AgroLife Scientific Journal - Volume 5, Number 2, 2016
ISSN 2285-5718; ISSN CD-ROM 2285-5726; ISSN ONLINE 2286-0126; ISSN-L 2285-5718

RESULTS REGARDING BIOMASS YIELD AT MAIZE UNDER DIFFERENT PLANT DENSITY AND ROW SPACING CONDITIONS

Georgeta DICU[1], Viorel ION[2], Daniela HORHOCEA[1], Daniel STATE[1], Nicoleta ION[3]

[1]SC Procera Agrochemicals Romania SRL, 47 Muncii Street, 915200, Fundulea, Calarasi, Romania
[2]University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd,
District 1, 011464, Bucharest, Romania
[3]Apiculture Research and Development Institute of Bucharest, 42 Ficusului Blvd,
District 1, 013975, Bucharest, Romania

Corresponding author email: georgeta.dicu@procera.ro

Abstract

Maize (Zea mays L.) is important for supplying biomass to be used as substrate for biogas production either as energy crop or as crop residues. As energy crop for producing biomass, maize is recognized as being one of the most used crops. Maize as energy crop need a specific crop technology, with specific technological features among which there are counting the using of the suitable plant density and row spacing. From this perspective, the aim of the present paper is to present the results we have obtained regarding the biomass yield at several maize hybrids studied under different plant density and row spacing conditions. In this respect, four maize hybrids (H1, H2, Cera 400, and Cera 430) were studied at different plant densities (70,000; 80,000; 90,000; 100,000; 110,000; 120,000 and 125,000 plants.ha^{-1}) and at two row spacing conditions (75 cm and 37.5 cm). Researches were performed in a field experiment in the year 2015, under rainfed conditions. The field experiment was located in South Romania, respectively at Fundulea, Calarasi County (44^{o}28' N latitude and 26^{o}28' E longitude). The biomass determinations were performed in the early dough - dough plant growth stages, with the purpose to calculate the yields of above-ground biomass (expressed in tons.ha^{-1}) in the growth stages of the maize plants when the biomass could be used as raw material for biogas production, but also as fodder (silo) for animals. In our field experiment, increasing in plant density was associated with an increase of above-ground biomass yield up to a threshold beyond which the biomass yield is decreasing, this threshold being different according to row spacing. Smaller plant densities favoured the biomass yields at wide rows (row spacing of 75 cm), while higher plant densities favoured the biomass yields at narrow rows (row spacing of 37.5 cm). The biomass yields registered higher values at row spacing of 37.5 cm than at row spacing of 75 cm.

Key words: *biomass, yield, maize, plant density, row spacing.*

INTRODUCTION

Biomass is the most common form of renewable energy (McKendry, 2002), this being used as source of energy since ancient times. In a time when the human society has to rely more and more on renewable sources of energy, the importance of biomass became even greater. Within the agricultural systems, biomass could be used for energetic purposes either as crop residues or as energy crop.

Among the energy crops, maize (*Zea mays* L.) has a great potential to produce biomass which could be used for different energy purposes (Ion et al., 2016). Thus, maize is considered to be very suitable for producing biomass that can be used as substrate for biogas production (Amon et al., 2006; Balodis et al., 2011; Bășa et al., 2013). It seems that the most efficient utilization of maize is supplying of green maize biomass directly to biogas plants for heat and power energy production (Dubrovskis et al., 2010).

Energy crops used for biogas production have to be easy to be cultivated and they have to be not too much demanding for inputs. Apart these characteristics, they should provide high dry matter yield and high methane output per area unit (Dubrovskis et al., 2010). From this respect, maize as a C4 plant has a high capacity to produce biomass and it is already the most used crop for biogas production in several countries. For instance, maize is the main crop grown for biogas production (biomass crop) in Germany (Brauer-Siebrecht et al., 2016) and maize is the most important energy crop grown for co-digestion in Flanders (De Vliegher et al., 2012).

