Sunflower Yield and Yield Components under Different Sowing Conditions

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Abstract

The yield of achenes and the yield components of the head are specific to each sunflower hybrid, but they are influenced by the different growing factors (environmental and technological factors). Soil and climatic conditions are among the environmental factors with a great influence on the sunflower yield. Row spacing and plant population are of great importance among the technological factors. In this respect, the present study was aimed to study the influence of row spacing and plant population on yield of achenes and yield components of the head under different soil and climatic conditions from South Romania. Researches were performed in 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). In each location and experimental year there were studied four sunflower hybrids (Pro 111, Pro 953, LG56.62, and P64LE19), each of them under three row spacing (75 cm, 50 cm, and twin-rows of 75/45 cm) and under three plant populations (50,000, 60,000, and 70,000 plants ha\textsuperscript{-1}). The row spacing influenced differently the yield components of sunflower head according to the soil and climatic conditions. The highest yields were obtained at row spacing of 75 cm under favourable growing conditions and at row spacing of 50 cm under less favourable growing conditions. The increasing of plant population from 50,000 to 60,000 and further to 70,000 plants ha\textsuperscript{-1} decreased the values of yield components of the head. In the same time, the increasing of plant population increased the yield under favourable growing conditions and decreased the yield under less favourable growing conditions.

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Peer-review under responsibility of the University of Agronomic Sciences and Veterinary Medicine Bucharest

Keywords: sunflower, yield, yield components, row spacing, plant population, growing conditions.

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1. Introduction

Sunflower is a temperate zone crop, which can perform well under a variety of climatic and soil conditions (Canavar et al., 2010). It combines high yield with great adaptation capacity (Agele, 2003).

In South Romania (the most important area for growing sunflower in Romania), sunflower is a better adapted crop to water stress than maize (Ion et al., 2013). This is explaining the large surfaces cultivated with sunflower in this area, and in the same time this is explaining the great interest the Romanian farmers show to this crop. However, less favourable climatic conditions from the years 2006 and 2007 in South Romania affected the yield components and the seed yield, especially in the year 2007 which can be characterized as a very drought year (Ion et al., 2010).

The yield of achenes and the yield components of the head are specific to the sunflower hybrid, but they are influenced by the different growing factors (environmental and technological factors).

A hybrid yield is conditioned by its capacity to use efficiently the environmental variables in different phenophases (Gonzáles et al., 2013). Thus, the genetic potential of the sunflower hybrid is reduced by the action of the growing factors, either environmental or technological ones.

Agronomic practices in addition to high yielding varieties are the two most important items for higher productivity of the sunflower crop (Beg et al., 2007). Productivity per unit area of sunflower is determined by many factors including plant population and variety (Hossam, 2012).

Due to increasing interplant competition for light and other factors, the yield of achenes of individual plants is expected to decrease with increasing plant density (Diepenbrock et al., 2001). However, under favourable growing conditions it is expected that yield of achenes per unit area to increase with increasing plant density up to a level which define the optimum plant population. Final yield for a sunflower crop on a field basis is the sum result of individual plants emerging, developing, growing, and ultimately producing a head (McMaster et al., 2012). But, further increasing of plant density can lead to a constant and even decreased yield of achenes, all these being influenced by the environmental factors, as well as by the technology which is used.

The change in growth habit led to speculation that new hybrids may respond differently to row spacing than their predecessors (Gubbels and Dedio, 1988). Sunflower can be manipulated over a wide range of plant populations and row spacing without seriously affecting yield (Vijayalakshmi et al., 1975). The experimental results show that different planting patterns sometimes produced higher yield, but not always (Zarea et al., 2005). Narrow rows make sunflower plants more able to use in an efficient way the growing resources, respectively the solar radiation, water and nutrients, but this seems to be influenced by the specific environmental factors.

All the previous aspects underline the importance of studying the effect of the row spacing and plant population under different growing conditions and identify their influence on the sunflower yield and yield components of the head. In this respect, the present study was aimed to study the influence of row spacing and plant population on yield of achenes and yield components of the head under different soil and climatic conditions from South Romania.

