**Advances in Bioresearch**
Adv. Biores., Vol 12 (2) March 2021: 108-115

Print ISSN 0976-4585; Online ISSN 2277-1573
Journal's URL:http://www.soeagra.com/abr.html
CODEN: ABRDC3
DOI: 10.15515/abr.0976-4585.12.2.108115

Advances in Bioresearch

**ORIGINAL ARTICLE**

# Yield response of maize hybrids to water supply, fertilization and planting density

**Karamchand Bramdeo and Rátonyi Támas**
University of Debrecen, Faculty of Agricultural and Food Sciences and Environmental Management,
Institute of Land Use, Technology and Regional Development
Email: bramdeo@agr.unideb.hu

**ABSTRACT**
*This research was conducted at the Látókép Research Station of the University of Debrecen, site (N 47°33' E 21°27') in 2018 and 2019.Yield response of three hybrids of maize, Loupiac (FAO 380), Fornad (FAO 420) and Armagnac (FAO 490) were investigated under different agro-technical conditions which include, irrigated and non-irrigated (rainfed) treatments ,three levels of fertilizer (N 160 kg ha$^{-1}$, N80 kg ha$^{-1}$, N0 kg ha$^{-1}$) and two levels of plant densities(60,000 and 80,000 plants ha$^{-1}$).The experiment was set up in a split plot design with the main plot equally divided into irrigated and non-irrigation(rainfed). Maize hybrids were sown at 76 cm interrow spacing in the main plot which was subdivided to accommodate the fertilizer treatments with four replications. There was a total of 216 treatment plots, each 3x10m. The crop was harvested at the end of the growing cycle and grain moisture content adjusted to 15% to arrive at the final yield. Data collected were analyzed using IBM SPSS 26 descriptive statistics and Microsoft Excel. The results indicated, water supply, fertilization and planting density influenced the yield of the test hybrids to varying extent. Fertilizer application greatly enhanced yield and accounted for 43.7% of yield variance. N80 and N160 appreciate yield by 2.77 t ha$^{-1}$and 4.01 t ha$^{-1}$ respectively. Significant interaction ($p<0.05$)was observed between, fertilization x irrigation; planting density x irrigation, and fertilization x planting density. Effect of irrigation on yield of hybrids varied with fertilizer dosages and planting density. At 60,000 plants ha$^{-1}$, irrigation depressed yield of N0and N80 treatments by 11.7% and 6.5% respectively, while at 80,000 plants ha$^{-1}$ there was no significant difference in yield between irrigated and non-irrigated, N0 and N80 treatments. Yield increasing benefits of irrigation was only realized with N160 kg ha$^{-1}$ at both planting densities and was significantly higher at 80,000 plants ha$^{-1}$ (1.18 t ha$^{-1}$ vs. 0.70 t ha$^{-1}$). Higher planting density resulted in higher yield and yield variations and impacted negatively on individual plant productivity. Mean yield of 80,000 plants ha$^{-1}$ was 13.8% (1.30t ha$^{-1}$) higher than 60,000 plants ha$^{-1}$, concurrent with 14.6% decline in individual plant productivity at the higher density. Reduction in individual plant productivity for the hybrids ranged from 11.2 to 18% with the highest decline (18%) in Fornad (FAO 420), followed by Lopiac (FAO 380) with 14.5% and the least(11.2%) in Armagnac(FAO 490). The adaptability of Loupiac(FAO 380) and Armagnac (FAO 490) to higher planting density was superior to Fornad (FAO 420), with Armagnac (FAO 490) being the most tolerant of the hybrids.*
***Keywords:*** *irrigation, fertilization, maize, hybrids, plant density*

Received 26.12.2020 Revised 11.02.2021 Accepted 02.03.2021

**How to cite this article:**
K Bramdeo and R Támas. Yield response of maize hybrids to water supply, fertilization and planting density. Adv. Biores. Vol 12 [2] March 2021. 108-115

## INTRODUCTION

Maize (*Zea mays* L.) is amongst the most important grain crops in Hungary, cultivated on approximately 1.0 M ha with significant fluctuation in yield, ranging from 4.0 to 8.6 t ha$^{-1}$ in the last decade [14]. Achieving high and sustainable yield under changing climatic conditions and limited resources is a major challenge facing the agriculture sector.