Energy crops are demanding appropriate cultivation technologies according to the growing conditions as high biomass yields to be possible to be obtained. Within the cultivation technologies, plant density and row spacing could contribute to the production of biomass in an efficient way (Ion et al., 2015).

Biomass yield is significantly affected by different plant population densities (Abuzar et al., 2011). Plant densities can be increased to provide maximum dry matter production (Yilmaz et al., 2007). In this respect, planting density in maize has kept an upward trend for several decades, increasing at a rate of approximately 1000 plants $ha^{-1}.yr^{-1}$, and may continue to increase in the foreseeable future (Duvick, 2005).

Increasing plant density is one of the ways of increasing the capture of solar radiation within the canopy (Moderras et al., 1998). However, the efficiency of the conversion of intercepted solar radiation into maize yield decreases with a high plant population density because of mutual shading of plants (Sharifi and Zadeh, 2012). The increasing of plant density determines a decreasing of dry biomass of the maize plant (Ion et al., 2014). Despite the decreasing of dry biomass of the maize plant, the increasing of plant density is associated with an increase of the biomass yield ($kg.ha^{-1}$) up to a certain level. When the plant density is too high, the maize plants compete with each other for available resources. That is why an increase in plant population density in excess is not expected to have an effect on biological yield (Van Averbeke and Marais, 1992). Anyway, the relationship between planting density and biomass increase is not linear, particularly at high densities (Dhugga, 2007). Plant densities which are lower than optimum values are leading to low yields and less efficient use of the resources available to plants.

As maize do not have tillering capacity to adjust to variation in plant stand, optimum plant population is important (Azam et al., 2007). Optimum population levels should be maintained to exploit maximum natural resources, such as nutrients, sunlight, soil moisture and to ensure satisfactory yield (Sharifi and Zadeh, 2012). But optimum plant density is affected by the genetic properties and vegetation time of the given hybrid, by the conditions of the production area, by the crop year and the extent of water and nutrient supply (Murányi, 2015). So, the optimum plant density is different according to environmental and technological conditions.

Generally, maize is cultivated in wide spaced rows (Nik et al., 2011). But, maize produced in narrow rows can increase yields and result in a quicker canopy closure (Satterwhite et al., 2006). Narrow rows provide advantages through earlier row closure (lessening erosion), better plant distribution (utilisation of nutrients) and higher yield (Reckleben, 2011). That is why narrow compared with standard row spacing had positive effects on whole-plant yield of one hybrid (Baron et al., 2006).

Especially for energy maize production, where the energy must not strictly be contained in the cob, other row distances such as 55 cm, 50 cm, 37.5 cm or even 25 cm are conceivable in order to achieve better utilisation of space and fertiliser (Reckleben, 2011). Also, 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 (Robles et al., 2012).

As row spacing is narrowed seeding rate should be towards the higher end of what is recommended for the area; in this respect, researches have shown that higher yields can be achieved with higher seeding rates, but must have adequate water (Bean and Marsalis, 2012).

The aim of the present paper is to present the results we have obtained regarding the biomass yield at several maize hybrids studied under different plant density and row spacing conditions.

MATERIALS AND METHODS

Researches were performed is a field experiment located within the experimental field belonging to Procera Company from Fundulea area in South Romania ($44^{o}28'$ N latitude and $26^{o}28'$ E longitude). The field experiment was under rainfed conditions, in the year 2015, and had three experimental factors, respectively: maize hybrid, with four variants (H1 and H2, which are hybrids specially designed for high plant densities; Cera 400 and Cera 430, which are hybrids designed for usual plant densities); row spacing (75 cm and 37.5 cm); plant density, with the following variants: 70,000; 80,000; 90,000; 100,000; 110,000 and 120,000 plants.ha^{-1} for row spacing of 75 cm; 80,000; 90,000; 100,000; 110,000; 120,000 and 125,000 plants.ha^{-1} for row spacing of 37.5 cm. The field experiment was designed in split plots with 4 replications.

