Maize plant biomass at different hybrids, plant populations, row spacing and soil conditions

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Abstract

Maize (Zea mays L.) is one of the most important crops for biomass production. The plant biomass depends on growth factors among which the cultivated hybrid, plant population, row spacing and soil conditions have a significant influence. The objective of this study was to determine the above-ground biomass of the maize plant and its components at different hybrids, row spacing, plant populations, and soil conditions. For reaching this objective, field experiments were performed in two locations from South Romania in 2013, at six maize hybrids (Cera 440, Cera 540, Flanker, ES Feria, PR35T36, Janett) studied under three row spacings (75 cm, 50 cm, and twin-rows of 75/45 cm), three plant populations (60,000, 70,000, and 80,000 plants per hectare), and two soil conditions (chernozem and reddish preluvosoil). The determinations were performed in the early dough - dough plant growth stage. The row spacing of 50 cm determined the highest dry biomass on maize plant. The increasing of plant population determined a decreasing of dry biomass of the maize plant, as well as a decreasing of moisture content. On reddish preluvosoil, dry biomass of maize plant registered smaller values than those on chernozem soil and the whole plant and its components had less moisture content.

Key words: maize, biomass, moisture content, hybrid, plant population, row spacing, soil conditions.

1. Introduction

Maize (Zea mays L.) is one of the most important crops for biomass production used both as forage for animals, in particular beef and dairy cattle, and raw material for biogas producing. Maize forage is an important source of energy for livestock animals (1). Also, maize is one of the most important crops for biomass production as source for producing biogas (2).

Maize is generally cultivated in wide spaced rows (3). 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 (4). An alternative to planting narrow rows, while maintaining many of the benefits, is twin-rows (5). Twin-row planting systems in maize have been proposed as an alternative spatial arrangement that should theoretically decrease plant-to-plant competition, alleviate crop crowding stress and improve yields (6). Twin-row spacing as an alternative planting practice for maize silage production leads to greater maize silage yields through greater water use efficiency and faster canopy development (7).

Maize hybrid selection and plant density are important management considerations for successful forage production in dairy and livestock operations (8). Hybrid, population density and row spacing interact to influence whole-plant yield (9). Plant density has significant effect
on biomass yield as biomass yield increased progressively with successive increase in plant density (10).

The biomass of maize plant is depending on a sum of growth factors among which the cultivated hybrid, plant population, row spacing and soil conditions have a significant influence on the accumulation of the above-ground biomass and its repartition between plant components.

The objective of this study was to determine the above-ground biomass of the maize plant and its components at different hybrids, row spacing, plant populations, and soil conditions. It was also determined the plant moisture content and the percentage of dry biomass on plant components. The determinations were performed in the early dough-dough plant growth stage, which is the growth stage for harvesting the plants for producing silage as forage for animals or raw material for producing biogas.

2. Materials and Methods

Researches were performed in field experiments in 2013, in two locations from South Romania, respectively Fundulea (44°28' North latitude and 26°27' East longitude) and Moara Domneasca (44°29' North latitude and 26°15' East longitude).

The soil from Fundulea area is chernozem (cambic chernozem soil), with 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, with clay loam texture, pH between 6.2 and 6.6, and humus content between 2.2 and 2.8%.

Fundulea area is characterised by the average multiannual temperature of 10.7°C and average multiannual sum of rainfall of 613.4 mm; in the period September 2012 – August 2013, the average temperature was of 12.0°C, and the sum of rainfall was of 700.6 mm. Moara Domneasca area is characterised by the average multiannual temperature of 10.8°C and average multiannual sum of rainfall of 553.6 mm; in the period September 2012 – August 2013, the average temperature was of 12.6°C, and the sum of rainfall was of 288.0 mm.

In the field experiments from Fundulea, six maize hybrids were studied, respectively: Cera 440 (FAO precocity group 440), Cera 540 (FAO precocity group 540), Flanker (FAO precocity group 450), ES Feria (FAO precocity group 550), PR35T36 (FAO precocity group 500), and Janett (FAO precocity group 550). The hybrids Cera 440 and Cera 540 are specialised for grain production, hybrids Flanker and ES Feria are specialised for biomass production, and hybrids PR35T36 and Janett can be used both for grain and biomass production. In the field experiments from Moara Domneasca (on reddish preluvosoil), only five maize hybrids were studied, respectively: Cera 440, Cera 540, Flanker, ES Feria, and PR35T36.

Each hybrid was studied under three row spacings (75 cm, 50 cm, and twin-rows of 75/45 cm) and three plant populations (60,000, 70,000, and 80,000 plants per hectare).