Maize, a C4 plant with high productivity, is very sensitive to the agroecological and agrotechnical conditions. Under optimal conditions, the yield is determined by the potential of the hybrids, however, in situation of unfavorable climatic condition or deficiencies in the agrotechnological inputs, the adaptability of the hybrids is of paramount importance [7, 19]. The effects of the agrotechnological factors on the yield stability of maize are especially important and exert their influence via interactions, rather than in isolation [27].

Plant density has a determining effect on yield and is one of the most important cultural practices utilized for maximizing yield by increasing the interception of solar radiation within the canopy [30, 20]. The impact of plant density on yield is dependent on complex interactions between the genotype, agroecological condition and agrotechnical factors. Increasing planting density, increases yield up to a maximum for a given maize genotype, under a specific set of agroecological and agrotechnical conditions, beyond which, yield decline with any further increase in plant density [31, 32, 36]. Testa *et al.* [34] found higher plant density led to a decrease in the stalk area (-20%), leaf greenness (-5.2%) and cob length (-10.8%) and also negatively affected the kernel weight (-7.1%) and the number of kernels per row (-10%). The increase in yield from higher planting density in modern hybrids, resulted from better tolerance over a variety of environments, including stress associated with high plant populations and not yield potential on an individual plant basis [10, 12, 8].

According to Pepó *et al.* [28], the optimum plant density of maize was found to be 50,000 plant $ha^{-1}$in dry, while 80,000 plant $ha^{-1}$ in wet years. Berzsenyi *et al*. [3] reported similar findings with maximum yields for maize being achieved in drought years at low plant density.

Maize needs relatively large quantity of water (500-600 mm) during its vegetation period and the most critical periods of water supply are tasseling, silking and early grain formation in maize production. Results of long-term experimental data showed that the yield surpluses of irrigation varied with rainfall amount and distribution during the growing season. In drought crop years, yield increment from irrigation was between 4-5 t $ha^{-1}$, while in average and wet crop years, 1-2 t $ha^{-1}$ and 0-0.4 t $ha^{-1}$, respectively [37, 27].

Water stress can have detrimental impact on maize, resulting in reduced biomass and consequently yield. Khan *et al.* [16], reported stem height, stem diameter, leaf area and days to complete flowering, decreased significantly with increasing water stress. Yield components such as number of grains per cob, 1000-grainweight and grain yield have also been decreased by increasing water stress. Irrigation prevents water stress situation and improves the efficiency of fertilization. Wang and Xing [39] found interaction of nitrogen and irrigation has significant effects on biomass yield and the physiological indices of maize were increased with irrigation amount and fertilizer level. With higher fertilizer doses, the yield increasing effect of irrigation is greater due to the positive correlation between nutrient and water supply. Without irrigation, the negative effect of the insufficient water supply was further compounded by the increasing fertilizer dosages and plant density [1, 22, 23, 18].

The most important yield-enhancing factor in maize production was the nutrient supply, followed by the variety and the effects of unfavorable abiotic stress can be reduced by appropriate cultivar selection and the optimum use of different agrotechnical factors [9, 27].

Maize absorbs nutrients partiallyfrom the soil and from fertilizers applied, however, the nutrient demand of maize is predominantly satisfied with chemical fertilizers. The applied fertilizer dosage is influenced by several factors which include planned yield level, the nutrient pool and nutrient providing ability of soil, the specific nutrient demand of maize, the water supply of the soil at sowing, the characteristic of the hybrid and preceding crop [5, 29].