The preceding crop was maize and the crop fertilization was performed with 83 kg.ha^{-1} of nitrogen (200 kg.ha^{-1} of complex fertilizer of type 10:20:0 + 300 kg.ha^{-1} of ammonium sulphate fertilizer with 21% of nitrogen as active substance) and 40 kg.ha^{-1} of phosphorous (from the 200 kg.ha^{-1} of complex fertilizer of type 10:20:0). The fertilizers were applied before seedbed preparation. The sowing was performed on 15th of April 2015. The weed control was realised by the help of herbicide Frontier Forte (720 g.l^{-1} of dimetenamid-P), which was applied in a rate of 1 l.ha^{-1} in pre-emergence (before emergence).

The soil from Fundulea area is of chernozem type and it has a humus content of 2.8-3.2%, texture of type loam to clay loam, and pH of 6.4-6.8. The climatic conditions registered in the studied area in 2015, for the period April-August, are the following: 19.9°C the average temperature, while 18.6°C is the multiannual average; 260 mm sum of rainfall, while 327.9 mm is the multiannual average rainfall for the analysed period. The year 2015 is characterised as being warmer and drier (even drought) than normal years for the studying area.

The biomass determinations were performed in the early dough - dough plant growth stages, this being the moment when the maize biomass can be used as substrate for biogas production, but also as fodder (silo) for animals. For this purpose, the maize plants from one square meter were cut at soil level. The plant samples were weighed immediately in the field, as the fresh biomass to be calculated. From each sample, one average maize plant was weighed separately, and then it was cut into pieces and taken into the laboratory where it was dried in the oven for 24 hours at 80°C, as the dry biomass content to be determined and the dry biomass yield to be calculated. The fresh and dry biomass yields are presented in the present paper as average values for the four studied maize hybrids, they represent the above-ground biomass, and they are expressed in tons per hectare.

RESULTS AND DISCUSSIONS

It is known and it is expected that the increasing of plant density determines a decreasing of dry biomass of the maize plant (Ion et al., 2014). However, the increasing of plant density in our field experiment was associated with an increase of fresh and dry biomass yield (Figures 1 and 2).

The increase of fresh and dry biomass yield is happening up to a threshold beyond which the biomass yield is decreasing. It has to be highlighted that the increasing of biomass yield with the increasing of plant density takes place for both row spacing, respectively 75 cm and 37.5 cm between rows. But, the threshold plant density is different according to row spacing, being of 100,000 plants.ha^{-1} for row spacing of 75 cm and of 120,000 plants.ha^{-1} for row spacing of 37.5 cm.

Regarding the highest values of the fresh biomass yield, the highest fresh biomass yield for row spacing of 75 cm was of 30.7 tons.ha^{-1} at plant density of 100,000 plants.ha^{-1}, while for row spacing of 37.5 cm the highest fresh biomass yield was of 32.5 tons.ha^{-1} at plant density of 120,000 plants.ha^{-1} (Figure 1).

Regarding the highest values of the dry biomass yield, it was registered the same situation as in the case of fresh biomass, respectively the highest dry biomass yield for row spacing of 75 cm was of 14.7 tons.ha^{-1} at plant density of 100,000 plants.ha^{-1}, while for row spacing of 37.5 cm the highest dry biomass yield was of 15.3 tons.ha^{-1} at plant density of 120,000 plants.ha^{-1} (Figure 2).

The smaller plant densities (70,000; 80,000, and 90,000 plants.ha^{-1}) favoured the biomass yields at row spacing of 75 cm, while higher plant densities (over 100,000 plants.ha^{-1}) favoured the biomass yields at row spacing of 37.5 cm.

