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THE SOWING DENSITY INFLUENCE ON YIELD OF THE MAIZE HYBRID P0217

Aurica SOARE

"Dunărea de Jos" Universiy of Galaţi, 47 Domnească Street, Galaţi, Romania

Corresponding author email: aurica.soare@gmail.com

Abstract

The study aims at determining the extent to which increasing plant density in maize crops is a means of increasing yield per unit area, and the objective is to determine the level of plant tolerance in terms of plant density per unit area with no consequences on the size of productivity elements. As a consequence of downsizing the nutrition area from 0.15 m² (for the 70 cm sown variant) to 0.076 m² (for the 35 cm sown variant), the vegetative growth was diminished with implications on the size of the intake area at the level of each plant, but with an increase in the leaf area index values due to the high density covering the soil surface much better. The yield obtained was 10.16 tons of grains/hectare in the case of the equally spaced row seeding scheme at 70 cm clearance and 7.33 tons of grains/hectare in the equidistant row seeding scheme at 35 cm spacing between rows.

Key words*: foliar surface, phenophase, productivity elements.*

INTRODUCTION

Out of the total area cultivated with cereals worldwide, maize occupies 27.3% whereas out of the total area cultivated with cereals in the European Union, maize occupies 17.7%. The optimum plant density for maximum maize yield per unit area differs from one maize hybrid to another due to interactions between the hybrid and different densities (Luca and Tabără, 2011).
Density increase is not always accompanied by the yield increase because stress occurs due to nutrient area depletion, but yield increases when other factors are provided at optimal requirements (Winans et al., 2021). However, in situations where not all environmental factors can be provided at the optimal level (water), it is found that better results are obtained in case of lower plant densities (Tokatlidis et al., 2022).
Given the limited land resources, increasing plant density is considered an efficient method of increasing maize production. (Adnan et al., 2021). Against the background of human population growth, increasing meat and milk consumption and biofuel demand, the results of several studies have shown that global production needs to double by 2050 as regards four key crops - maize, rice, wheat and soybeans (Ray et al., 2013). This output boost can be achieved by increasing density per unit area; research has shown that the contribution of plant density to maize yield growth has ranged from 8.5% to 17% (Assefa et al., 2018), but the optimal density should be decided based on a detailed analysis of the interaction between genotype and environment (Assefa et al., 2016). However, according to research, increasing plant density per unit area leads to competition between plants and decreases plant growth and productivity (Liu et al., 2022), and the recommendation to use higher or lower densities is closely related to the provision of the required plant moisture during the growing season (Haarhoff and Swanepoel, 2022).
Studies conducted on sweet corn by way of using different densities have shown that modern hybrids allow the use of high densities. Nevertheless, with densities of 79,000 plants/hectare the yield per plant has remained unchanged over time regardless of the density level (Daljeet et al., 2021).
Some corn hybrids have the ability to adapt to lower light intensity. Even under these conditions, a high photosynthetic efficiency is found, with beneficial consequences on yield (Yunshan et al., 2021).
At the same time, it was noticed that an increase in planting density significantly increased the leaf area index and the amount of photosynthetically active radiation intercepted, thus favoring plant growth and crop productivity (Yuanhong et al., 2021).

In case of using high densities, competition for nutrients among plants increases with a negative impact on plant productivity growth, but the application of nitrogen and growth regulators clearly have improved the enzymatic activities of carbon and nitrogen metabolism in leaves (Xiaoming et al., 2022). Despite that, there are maize hybrids that react differently to shading stress caused by increasing plant density (Federico et al, 2022).

When using high plant densities (90,000 plants/hectare), the application of nitrogen fertilizer has significantly improved the average kernel filling rate and has optimized the transport system of photosynthetically synthesized substances (Hong et al., 2021) and in semi-arid areas high density combined with high nitrogen fertilization improves soil water utilization and specifically water that is prone to evaporation (Yang et al., 2022).

Higher seeding densities and reduced nitrogen application rates should be considered for yield increase in order to stimulate improved soil nitrogen utilization (Cailong et al., 2017), although using higher amounts of nitrogen fertilizers has resulted in higher amounts of synthesized substances in the plant which facilitates flower development and increases the number of grains in the corncob (Hong et al., 2022).