The field experiments were performed in four replications. The number of variants was 54 at Fundulea location and 45 at Moara Domneasca location. The sowing was performed on 17th of April at Fundulea and on 26th of April at Moara Domneasca. Each variant consisted in four lines with a length of 10 m (the total length for the four replications was of 40 m). The cultivation technology was a regular one for South Romania, under rainfed conditions.

In each location and from each variant a number of three maize plants were cut at soil level and analyzed for determining the fresh biomass (above-ground biomass). The plants were weighed directly into the field as total weight and weight per plant components, respectively: leave blades; stalk, leave sheaths, and tassel; ear; husks. The components of one maize plant for each variant were taken into the laboratory for determining the dry biomass by
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oven drying at 80°C for 24 hours. The determinations were performed in the early dough-dough plant growth stage, respectively on 5th of August at Fundulea (chernozem soil), and on 8th of August at Moara Domneasca (reddish preluvosoil).

An analysis of variance was performed for the dry biomass of the whole maize plant and plant components at different row spacings, plant populations and hybrids.

3. Results and Discussions

Dry biomass of maize plant and its components at different row spacings (figure 1). On chernozem soil, compared to the row spacing of 75 cm, the dry biomass of maize plant components increased at 50 cm and twin-rows of 75/45 cm, the differences being statistically significant for both variants. The most significant differences were registered for ear and husks, while the smallest significant differences were registered for stalk, leaf sheaths and tassel. Whether the dry biomass of maize plant components registered positive differences statistically significant at 50 cm row spacing and twin-rows of 75/45 cm compared to 75 cm row spacing, the total dry biomass of plant increased at 50 cm and at twin-rows of 75/45 cm, but without statistically significant differences. The most important increase of total dry biomass was registered at 50 cm row spacing.

Compared to the dry biomass on chernozem soil, the dry biomass on reddish preluvosoil registered smaller values. Compared to values at 75 cm row spacing, the dry biomass at 50 cm row spacing and twin-rows of 75/45 cm did not register any significant differences either for plant components or for the whole plant. At 50 cm row spacing, the dry biomass of the whole plant and the dry biomass of plant components registered very slight positive differences compared to 75 cm row spacing, while at twin-rows of 75/45 cm the differences were very slight negative.

Dry biomass of maize plant and its components at different plant populations (figure 2). On chernozem soil, compared to 60,000 plants per hectare, the dry biomass of maize plant components registered negative differences statistically significant once with increasing of plant populations at 70,000 and 80,000 plants per hectare. The smallest values were registered at 80,000 plants per hectare. Also, the total dry biomass of the plant registered negative differences statistically significant once with increasing of plant populations, the smallest value being registered at 80,000 plants per hectare.

Compared to the dry biomass on chernozem soil, the dry biomass on reddish preluvosoil registered smaller values and the same tendency, but with negative differences...
The dry biomass of the ear seems to be the most affected by the increasing of plant population, followed by the biomass of stalk, leaf sheaths and tassel.

The decreasing of dry biomass once with increasing of plant population is explained by the increased competition among maize plant for growth factors, especially for water, nutrients and solar radiation.

**Dry biomass of maize plant and its components at different hybrids** (figure 3). On chernozem soil, compared to the average of the six studied hybrids, the dry biomass of stalk, leaf sheaths and tassel registered the largest variations, with positive differences statistically significant for Flanker and ES Feria hybrids, and with negative differences statistically significant for Cera 440 and Janett hybrids. Also, for leaf blades biomass, the hybrids Flanker and ES Feria registered positive differences statistically significant, and the hybrid Cera 440 registered negative differences statistically significant. The dry biomass of ear and husks did not register any differences statistically significant. The dry biomass of the whole plant registered positive differences statistically significant only at Flanker hybrid and negative differences statistically significant at Cera 440 hybrid.

Compared to the dry biomass on chernozem soil, the dry biomass on reddish preluvosoil registered smaller values. Compared to the average of the five studied hybrids on reddish preluvosoi, positive differences statistically significant registered only Cera 540 hybrid for leaf blades and ES Feria hybrid for stalk, leaf sheaths and tassel, while negative differences statistically significant registered only Cera 440 hybrid for stalk, leaf sheaths and tassel.

The hybrids Flanker and ES Feria are specialised for biomass productions, which is explaining the high values of dry biomass obtained by these two maize hybrids.

**Percentage of dry biomass on maize plant components at different row spacings** (figure 4). On chernozem soil, the percentage of the dry biomass of leaf blades registered the highest value at 50 cm row spacing (13.7%), the percentage of the dry biomass of stalk, leaf sheaths and tassel registered the highest value at 50 cm row spacing and at twin-rows of 75/45 cm (29.4%), the percentage of the dry biomass of ears registered the highest value at twin-rows of 75 cm (51.2%), and the percentage of the dry biomass of husks registered the highest value at 50 cm row spacing (8.1%).