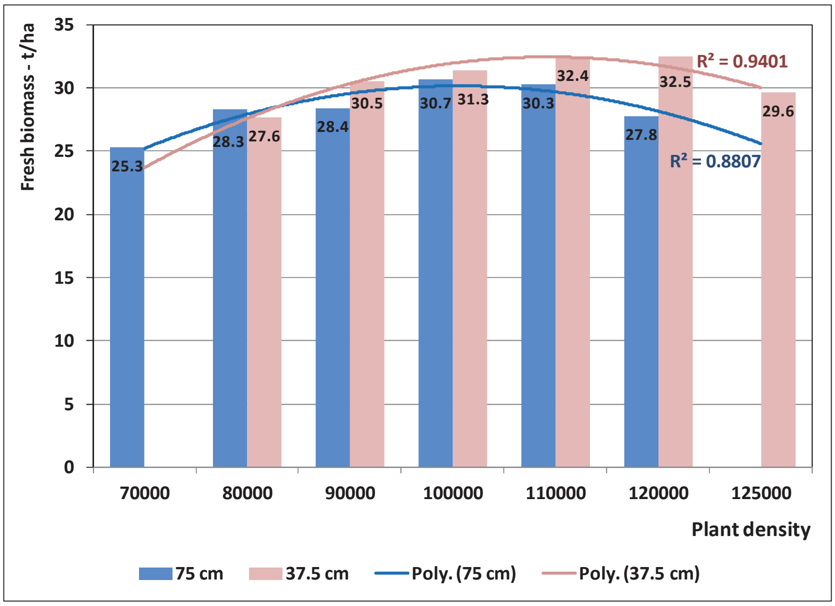

Figure 1. Fresh biomass yields at maize under different row spacing and plant density conditions

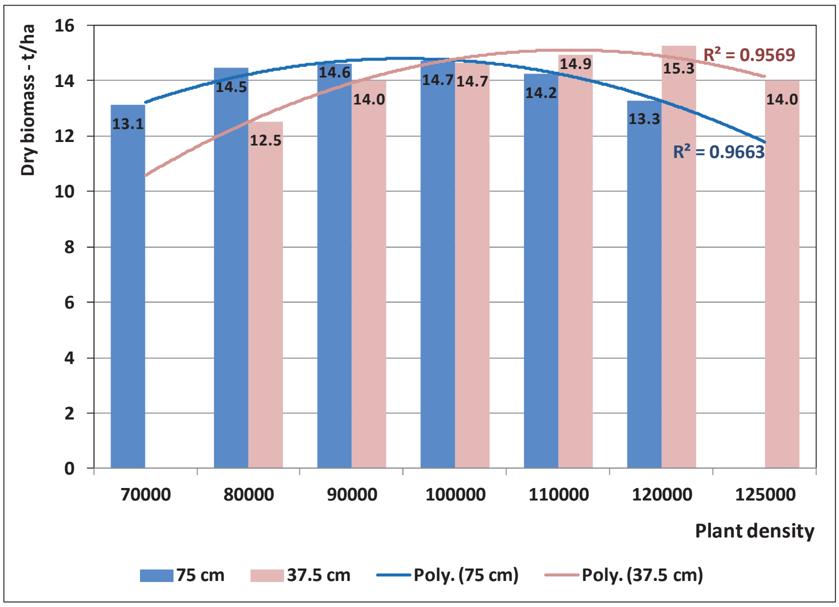

Figure 2. Dry biomass yields at maize under different row spacing and plant density conditions

The fresh and dry biomass yields registered higher values at row spacing of 37.5 cm than those registered at row spacing of 75 cm (Figure 3).

Thus, the average fresh biomass yield registered at row spacing of 37.5 cm was of 30.67 tons.ha^{-1}, while that registered at row spacing of 75 cm was of 28.43 tons.ha^{-1}.

The average dry biomass yield registered at row spacing of 37.5 cm was of 14.23 tons.ha^{-1}, while at row spacing of 75 cm the average dry biomass yield was of 14.07 tons.ha^{-1}.