It is recommended that the choice of hybrids be made under conditions of stress and high plant density because under such conditions, the rate of water loss from the grain increases (Pin et al., 2022). Research has been conducted in maize by growing alternating low-density rows with high-density rows and it has been found that diversified management approaches can provide both economic and environmental benefits of the cropping system (Amanda et al., 2022). A high density of up to 10.5 plants/square metre can lead to a significant increase in yield only when combined with narrow row spacing, as it guarantees greater equal distancing among plants (Giulio et al., 2016). In dry areas, increasing plant density can effectively improve maize yield, but more irrigation water is needed to obtain higher yields. (Guoqiang et al., 2022).

There is a need for new improvement strategies on adaptation of maize plants to stress using novel breeding strategies for alleles harvesting which govern physiological adaptive traits. (Welcker et al., 2022)

Using a low or medium density in maize by alternating low- and high-density rows leads to an optimization of economic production and yield (Amanda and Kemania, 2022) and by using intercropping maize-soybean it was found that the decrease in maize yield is generated by the aboveground intraspecific competition which has reduced biomass accumulation without changing the number of grains per cob and therefore intercropping is not a solution to increase yield (Bing et al., 2022). Yield potential can be increased by extending the flowering and physiological maturity period with constant maintenance of the growing season by complete interception of radiation during the flowering period (Capristo et al., 2007).

Hybrids with low leaf area have tolerated higher plant density better (Lambert et al., 2014).

Increasing plant density is one way to increase leaf area, but brightness decreases proportionally with leaf system development and leaf position.

Following the investigation undertaken, the research hypothesis that we started from was to determine how much the decrease in plant nutrient surface area influences the size of productivity elements in maize crops.

The aim of this paper is to examine the extent to which increasing plant density is a means of increasing production per unit area, and the objective is to determine what level of plant density is tolerable without any consequences on the size of the productivity elements.

MATERIALS AND METHODS

The biological material tested was the hybrid P0217, a medium-late hybrid (FAO group 420), characterized by stability and productivity and very good drought tolerance, recommended for arid and semi-arid lowland areas in the south and west of the country.

The crop establishment was performed on a typical chernozem soil, on April 26th 2021, in Suțu village, Braila county, with two experimental varieties: a variety seeded in equidistant rows at a distance of 70 cm between rows and a variety seeded in equidistant rows at a distance of 35 cm bandwidth, each variety with 3 repetitions, randomly placed.

The soil where the maize crop was established is a typical chernozem with physical and chemical properties favourable to the growth and development of maize plants, the area is characterized by a semi-arid steppe climate, the main restricting factor being water. Soil agrochemical determinations (soil reaction, humus content, mobile phosphorus and mobile potassium) were carried out on soil samples collected up to a depth of 30 cm, the determination methods used being according to the National Research-Development Institute for Pedology, Agrochemistry and Environmental Protection Bucharest. The determination of soil reaction was done by the potentiometric method in aqueous suspension in a ratio of 1:2.5, humus content was determined by the wet oxidation method and titrimetric determination (Walkley - Black), whereas the mobile phosphorus was determined by the Egner-Riehm-Domingo method in ammonium acetate lactate solution and the mobile phosphorus was determined by the photometric method in Egner-Riehm-Domingo extract.

During the growing season, the sequence of growth and development phenotypes of the plants was monitored and biometric measurements (average stem height, average height of cob insertion and stem diameter) were taken on May 14th, June 10th, July 01st and August 28th 2021 using a measuring tape and ruler. Among the productivity elements, the weight of grains per cob (grams) was determined by weighing and the yield obtained (tons/hectare) at harvest time.

Determination of plant leaf area was done by measuring leaf width and leaf length on several plants determining the average leaf area and then the average leaf area per plant, and the leaf area index was estimated using the formula (Dugje, 1992) cited by (Albert Berdjou et. al, 2020) LAI = (P × L × A)/(GA), where, LAI = Leaf area index, P = Plant population/ground area (ha), L = Number of fully expanded green leaves/plant, A = Single leaf area (cm^2), GA = Ground area or hectares.

RESULTS AND DISCUSSIONS

The results of the agrochemical determinations carried out show that the pH values of the analysed soil of 7.5 are slightly alkaline, which reveals the presence of carbonates in the soil and ensures good growth and development conditions for maize, whose soil reaction requirements lie between pH values of 6.5-7.5.