Nitrogen is a vital plant nutrient and a major yield determining factor required for maize production. It is very essential for plant growth and makes up 1 to 4percent of dry matter of the plants. When nitrogen is inadequate, growth is reduced [2, 11]. According to Nagy, [23] under rainfed condition 90 kg N $ha^{-1}$ fertilizer dose was found to be adequate to achieve yield that are close to maximum, while in irrigated treatments it was 120 kg $Nha^{-1}$.

Genotypes showed a differential grain yield response depending on planting density and incidence of drought, [2, 11]. The advantage of genotype may not only be in the area of increased yield, but also for the greater stability in production across the environments [24]. According to Veldboomand Lee [24] the different response in yield of hybrids is attributed to different sets of alleles and possibly different loci are being expressed under different environmental conditions. The response of genotypes to drought intensity and time differs according to their genetic structure and adaptability. Wenzel [40] found that some genotypes yielded more under moisture stress than under near-ideal moisture conditions. The biological bases, the selection of appropriate hybrids will be of greater importance in the future due to changing climatic conditions, hence good agronomical and stress bearing traits will be fundamental for achieving optimum result [3].

## MATERIAL AND METHODS

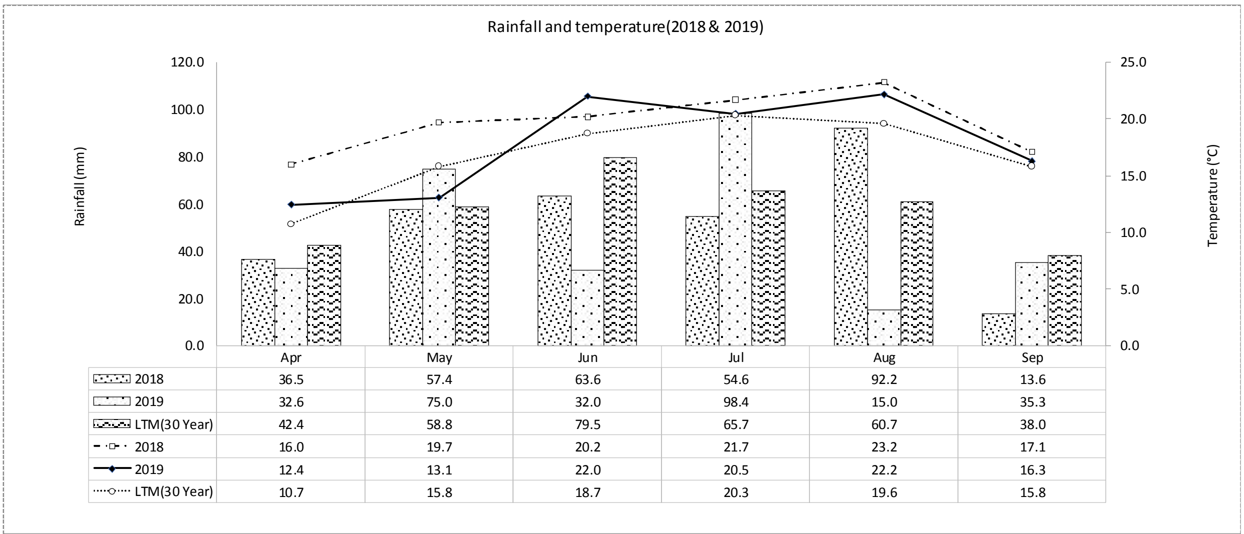
Yield response of three hybrids of maize, Loupiac (FAO 380), Fornad (FAO 420) and Armagnac (FAO 490) were investigated under different agrotechnical conditions which include, three levels fertilizer treatments, two levels of plant densities, irrigated and unirrigated (rainfed) treatments. The experiment was conducted in 2018 and 2019 at the Látókép Research Station Site (N 47°33' E 21°27) of the University of Debrecen. The soil type was calcareous chernozem soil, consisting of 11 % sand, 65 % silt and 24 % clay in the upper soil layers, with a near neutral pH value ($pH_{KCl}$=6.46). It has a humus content of 2.8 % and humus depth of approximately 80 cm, with good water holding capacity. The available water is approximately 50% of field capacity and the minimum field capacity ($WC_{min}$) is 275 mm in the 0-100 cm and 265 mm in the 100-200 cm.