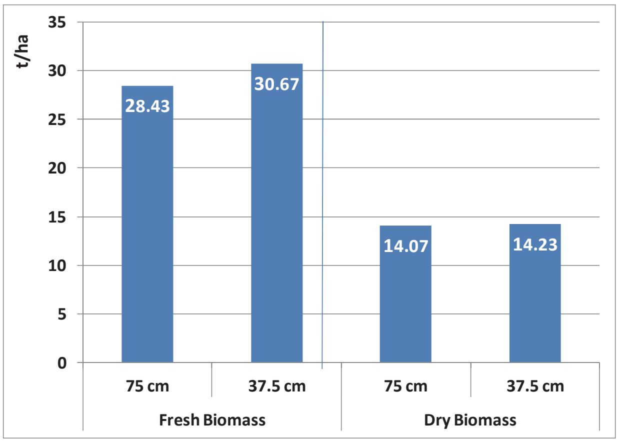

Figure 3. Average fresh and dry biomass yield at maize under different row spacing

CONCLUSIONS

In our field experiment, increasing in plant density was associated with an increase of above-ground biomass yield up to a threshold beyond which the biomass yield is decreasing. This threshold was different according to row spacing. Thus, for the studied conditions, the threshold in plant density was of 100,000 plants.ha^{-1} for row spacing of 75 cm and 120,000 plants.ha^{-1} for row spacing of 37.5 cm. The smaller plant densities (up to 100,000 plants.ha^{-1}) favoured the biomass yields at row spacing of 75 cm, while higher plant densities (over 100,000 plants.ha^{-1}) favoured the biomass yields at row spacing of 37.5 cm. The biomass yields registered higher values at narrow rows (row spacing of 37.5 cm) than at wide rows (row spacing of 75 cm).

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.

REFERENCES

Abuzar M.R., Sadozai G.U., Baloch M.S., Baloch A.A., Shah I.H., Javaid T., Hussain N., 2011. Effect of plant population densities on yield of maize. The J. of Animal & Plant Sciences, 21(4): p. 692-695.

Amon T., Kryvoruchko V., Amon B., Bodiroza V., Zollitsch W., Boxberger J., 2006. Biogas Production from Energy Maize. Landtechnik 61, No. 2, p. 86-87.

Azam S., Ali M., Amin M., Bibi S., Arif M., 2007. Effect of plant population on maize hybrids. Journal of Agricultural and Biological Science, Vol. 2, No. 1, January, p. 13-20.

Balodis O., Bartuševics J., Gaile Z., 2011. Biomass yield of different plants for biogas production. Proceedings of the 8th International Scientific and Practical Conference, Vol. 1, p. 238-245.

Baron V.S., Najda H.G., Stevenson F.C., 2006. Influence of population density, row spacing and hybrid on forage corn yield and nutritive value in a cool-season environment. Canadian Journal of Plant Science, p. 1131-1138.

Băşa A.Gh., Ion V., Dicu G., State D., Epure L.I., Ştefan V., 2013. Above-ground Biomass at Different Hybrids of Maize (*Zea mays* L.) Cultivated in South Romania in Drought Conditions. Scientific Papers. Series A, Agronomy, Vol. LVI, p. 177-184.

Bean B., Marsalis M., 2012. Corn and Sorghum Silage Production Considerations. High Plains Dairy Conference, Amarillo, Texas, p. 1-7.

Brauer-Siebrecht W., Jacobs A., Christen O., Götze P., Koch H.J., Rücknagel J., Märländer B., 2016. Silage Maize and Sugar Beet for Biogas Production in Rotations and Continuous Cultivation: Dry Matter and Estimated Methane Yield. Agron., 6(2): p. 2-12.