The humus content of the soil was 2.5% showing a medium humus supply, the results regarding the mobile phosphorus content was 42 ppm showing a good mobile phosphorus supply of the soil and for potassium supply it was 198 ppm mobile potassium showing a good potassium supply of the soil as well.

From a climatic point of view, during the vegetative period, rainfall was below the multiannual monthly average, except in June, when rainfall was above the multiannual monthly average. From a thermal point of view during the whole growing season the average monthly temperatures were above the multiannual monthly mean.

The preplant was also maize, considering that maize is a plant with modest requirements in relation to the preplant, but maize monoculture practised for more than 2-3 years leads to crop losses directly proportional to the duration and the technology applied, resulting in the so-called phenomenon of “soil exhaustion”. Rotations that also involve fodder crops are much more sustainable compared to current short-term rotations (Trenton and Lauerb, 2008).

Seedbed preparation was done by a disc harrow pass followed by tillage with a seedbed cultivator at a right angle to the direction of sowing, on the day before sowing.

Sowing was achieved on 26 April 2021, the start of the sowing was on 04 May 2021, the density at sprouting was 6.7 plants/m² in the case of sowing in equidistant rows at a distance of 70 cm and 13.1 plants/m² in the case of sowing in equidistant rows at a distance of 35 cm between rows.

Complex fertilizers with a ratio of 20:20:20 at a rate of 200 kg/hectare were also applied with sowing.

After sowing, before sprouting, TENDER 1.5 l/hectare was applied as herbicide for a superior and long-lasting control of grass weeds and some dicotyledonous weeds.

On May 24th 2021, herbicide Fornet extra 0,7l/hectare was sprayed for the control of annual grass weeds but also for *Sorghum halepense* (Johnson grass) from rhizomes. The harvesting was carried out on October 02nd 2021.

The results on phenophase sequence are presented in Tables 1 and 2.

Table 1. Phenophase succession and biometric measurements for the distance between rows of 35 cm

Date	Phenophase	Medium stem height (cm)	The average insertion height of the cob (cm)	Stem diameter (cm)
14.05. 2021	four fully formed leaves	17.50	-	-
10.06. 2021	six fully formed leaves, seven in the cornet	45.80	-	-
01.07. 2021	ten fully formed leaves, leaf 11 in cone	189.00	-	-
26.08. 2021	fourteen fully formed leaves	291.00	128.00	2.11

Table 2. Phenophase succession and biometric measurements for the distance between rows of 70 cm

Date	Phenophase	Medium stem height (cm)	The average insertion height of the cob (cm)	Stem diameter (cm)
14.05. 2021	four fully formed leaves	17.06	-	-
10.06. 2021	six fully formed leaves, seven in the cornet	43.50	-	-
01.07. 2021	ten fully formed leaves, leaf 11 in cone	180.30	-	-
26.08. 2021	fourteen fully formed leaves	278.20	124.80	2.73

Looking into the results presented in Table 1 and 2, one can see that there are differences related to both stem height and the corncob insertion height.

Thus for the 70 cm clearance sown variety, the stem height is 278.20 cm as compared to the 291.00 cm for the 35 cm range sown variety, while the corncob insertion height is 128.00 cm in the 35 cm range sown variant, compared to 124.8 cm in the 70 cm range sown variant. The conclusion is that the higher plant stem and corncob insertion height for the denser sown variant can be explained by the competition for light of the plants which causes a slight increase in both height and corncob insertion height.

For the two sowing variants analysed, the stem diameter was also determined and it was observed that in the case of the variant sown at 35 cm distance, the stem diameter was smaller compared to the variant sown at 70 cm by 0.62 cm, which also resulted in a decrease in the resistance of the stem to fall and breakage.

In the phenophase of ten fully formed leaves, the leaf area of the plants was determined and resulted in a leaf area/plant of 4,888.64 cm² for the variety sown at 35 cm range and 5,144.33 cm² for the variety sown at 70 cm, range. Based on these findings, the leaf area index was also determined, which for the variety sown at 70 cm distance has values of 3.44 and for the variety sown at 35 cm distance has values of 4.60.

As a result, the reduction of the nutrient area from 0.15m² (in the 70 cm-weighed variant) to 0.076 m² (in the 35 cm-weighed variant) resulted in a reduction of the vegetative growth with implications on the size of the uptake area for each plant, but with an increase of the leaf area index values due to the higher density of the soil covering the soil surface.