The experimental design was split plot, equally divided into irrigated and non-irrigated. Maize hybrids, Loupiac (FAO 380), Fornad (FAO 420) and Armagnac (FAO 490) were sown at 60,000 and 80,000 seeds $ha^{-1}$ with Gaspardo 6-row automatic planter and a row spacing of 76 cm. The main plot was subdivided to accommodate two levels fertilizer treatments (N80 & N160 kg $ha^{-1}$) along with the control (N0 kg $ha^{-1}$) which was replicated four times in both irrigated and non-irrigated (rainfed) plots. Nitrogen was applied in the form of ammonium-nitrate ($NH_4NO_3$) with a total of 216 treatments plots, each 3m x 10 m.

Irrigation was applied in an amount that is close to the calculated needs of the plant (273 mm) and was done with a self-propelled, 75 cm division linear sprinkler irrigation system, equipped with sensors to maintain uniformity in movement during operation.

The crop was harvested at the end of the growing cycle each year and the grain moisture content corrected to 15% to arrive at the final grain yield. Yield data were analyzed using IBM SPSS 26 and Microsoft Excel. (figure 1).

*Figure 1* Monthly precipitation and temperature were recorded during the growing season and compared to the 30-year mean




## RESULTS AND DISCUSSION

Growing season rainfall (Apr-Sep) in 2018 was 29.5mm higher than 2019, with a mean temperature of 19.65 °C compared to 17.74 °C in 2019. Mean yield in 2018 was 2% higher than 2019 (10.35 vs. 10.15 t $ha^{-1}$) and could be attributed to the slightly favourabe weather based on the meteriological data (table 1).Crop year reportedly had

significant influence on the size of yield of maize and in particular, the amount and distribution of precipitation of the crop year, coupled with the temperature during the winter [22, 33].

Plant density impacted significantly($p<0.05$)on yields of the hybrids and accounted for 9.6% of yield variance. According to Sangoi [30], plant density is one of the most important cultural practices determining grain yield of maize, as well as other important agronomic attributes of the crop.

Mean grain yield of 80,000 plants $ha^{-1}$was 13.7% (1.29 t $ha^{-1}$) higher than 60,000 plants $ha^{-1}$.The increased yield at higher planting density was concomitant with a 14.5% reduction of individual plant productivity(*fig.2*). Similar observations were made by Hammer *et al.,* [10] & Ku *et al*. [17] who stated that grain yield per plant is typically reduced with increasing planting density as a result of the reduction in light penetration into the canopy and greater competition for soil resources. According to Sárvári [31], with increasing plant density, the yield per plant decreases, but the yield per unit area increases until the optimal number of plants density is reached.