2. Materials and Methods

2.1. Experimental design

Researches were performed in 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), under rainfed conditions. The specific soil from Fundulea area is chernozem (cambic chernozem soil), with a humus content between 2.8 and 3.2%, loam to clay loam texture, and pH between 6.4 and 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 and 6.6.

In both experimental years (2013 and 2014) and locations (Fundulea and Moara Domneasca), there were studied four sunflower hybrids, respectively: Pro 111, Pro 953, LG56.62, and P64LE19. Practically, each hybrid in each location was sown under three row spacing (75 cm, 50 cm, and twin-rows of 75/45 cm) and at three plant populations (50,000, 60,000, and 70,000 plants ha⁻¹).

The field experiments were performed in four replications, with a number of variants of 36. Each variant consisted in four lines with a length of 10 m.
2.2. Crop management

In 2013, the sowing was performed on 17th of April at Fundulea (chernozem soil) and on 25th of April at Moara Domneasca (reddish preluvosoil). In 2014, the sowing was performed on 9th of April at Fundulea and on 5th of April at Moara Domneasca. The sowing was performed manually at distances along the rows calculated as to assure the three levels of plant population (50,000, 60,000, and 70,000 plants ha\(^{-1}\)) for each row spacing (75 cm, 50 cm, and twin-rows of 75/45 cm). In this respect, the sowing distances for each plant population and row spacing were marked on a rope that was stretched along the row.

The preceding crop was maize in both experimental years and locations. 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-metolachlor 960 g/l) applied at a dose of 1.2 l ha\(^{-1}\) before seedbed preparation. Also, one manual hoeing was performed.

2.3. Climatic data

At Fundulea area and for the growing period of sunflower, respectively period April-August, the average temperature was 20.1\(^{\circ}\)C in 2013 and 18.9\(^{\circ}\)C in 2014, while the multiannual average value for the same period is 18.6\(^{\circ}\)C. The sum of rainfall for the same period was 381.1 mm in 2013 and 399.0 mm in 2014, while the multiannual average value is 327.9 mm.

At Moara Domneasca area and for the growing period of sunflower, respectively period April-August, the average temperature was 20.5\(^{\circ}\)C in 2013 and 18.8\(^{\circ}\)C in 2014, while the multiannual average value for the same period is 18.5\(^{\circ}\)C. The sum of rainfall for the same period was 115 mm in 2013 and 408 mm in 2014, while the multiannual average value is 313.2 mm.

In both experimental areas, the temperatures were higher than the multiannual average value, the year 2013 being warmer than the year 2014, and Moara Domneasca area being warmer than Fundulea area. At Fundulea area, the rainfall was higher than the multiannual average value, the year 2014 being more humid than the year 2013. At Moara Domneasca area, the rainfall in 2013 was much less than multiannual average value, this year being characterised as a drought one, while 2014 was a humid one with more rainfall than multiannual average value.

2.4. Determinations and data analysis

In each location and in each experimental year, from each variant a number of three representative sunflower heads (taken from average plants) in three replications (in total nine sunflower heads) were analyzed for determining the yield and yield components. The sunflower heads were cut and analysed into laboratory, being determined the following yield components: head diameter (cm), number of grains per head, grain weight per head (g), and weight of thousand seeds (g). Also, it was determined the grain (achene) moisture content by the help of a moisture analyser. Based on grain weight per head, plant population and grain moisture content, it was calculated the grain (achene) yield at 9% moisture content, which was expressed in kg ha\(^{-1}\). In both experimental locations and years, the yield and yield components of the head were expressed as average values of the four studied sunflower hybrids.

The determinations were performed at fully ripe stage, respectively: in 2013, on 2\(^{nd}\) of September at Fundulea and on 6\(^{th}\) of September at Moara Domneasca; in 2014, on 8\(^{th}\) of September at Fundulea and on 2\(^{nd}\) of September at Moara Domneasca. Analysis of variance (ANOVA) was performed for the obtained data. The control variant was taken the row spacing of 75 cm for distance between rows and respectively 50,000 plants ha\(^{-1}\) for plant population.