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**Figure 2.** Dry biomass of maize plant and its components at different plant populations and on different types of soils from South Romania, in the early dough - dough plant growth stage.
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On reddish preluvosoil, the percentage of the dry biomass of leaf blades, stalk, leaf sheaths, and tassel registered the highest value at 75 and 50 cm row spacing (15.1% for leaf blades and respectively 30.1% for stalk, leaf sheaths, and tassel). The percentage of the dry biomass of ears registered the highest value at twin-rows of 75/45 cm (48.0%), and for husks the highest value was registered at 75 cm row spacing (7.9%).

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**Figure 3.** Dry biomass of maize plant components at different maize hybrids and on different types of soils from South Romania, in the early dough - dough plant growth stage

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**Figure 4.** Percentage of dry biomass on maize plant components at different row spacings and on different types of soils from South Romania, in the early dough - dough plant growth stage

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**Percentage of dry biomass on maize plant components at different plant populations** (figure 5). On chernozem soil, the percentage of the dry biomass of leaf blades registered the highest value at 80,000 plants per hectare (14.1%), the percentage of the dry biomass of stalk, leaf sheaths and tassel registered the highest value at 70,000 plants per hectare (29.2%), the percentage of the dry biomass of ears registered the highest value at 80,000 plants per hectare (50.3%), and the percentage of the dry biomass of husks registered the highest value at 60,000 plants per hectare (8.3%).

On reddish preluvosoil, the percentage of the dry biomass of leaf blades, stalk, leaf sheaths and tassel registered the highest value at 80,000 plants per hectare (15.5% for leaf blades and respectively 30.8% for stalk, leaf sheaths and tassel), while the percentage of the dry biomass of ear and husks registered the highest value at 60,000 plants per hectare (47.8% for ear and respectively 8.2% for husks).

Increasing of plant population determined an increasing of the percentage of the dry biomass of vegetative components of the maize plant (leaf blades, leaf sheaths, and stalk) both...
on chernozem soil and reddish preluvosoi. Concerning the percentage of the dry biomass of ear, the increasing of plant population determined different effects according to soil conditions. Thus, on chernozem soil the increasing of plant population determined a decrease of the percentage of the dry biomass of ear at 70,000 plants per hectare and an increase of the percentage of the dry biomass of ear at 80,000 plants per hectare. On reddish preluvosoi, the increasing of plant population determined a decrease of the percentage of the dry biomass of ear. Both on chernozem soil and reddish preluvosoi the increasing of plant population determined a decrease of the percentage of the dry biomass of husks.

![Figure 5](https://example.com/figure5.png)

**Figure 5.** Percentage of dry biomass on maize plant components at different plant populations and on different types of soils from South Romania, in the early dough - dough plant growth stage

**Percentage of dry biomass on maize plant components at different hybrids** (figure 6). On chernozem soil, the percentage of the dry biomass of leaf blades exceeded 14% only at Cera 540 hybrid (14.7%). The percentage of the dry biomass of stalk, leaf sheaths, and tassel exceeded 30% at hybrids Cera 540 (30.1%), Flanker (30.2%) and ES Feria (30.3%). The percentage of the dry biomass of ear exceeded 50% at hybrids PR35T36 (50.0%), Cera 440 (50.7%) and Janett (52.1%). The percentage of the dry biomass of husks exceeded 8% at hybrids Flanker (8.0%), PR35T36 (8.3%) and Cera 440 (9.2%).

On reddish preluvosoi, the percentage of the dry biomass of leaf blades exceeded 14% at all the five studied hybrids. The percentage of the dry biomass of stalk, leaf sheaths, and tassel exceeded 30% at hybrids Cera 540 (32.0%) and ES Feria (32.8%). The percentage of the dry biomass of ear did not exceed 50% at any of the studied hybrids. The percentage of the dry biomass of husks exceeded 8% only at hybrid Cera 440 (8.5%).

**Moisture content of the maize plant and its components at different row spacings** (figure 7). On chernozem soil, compared to the values obtained at 75 cm row spacing, at 50 cm row spacing the moisture content of the vegetative components of the maize plant (leaf blades, leaf sheaths, and stalk) decreased, while the moisture content of the ear and husks increased, as well as the moisture content of the whole plant. At twin-rows of 75/45 cm, the moisture content of the leaf blades, leaf sheaths, stalk, tassel and husks decreased, as well as the moisture content of the whole plant, but the moisture content of the ear increased.

On reddish preluvosoi, compared to the values obtained at 75 cm row spacing, at 50 cm row spacing the moisture content of all the plant components as well as of the whole plant decreased, and the values decreased even more in the conditions of twin-rows of 75/45 cm.
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### Figure 6. Percentage of dry biomass on maize plant components at different maize hybrids and on different types of soils from South Romania, in the early dough - dough plant growth stage

### Figure 7. Moisture content of the maize plant components at different row spacings and on different types of soils from South Romania, in the early dough - dough plant growth stage

**Moisture content of the maize plant and its components at different plant populations** (figure 8). On chernozem soil, the increasing of plant population decreased the values of moisture content at all the plant components, including the whole plant.

