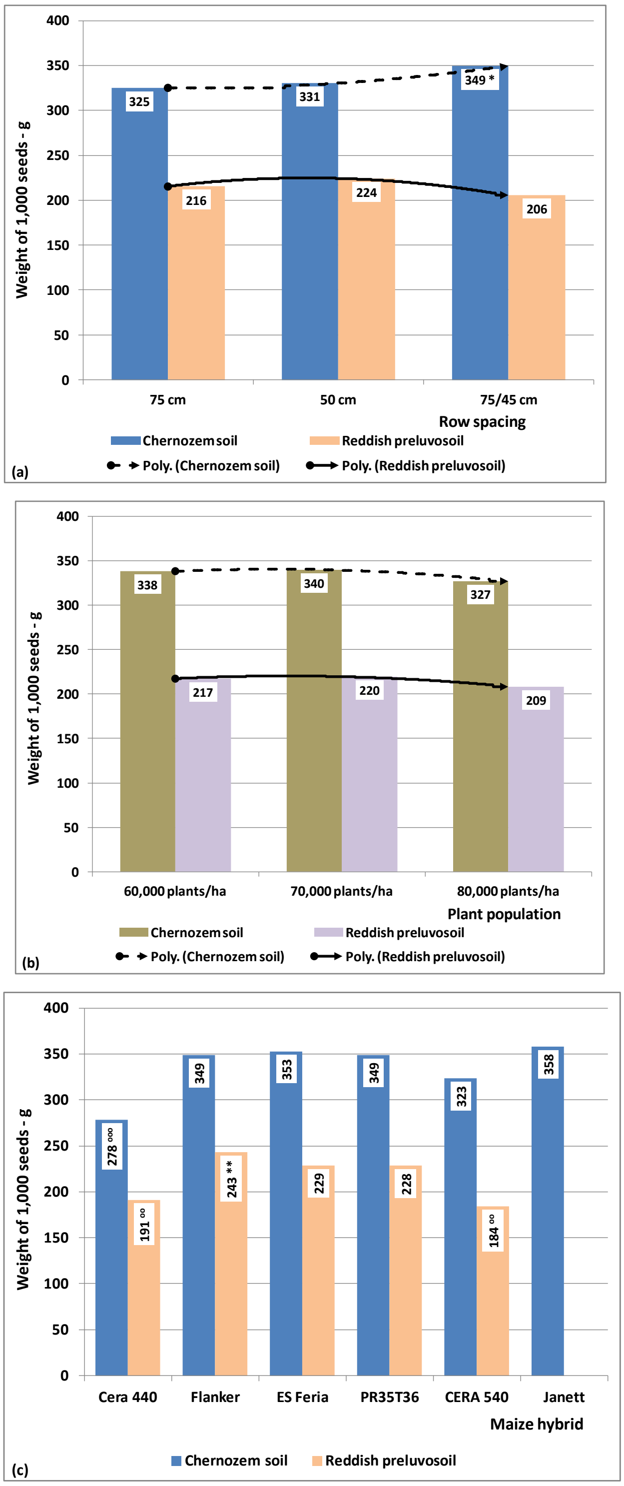

Figure 9. Weight of thousand seeds at different row spacing (a), plant population (b), maize hybrids (c), and on different soil and climatic conditions from South Romania