3. Results and Discussions

3.1. Head diameter

At different row spacing and in average for the studied sunflower hybrids, the head diameter varied between 17.0 and 21.5 cm, according to soil and climatic conditions (Figure 1.a). On chernozem soil, the highest values were obtained at row spacing of 75 cm, respectively 21.5 cm in 2013 and 18.9 cm in 2014. On reddish preluvosoil, the highest values were obtained at narrow rows (row spacing of 50 cm and twin-rows of 75/45 cm) in 2013 (21.4 cm) and at row spacing of 50 cm in 2014 (18.0 cm). Compared to row spacing of 75 cm, there were registered negative
differences statistically significant at narrow rows (50 cm and twin rows of 75/45 cm) on chernozem soil in 2014, and a positive difference statistically significant at row spacing of 50 cm on reddish preluvosoil in 2014.

At different plant populations and in average for the studied sunflower hybrids, the head diameter varied between 16.2 and 22.5 cm, according to soil and climatic conditions (Figure 1.b). The highest values of the head diameter were registered at plant population of 50,000 plants ha\(^{-1}\), while the smallest values were registered at plant population of 70,000 plants ha\(^{-1}\). Increasing of plant population from 50,000 to 60,000 and further to 70,000 plants ha\(^{-1}\) determined negative differences compared to the values obtained at 50,000 plants ha\(^{-1}\). These differences are statistically significant except for reddish preluvosoil in 2013.

The narrow rows (row spacing of 50 cm and twin-rows of 75/45 cm) decreased the head diameter on chernozem soil and increased the head diameter on reddish preluvosoil. It seems that under less favorable growing conditions, sunflower plants at narrow rows use much better the growing factors, which is reflected into larger head diameter.

The increasing of plant population decreased the head diameter in all growing conditions, this finding being in line with those obtained by different authors (Miller and Fick, 1978; Hossam, 2012; McMaster et al., 2012).

![Fig. 1. Head diameter (cm) at sunflower under different sowing conditions: a- different row spacing; b- different plant populations.](image)

### 3.2. Number of grains per head

At different row spacing and in average for the studied sunflower hybrids, the number of grains per head varied between 1167 and 1473, according to soil and climatic conditions (Figure 2.a). On chernozem soil, the highest values were obtained at twin-rows of 75/45 cm in 2013 (1473 grains per head) and at row spacing of 75 cm in 2014 (1251 grains per head). On reddish preluvosoil, the highest values were obtained at row spacing of 50 cm in 2013 (1286 grains per head) and at twin-rows of 75/45 cm in 2014 (1176 grains per head). Compared to row spacing of 75 cm, there were not registered differences statistically significant at different row spacing except for the twin-rows of 75/45 cm on chernozem soil in 2014, when the difference was negative statistically significant.

At different plant populations and in average for the studied sunflower hybrids, the number of grains per head varied between 1074 and 1561, according to soil and climatic conditions (Figure 2.b). The highest values of the number of grains per head were registered at plant population of 50,000 plants ha\(^{-1}\), while the smallest values were registered at plant population of 70,000 plants ha\(^{-1}\). Compared to plant population of 50,000 plants ha\(^{-1}\), the increasing of plant population to 60,000 and further to 70,000 plants ha\(^{-1}\) has determined negative differences which are statistically significant except for the plant population of 60,000 plants ha\(^{-1}\) on chernozem soil in 2013.

Row spacing influenced differently the number of grains per head according to growing conditions, respectively soil and climatic conditions. When the growing conditions were not so favourable (on reddish preluvosoil and in the climatic conditions of 2013) the narrow rows increased the number of grains per head. Under favourable climatic conditions, on reddish preluvosoil there were registered very slightly differences of the number of grains per head according to row spacing, while on chernozem soil the narrow rows decreased the number of grains per head.
The increasing of plant population decreased the number of grains per head, the effect being more significant under less favourable growing conditions such were those from South Romania on reddish preluvosoil and under climatic conditions of 2013.

3.3. Grain weight per head

At different row spacing and in average for the studied sunflower hybrids, the grain weight per head varied between 57.42 and 72.97 g, according to soil and climatic conditions (Figure 3.a). On chernozem soil, the highest values were obtained at row spacing of 75 cm, respectively 71.82 g in 2013 and 72.97 g in 2014. On reddish preluvosoil, the highest values were obtained at twin-rows of 75/45 cm in 2013 (68.95 g) and at row spacing of 50 cm in 2014 (70.92 g). There were not registered differences statistically significant at different row spacing on chernozem soil, but on reddish preluvosoil the differences were significant for narrow rows in 2013 and only for row spacing of 50 cm in 2014 compared to row spacing of 75 cm.