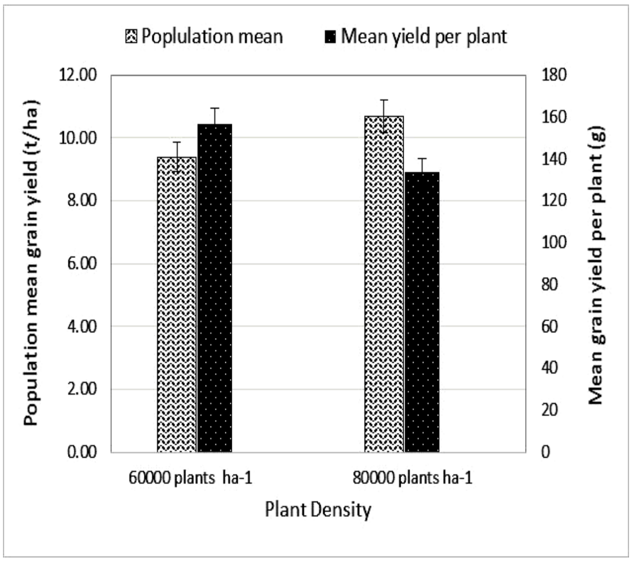



**Figure 2: Planting densities and yields**

Maize hybrids varied in their response to planting density. Yield variation was significantly higher at 80,000 plant $ha^{-1}$.At 60,000 plants $ha^{-1}$, Fornad (FA0 420) was the best performing hybrid with yield being 5.4% (0.49 t $ha^{-1}$) higher than Armagnac (FAO 490) and 2% (0.19 t $ha^{-1}$) above Loupiac (FAO 380). However, at 80,000 plants $ha^{-1}$, individual plant productivity for Fornad (FA0 420) significantly declined (18%), rendering it the least performing hybrid at high plant density (*table 1*).

*Table 1* **Plant density, mean yield of hybrids and percent yield variance**

| Hybrid | Plant Density | Population mean(t/ha) | Mean yield plant $^{-1}$ (grams) | % yield variance plant$^{-1}$ |
|---|---|---|---|---|
| Armagnac (FAO 490) | 60000 | 9.12 | 152 | -11.2 |
| | 80000 | 10.80 | 135 | |
| Loupiac (FAO 380) | 60000 | 9.42 | 157 | -14.5 |
| | 80000 | 10.74 | 134 | |
| Fornad (FAO 420) | 60000 | 9.61 | 160 | -18.0 |
| | 80000 | 10.51 | 131 | |

Armagnac (FAO 490) recorded the highest yield (10.80 t $ha^{-1}$), concurrent with the lowest decline in individual plant productivity (11.2%). Tollenaar & Wu [36] and Boomsma et al. [4], posited that variations in yield responses of hybrids to changes in plant population density, hinges on their ability to tolerate abiotic and biotic stresses, including tolerance to high planting density. Based on the foregoing, Armagnac (FAO 490) adaptability to higher planting density was superior to Fornad (FAO 420) and to a lesser extent Loupiac (FAO 380).

Fertilization significantly enhanced yield of maize hybrids and accounted for 43.7% yield variance. The highest yield was obtained with N160 (12.00 t $ha^{-1}$), while the lowest yield (7.99 t $ha^{-1}$) was in the control (N0 kg $ha^{-1}$). Yield difference between treatments was statistically significant (table 2).Yield increment for N80 and N160 was 2.77 and 4.01 t $ha^{-1}$, respectively. The role of fertilization in stabilizing yield was also evident with the highest CV in the control plots (N0 kg $ha^{-1}$) and the lowest in the N160 kg $ha^{-1}$ treatment (*fig. 3*). Interaction between fertilization and irrigation was significant ($p<0.05$). The benefits of irrigation in improving fertilizer utilization was only realized at N160 level. Grain yield of irrigated, N160 was 8.9% (1.01 t $ha^{-1}$) higher than non-irrigated treatment, however there was no yield increasing benefit from irrigation at N80 level and yield was adversely affected in the control (N0 kg $ha^{-1}$).The results suggested that the soil natural moisture content was adequate for utilization of N 80 kg $ha^{-1}$, hence irrigation was not necessary. Similar observation was made by Huzsvai and Széles [13] who concluded that the extent of water supply of maize can only adequately judged based on the degree of nutrient supply.

*Table 2:* **Comparisons between fertilizer treatments**

Dependent Variable: Yield
LSD

| (I) Fertilizer | (J) Fertilizer | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| N 0 kg | N 80 kg | -2.7681* | .13128 | .000 | -3.0257 | -2.5105 |
| | N 160 kg | -4.0110* | .13128 | .000 | -4.2686 | -3.7535 |
| N 80 kg | N 0 kg | 2.7681* | .13128 | .000 | 2.5105 | 3.0257 |
| | N 160 kg | -1.2429* | .13128 | .000 | -1.5005 | -.9854 |
| N 160 kg | N 0 kg | 4.0110* | .13128 | .000 | 3.7535 | 4.2686 |
| | N 80 kg | 1.2429* | .13128 | .000 | .9854 | 1.5005 |

*. The mean difference is significant at the .05 level.