By increasing plant density, the total leaf area expands and the land cover is accelerated, allowing a better use of light energy, although the light intensity inside the field decreases with the development of the foliar system, consequently increasing the shading of the lower leaves.

Among the elements of productivity, the weight of the kernels per cob was determined, which was 150 g for the variety sown at a distance of 70 cm and 55.73 g for the variety sown at a distance of 35 cm.

The weight of the kernels on the cob varies within quite large limits, so that the difference in this element of productivity for the two variants is 94.27 g per cob in favour of the variant planted at 70 cm, which is also shown by the difference in terms of size of the yields obtained for the two variants under analysis.

In order to see whether the differences recorded in terms of yields between the variants analysed are statistically reliable, we have used the JASP statistical analysis programme, the analysis of the variants being carried out using the ANOVA test, the results of which are shown in Table 3.

Table 3 ANOVA - Production

Cases	Sum of Squares	df	Mean Square	F	p
Variant	11.760	1	11.760	48.329	0.002
Residuals	0.973	4	0.243		

Note. Type III Sum of Squares

Since p = 0.002 is below the significance threshold of 0.05, the difference is highly significant between the averages of the two variants examined, the values of the coefficient of variation appear in Table 4.

Table 4. Descriptives - Production

Variant	N	Mean	SD	SE	Coefficient of Variation
Rows dist 35 cm	3	7.367	0.379	0.219	0.051
Rows dist 70 cm	3	10.167	0.586	0.338	0.058

Figure 1 shows the yields of each repetition (tons) in the experimental variants considered. In order to check the homogeneity of the dispersion, Levene's test was performed, and Figure 2 is a graphical representation of the homogeneity of the dispersion showing that there is no systematic deviation from the straight line.

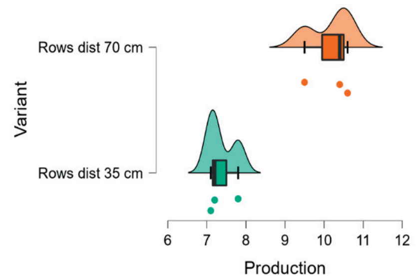

Figure 1. Yield per each repetition of the variants analysed (tons/hectare)

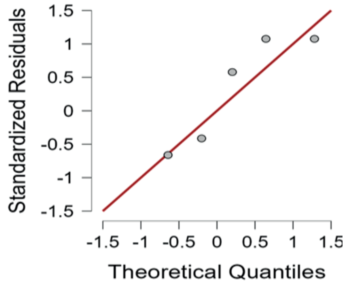

Figure 2. Dispersion homogeneity

Table 5. Post Hoc Comparisons – Variant

			95% CI for Mean Difference					
		Mean Difference	Lower	Upper	SE	t	p_{tukey}	p_{bonf}
Rows dist 35 cm	Rows dist 70 cm	-2.800	-3.918	-1.682	0.403	-6.952	0.002	0.002

CONCLUSIONS

The results obtained indicate that increasing the density causes a reduction in yield by influencing the size of the productivity elements due to a reduction in the uptake surface for each plant.
However, the increase in production can only be achieved by increasing the density, but on condition that the photosynthetic activity is maintained at a high level, and this can be achieved with the help of hybrids whose leaves are positioned closer to the vertical, which will be suitable for higher densities with consequences on the increase in the solar energy conversion coefficient.
Following the determinations made and the production results obtained, it appears that doubling the density per unit area results in a decrease in production, because the reduction in productivity of a plant cannot be compensated by an increase in the number of plants/hectare, so that when sown in equidistant rows at a distance of 35 cm, a yield of 7.33 tons/hectare has been obtained, 2.8 tons/hectare less than when sown in equidistant rows at a distance of 70 cm where a yield of 10.16 tons/hectare has been achieved.
Therefore, the increase in plant density does not result in an yield increase, because a density threshold is reached. Above this threshold, the yield does not increase, on the contrary, it starts to decrease, as light becomes a limiting factor and the rate of nutrients absorption decreases. This fact influences the number of plants per hectare corresponding to the optimal density of the maize crop.

According to the results obtained, it is recommended to increase the density especially in hybrids that are suitable for higher densities but with the maintenance of high photosynthetic activity.

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