On reddish preluvosol, the increasing of plant population decreased the values of moisture content at all the plant components except the ear moisture content, which increased with the increasing of plant population. Regarding the moisture content of the whole plant, it decreased with the increasing of plant population.

**Moisture content of the maize plant and its components at different hybrids** (figure 9). On chernozem soil, the smallest values for moisture content of all the plant components as well as for the whole plant were registered at Flanker hybrid. The highest values of the moisture content were obtain for the vegetative components of the maize plant (leaf blades, leaf sheaths, and stalk) at hybrid Cera 440 hybrid, for the husks at Janett hybrid, and for the ear and the whole plant at ES Feria hybrid.

On reddish preluvosol, the smallest values for moisture content of leaf blades and husks, as well as of the whole plant were obtained at PR35T36 hybrid, while the smallest values for moisture content of stalk, leaf sheaths, tassel, and ear were obtained at Flanker hybrid. The highest values for moisture content of leaf blades were obtained at Cera 440 hybrid, for moisture content of stalk, leaf sheaths, and tassel were obtained at Cera 540, while for ear, husks as well as for the whole plant were obtained at ES Feria hybrid.
Figure 8. Moisture content of the maize plant components at different plant populations and on different types of soils from South Romania, in the early dough - dough plant growth stage

Figure 9. Moisture content of the maize plant components at different maize hybrids and on different types of soils from South Romania, in the early dough - dough plant growth stage

Dry biomass and moisture content of the maize plant and its components on different types of soils, as average values (figure 10). As average values for all the studied hybrid and in all experimental conditions, respectively at different row spacings and at different plant populations, the dry biomass of the whole plant was of 336.6 g on chernozem soil and of 279.8 g on reddish preluvosoil.

The moisture content of the whole plant, as well as of the all plant components is smaller on reddish preluvosoil than on chernozem. Thus, the moisture content of the whole plant on chernozem was of 70.1% while on reddish preluvosoil was of 63.8%.

On the two soil conditions, the moisture content of plant components varied between 63.0 and 72.6% for leaf blades, between 74.6 and 80.3% for stalk, leaf sheaths and tassel, between 50.2 and 51.8% for ear, and between 64.8 and 70.1% for husks.
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Figure 10. Dry biomass (a) and moisture content (b) of maize plant components on different types of soils from South Romania, as average values in early dough - dough plant growth stage

Percentage of dry biomass on maize plant components at different types of soils, as average values (figure 11). As average values for all the studied hybrids and in all experimental conditions, respectively at different row spacings and at different plant populations, compared to values obtained on chernozem soil, on reddish preluvosoil the percentage of dry biomass of leaf blades, leaf sheaths, stalk, and tassel increased, while the percentage of dry biomass of ear and husk decreased.

On the two soil conditions, the percentage of dry biomass varied between 13.6 and 15.0% for leaf blades, between 28.8 and 30.0% for stalk, leaf sheaths and tassel, between 47.3 and 49.7% for ear, and between 7.6 and 7.8% for husks.

Figure 11. Percentage of dry biomass on maize plant components on different types of soils from South Romania, as average values in the early dough - dough plant growth stage

4. Conclusions

The row spacing of 50 cm determined the highest dry biomass on maize plant.

The increasing of plant population determined a decreasing of dry biomass of the maize plant, as well as a decreasing of moisture content.

Compared to the dry biomass of maize plant on chernozem soil, the dry biomass on reddish preluvosoil registered smaller values, these being also the effect of less amount of rainfall registered in the area with reddish preluvosoil. Also, on reddish preluvosoil all plant components as well as the whole plant registered a less moisture content.

The specialised hybrids for biomass productions (Flanker and ES Feria) produced the highest values of dry biomass on plant.

Compared to the values obtained on chernozem soil, on reddish preluvosoil which was associated with less favourable growing conditions the percentage of the dry biomass of
vegetative components of the maize plant (leaf blades, leaf sheaths, and stalk) increased, while the percentage of the dry biomass of ear and husks decreased. Also, an increasing of plant population determined an increasing of the percentage of the dry biomass of vegetative components of the maize plant (leaf blades, leaf sheaths, and stalk) both on chernozem soil and reddish preluvosol.

The average percentage of the dry biomass of the ear from total plant was of 49.7 on chernozem soil, and it was of 47.3% on reddish preluvosol.

Both on chernozem soil and reddish preluvosol, the most moisture plant components were the stalk, leaf sheaths, and tassel, while the less moisture plant components were the ears.

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