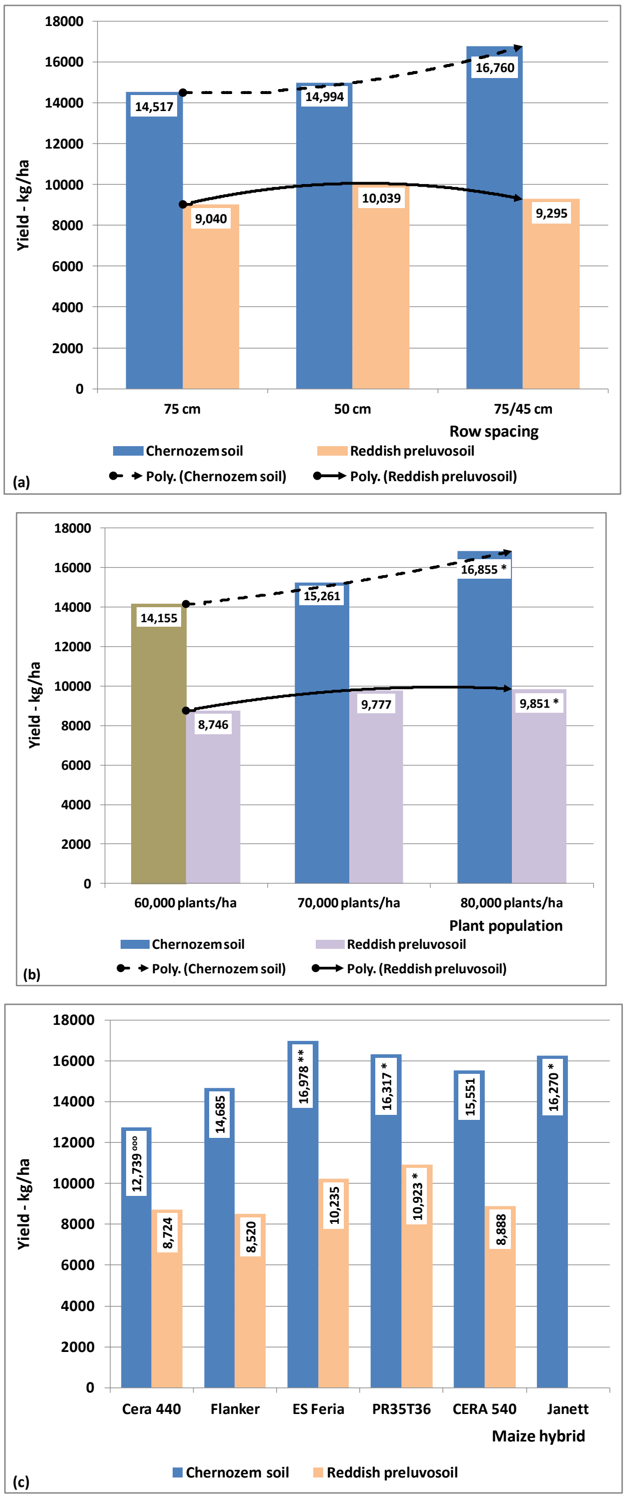

Figure 10. Grain yield at 14% moisture at different row spacing (a), plant population (b), maize hybrids (c), and on different soil and climatic conditions from South Romania

4 Conclusion

Under favourable growing conditions, the narrow rows decreased the ear length, number of kernel rows per ear, number of kernels per ear, number of kernels per kernel row, and kernel rate per ear. But, the narrow rows increased the ear weight, kernel weight on ear, and weight of thousand seeds.

Under less favourable growing conditions, the row spacing of 50 cm determined the highest value for the ear length, number of kernels per ear, number of kernels per kernel row, ear weight, kernel weight on ear, kernel rate per ear, and weight of thousand seeds. The ear diameter and the number of kernel rows per ear registered the highest values at twin-rows of 75/45 cm.

The increasing of plant population from 60,000 to 80,000 plants ha^{-1} decreased ear length, number of kernels per ear, number of kernels per kernel row, ear weight, and kernel weight per ear, both on favourable and less favourable growing conditions.

The increasing of plant population decreased the number of kernel rows per ear, but only under favourable growing conditions. Under less favourable conditions, the highest value was obtained at 70,000 plants ha^{-1}.

Ear diameter and weight of thousand seed registered the highest values at 70,000 plants ha^{-1}, on favourable and less favourable growing conditions.

The narrow rows increased the grain yield, but the highest values were registered at twin-rows of 75/45 cm under favourable growing conditions and at row spacing of 50 cm under less favourable growing conditions.

Increasing of plant population determined the increasing of yield, both under favourable and less favourable growing conditions.

Under less favourable growing conditions, compared to the favourable growing conditions, the yield components were affected as follows:

- The most affected were the kernel weight on ear, ear weight, and weight of thousand seeds;
- The middle affected were the ear diameter and ear length;
- The less affected were the number of kernels per ear, number of kernels per kernel row, number of kernel rows per ear, and kernel rate per ear.

The obtained results confirm the conclusion found by Ion et al. [2] saying that at maize the weight components of grain yield are much more affected by less favourable growing conditions than the numerical components of grain yield.

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