The negative impact of irrigation on grain yield in the control plots (N0 kg $ha^{-1}$) is tantamount to over-irrigation and also supports several research findings, that there exists, a positive correlation between fertilization and irrigation [6, 15, 22] and both need to be synchronized to achieved maximum results, i.e. increasing fertilizer dosages will necessitate an increase in irrigation and conversely, increasing irrigation will require an increase in fertilization.

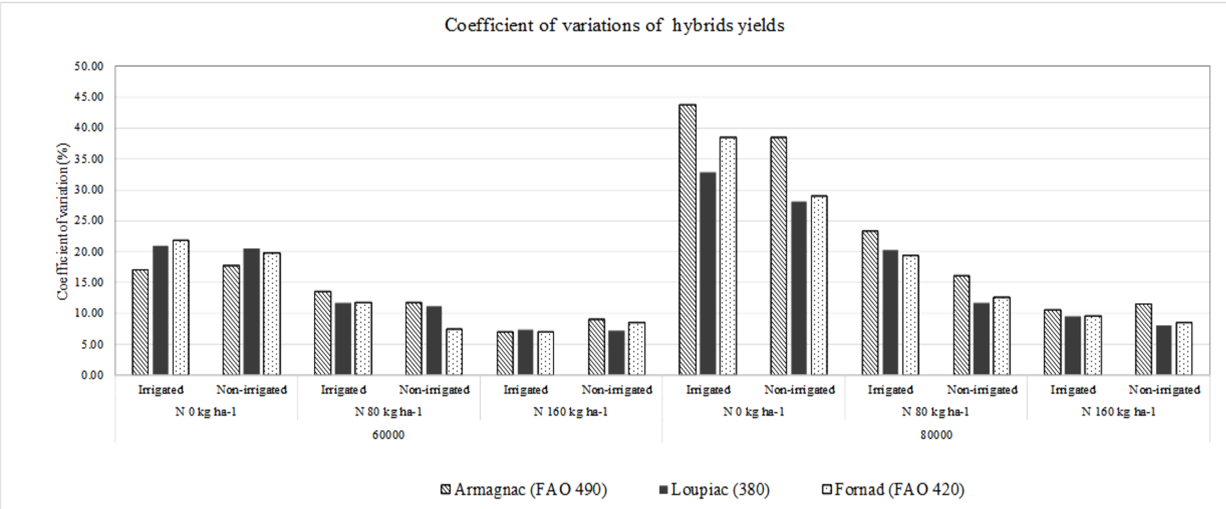



*Figure 3*: **Coefficient of variations of hybrids yields at different treatments levels**

Planting density x irrigation interaction was significant (p=0.002). Irrigation increased yield of 80,000 plants $ha^{-1}$ by 4.1% (0.43 t $ha^{-1}$) but depressed yield in 60,000 plants $ha^{-1}$, resulting in 2.8% yield decline. The negative impact of irrigation on lower plant population density was confined to the N0 and N80 treatments (*fig.4*) and could be explained by the disproportionate nutrient to water supply ratio, as proffered earlier. At 80,000 plants $ha^{-1}$the water demand would have been greater as a result of increased transpiration and biomass production, thus reducing the wide disparity between available nutrient and water supply, hence the positive impact. The largest yield increasing benefit of irrigation was obtained with N160 treatment at both planting densities. Based on the results (*fig. 4*), it was evident that yield increasing benefits from higher plant population density can only be achieved under irrigated condition and N160 treatment.