At different plant populations and in average for the studied sunflower hybrids, the grain weight per head varied between 54.51 and 79.78 g, according to soil and climatic conditions (Figure 3.b). The highest values of the grain weight per head were registered at plant population of 50,000 plants ha\(^{-1}\), while the smallest values were registered at plant population of 70,000 plants ha\(^{-1}\). Compared to plant population of 50,000 plants ha\(^{-1}\), the increasing of plant population to 60,000 and further to 70,000 plants ha\(^{-1}\) determines negative differences which are statistically significant.

Under favourable growing conditions (chernozem soil and good climatic conditions) the grain weight per head registered the highest values at wider row spacing, respectively at 75 cm between rows, while under less favourable growing conditions (reddish preluvosoil and not so good climatic conditions) the grain weight per head registered the highest values at narrow rows, especially at row spacing of 50 cm. Under less favourable growing conditions, sunflower plants at narrow rows seem to better use the growing factors.

The increasing of plant population from 50,000 to 60,000 and further to 70,000 plants ha\(^{-1}\) decreased the grain weight per head this being a consequence of the fact that the sunflower plants compete among them for acquiring growing factors. Under less favourable growing conditions the increasing of plant population determined a more significant decrease of the grain weight per head (this was the case especially on reddish preluvosoil in 2013), as a consequence of a much stronger competition between sunflower plants. These findings were in line with those obtained by different authors (Gubbels and Dedio, 1990; Vrânceanu, 2000). McMaster et al. (2012) stated that while we found a highly significant positive relationship between plant spacing and individual plant yield for all irrigation treatments, the relationship was not strengthened with increased water deficits. Also, Gholinezhad et al. (2009) stated that grain yield of single plant decreased significantly with increasing severe drought stress and density, while Barros et al. (2004) stated that the lowest plant density increased significantly the mean seed weight, but that was not enough to compensate the significant decrease in seeds m\(^{-2}\).
3.4. Weight of thousand seeds

At different row spacing and in average for the studied sunflower hybrids, the weight of thousand seeds varied between 50.9 and 60.5 g, according to soil and climatic conditions (Figure 4.a). On chernozem soil, the highest values were obtained at row spacing of 50 cm in 2013 (53.1 g) and at twin-rows of 75/45 cm in 2014 (59.3 g). On reddish preluvosoi, the highest values were obtained at row spacing of 50 cm (56.7 g in 2013 and 60.5 g in 2014). Compared to row spacing of 75 cm, there were not registered differences statistically significant at different row spacing except for the row spacing of 50 cm in 2014 on reddish preluvosoi (with difference statistically significant).

At different plant populations and in average for the studied sunflower hybrids, the weight of thousand seeds varied between 50.4 and 63.7 g, according to soil and climatic conditions (Figure 4.b). The highest values of the weight of thousand seeds were registered at plant population of 50,000 plants ha\(^{-1}\), while the smallest values were registered at plant population of 70,000 plants ha\(^{-1}\). Compared to plant population of 50,000 plants ha\(^{-1}\), the increasing of plant population at 60,000 and further to 70,000 plants ha\(^{-1}\) determined negative differences, but which are statistically significant only on chernozem soil in 2014.

On chernozem soil the row spacing influenced differently the weight of thousand seeds according to climatic conditions. On reddish preluvosoi the narrow rows increased the weight of thousand seeds, the increasing being higher under less favourable climatic conditions as those reported in 2013 in South Romania.

The increasing of plant population decreased the weight of thousand seeds, the decreasing being more accentuated when the climatic conditions were more favourable. The decreasing of the weight of thousand seeds with increasing of plant population was reported also by other authors (Miller and Fick, 1978; Hossan, 2012).
3.5. Yield

At different row spacing and in average for the studied sunflower hybrids, the yield at 9% moisture content of achenes varied between 3,325 and 4,466 kg ha\(^{-1}\), according to soil and climatic conditions (Figure 5.a). On chernozem soil, the highest values were obtained at row spacing of 75 cm, respectively 4,260 kg ha\(^{-1}\) in 2013 and 4,466 kg ha\(^{-1}\) in 2014. On reddish preluvosoil, the highest values were obtained at twin-rows of 75/45 cm in 2013 (4,055 kg ha\(^{-1}\)) and at row spacing of 50 cm in 2014 (4,355 kg ha\(^{-1}\)). Compared to row spacing of 75 cm, there were not registered differences statistically significant at narrow rows on chernozem soil, while on reddish preluvosoil the narrow rows registered differences statistically significant except for twin-rows in 2014.