De Vliegher A., Van Waes C., Baert J., Van Hulle S., Muylle H., 2012. Biomass of annual forage crops for biogas production. Grassland Science in Europe, Vol. 17, Proceedings of the 24th General Meeting of the European Grassland Federation, Lublin, Poland, 3-7 June, p. 463-465.

Dubrovskis V., Plume I., Bartusevics Ja., Kotelenecs V., 2010. Biogas production from fresh maize biomass. Engineering for Rural Development, Jelgava, 27-28.05, p. 220-225.

Dhugga K.S., 2007. Maize Biomass Yield and Composition for Biofuels. Crop Science, Vol. 47, November-December, p. 2211- 2227.

Duvick D.N., 2005. Genetic progress in yield of United States maize (*Zea mays* L.). Maydica 50: p. 193-202.

Ion V., Băşa A.Gh., Temocico G., Dicu G., Epure L.I., State D., 2014. Maize plant biomass at different hybrids, plant populations, row spacing and soil conditions. Romanian Biotechnological Letters, Vol. 19, No. 4, p. 9551-9560.

Ion V., Basa A.Gh., Dicu G., Dumbrava M., Epure L.I., State D., 2015. Biomass yield at maize under different sowing and growing conditions. Book of Proceedings, Sixth Internat. Scientific Agricultural Symposium „Agrosym 2015“, p. 285-290.

Ion V., Băşa A.Gh., Dumbravă M., Ion N., 2016. Results regarding biomass yield at maize under different crop technology conditions and in a situation of drought. 16th International Multidisciplinary Scientific GeoConference (SGEM 2016), Energy and Clean Technologies Conference Proceedings, Book 4 - Renewable Energy Sources and Clean Technologies, Vol. I, 30 June - 6 July, Albena, Bulgaria, p. 603-608.

McKendry P., 2002. Energy Production from Biomass (part 1): Overview of Biomass. Bioresource Technology, 83, p. 37-46.

Moderras A.M., Hamilton R.L., Dijak M., Dwyer L.M., Stewart D.W., Mather D.E., Smith D., 1998. Plant population density effects on maize inbred lines grown in short-season environments. Crop Science 34: p. 104-108.

Murányi E., 2015. Effect of plant density and row spacing on maize (*Zea mays* L.) grain yield in different crop year. Columella - Journal of Agricultural and Environmental Sciences, Vol. 2, No. 1, p. 57-63.

Nik M.M., Babaeian M., Tavassoli A., Asgharzade A., 2011. Effect of plant density on yield and yield components of corn hybrids (*Zea mays*). Scientific Research and Essays, 6(22): p. 4821-4825.

Reckleben Y., 2011. Cultivation of maize - which sowing row distance is needed? Landtechnik 66, No. 5, p. 370-372.

Robles M., Ciampitti I.A., Vyn T.J., 2012. Responses of Maize Hybrids to Twin-Row Spatial Arrangement at Multiple Plant Densities. Agronomy Journal, Vol. 104, Issue 6, p. 1747-1756.

Satterwhite J.L., Balkcom K.S., Price A.J., Arriaga F.J., van Santen E., 2006. Hybrid, row pattern, and plant population comparisons for conservation tillage corn production. Southern Conservation Systems Conference, Amarillo TX, June 26-28, p. 104-112.

Sharifi R.S., Zadeh N.N., 2012. Effects of plant density and row spacing on biomass production and some of physiological indices of corn (*Zea mays* L.) in second cropping. Journal of Food, Agriculture & Environment Vol. 10 (3&4): p. 795-801.

Van Averbeke W., Marais J.N., 1992. Maize response to plant population and soil water supply: I. Yield of grain and total above-ground biomass. South African Journal of Plant and Soil, 9(4): p. 186-192.

Yilmaz S., Gozubenli H., Konuskan O., Atis I., 2007. Genotype and plant density effects on corn (*Zea mays* L.) forage yield. Asian Journal of Plant Sciences, 6 (3): p. 538-541.