At different plant populations and in average for the studied sunflower hybrids, the yield at 9% moisture content of achenes varied between 3,745 and 4,711 kg ha\(^{-1}\), according to soil and climatic conditions (Figure 5.b). The highest values of the yield were registered at plant population of 70,000 plants ha\(^{-1}\) except on reddish preluvosoil in 2013 when the highest value of the yield was registered at plant population of 50,000 plants ha\(^{-1}\). The smallest values of the yield were registered at plant population of 50,000 plants ha\(^{-1}\) except on reddish preluvosoil in 2013 when the smallest value of the yield was registered at plant population of 60,000 plants ha\(^{-1}\). Compared to plant population of 50,000 plants ha\(^{-1}\), the increasing of plant population at 60,000 plants ha\(^{-1}\) did not determine differences which are statistically significant, but further increasing of plant population at 70,000 plants ha\(^{-1}\) determined differences statistically significant except on reddish preluvosoil in 2013, which was a drought year.

On chernozem soil the highest yields were obtained at row spacing of 75 cm, the narrow rows decreasing the yield in both experimental years (2013 and 2014). In exchange, on reddish preluvosoil the narrow rows increased the yield in both experimental years, the sunflower plants being able to use in a more efficient way the growth factors. The increasing in yield determined by narrow rows was more significant under less favourable growing conditions. It has to be underlined the row spacing of 50 cm which determined the smallest yields on chernozem soil but the highest yields on reddish preluvosoil. All these findings are showing the attention that should be paid to the row spacing according to growing conditions.

On chernozem soil the increasing of plant population increased the yield, the highest values being obtained at 70,000 plants ha\(^{-1}\). On reddish preluvosoil, when the climatic conditions were less favourable the increasing of plant population decreased the yield, the highest values being obtained at 50,000 plants ha\(^{-1}\). When climatic conditions were more favourable on reddish preluvosoil, compared to the yield obtained at 50,000 plants ha\(^{-1}\), the yield was slightly higher at 60,000 plants ha\(^{-1}\) and became significant higher at 70,000 plants ha\(^{-1}\).

There are authors (Diepenbrock et al., 2001; Kazemeini et al., 2009) who found that achene yield was higher at row spacing of 75 cm than at row spacing of 50 cm, while other authors (Zarea et al., 2005) found that reduced row spacing increased the yield. Also, there are authors (Miller and Fick, 1978) that found a downwards trend in yield at
increased plant population, while other authors (Gubbels and Dedio, 1990; Hossam, 2012) registered an increasing of yield at increased plant population.

4. Conclusions

The row spacing influenced differently the yield components of sunflower head according to the growing conditions, respectively soil and climatic conditions. Under less favourable growing conditions the narrow rows seem to make sunflower plants to use the growing factors in a more efficient way which is reflected into higher values for the yield components of the head.

The increasing of plant population from 50,000 to 60,000 and further to 70,000 plants ha⁻¹ under the specific soil and climatic conditions from South Romania decreased the values of yield components of the head.

The optimal row spacing and plant population depends on growing conditions (soil and climatic conditions), at their turn these being influenced up to a certain level by the applied crop technology.

The highest yields were obtained at row spacing of 75 cm under favourable growing conditions and at narrow rows under less favourable growing conditions, especially at row spacing of 50 cm. Also, the highest yields were obtained at increased plant population under favourable growing conditions. The increasing of plant population under less favourable growing conditions decreased the yield.

5. Acknowledgements

The researches carried out for the elaboration of the present paper were financed by Romanian Program “Partnerships for Priority Domains”, project PN-II-PT-PCCA-2011-3.2-1778 “OPTImization of BIOMass and Approach to Water conservation” (OPTIBIOMA-W), Contract no. 45/2012.

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