Figure 4: Interactions of plant density, irrigation and fertilization

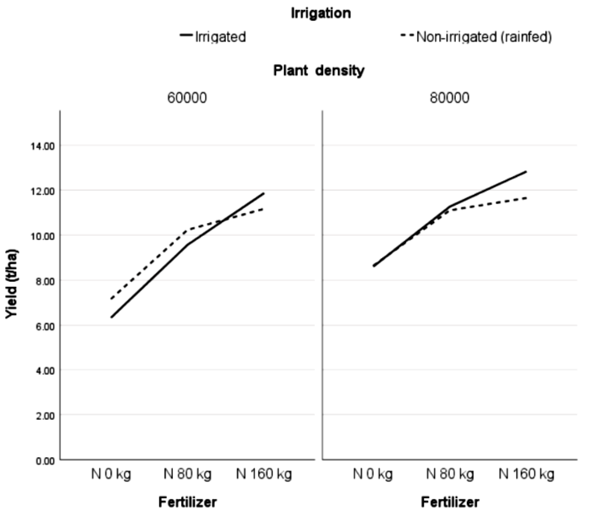
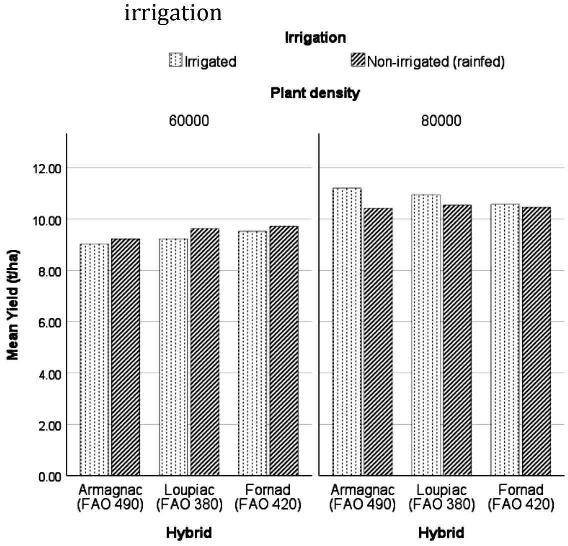



Figure 5: Interactions of hybrids, plant density and irrigation




Hybrids yield response to irrigation varied with planting density. Yield increase from irrigation at 80,000 plants $ha^{-1}$ was highest for Armagnac (FAO 490) with 7.5% (0.78 t $ha^{-1}$), Loupiac (FAO 380) 3.5% and Fornad (FAO 420) 1.2% (*31*). At 60,000 plants $ha^{-1}$ yield of all three hybrids declined with irrigation. Loupiac (FAO 380) recorded 4.4% decline; Armagnac (FAO 490) 2.2% and Fornad (FAO 420) 2.0%.

Fertilizer accounted for the largest yield variance (43.7%), followed by planting density (9.6%). Fertilizer x irrigation and fertilizer x planting density interactions were significant (*table 3*). Effect of irrigation was not significant(p=4.64), however, irrigation x planting density interaction was significant (p=0.02).

Crop year x planting density interaction was significant (p=0.024). Yield of 80,000 plants $ha^{-1}$ was 3.5% (0.37 t $ha^{-1}$) higher in 2018 due to the more favorable growing condition.

*Table 3:* **Tests of Between-Subjects Effects**

Dependent Variable: Yield

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared |
|---|---|---|---|---|---|---|
| Corrected Model | 4555.124[a] | 71 | 64.157 | 17.235 | .000 | .500 |
| Intercept | 115994.298 | 1 | 115994.298 | 31159.746 | .000 | .962 |
| Irrigation | 1.998 | 1 | 1.998 | .537 | .464 | .000 |
| Year | 3.505 | 1 | 3.505 | .941 | .332 | .001 |
| Plantingdensity | 484.322 | 1 | 484.322 | 130.104 | .000 | .096 |
| Hybrid | 3.097 | 2 | 1.549 | .416 | .660 | .001 |
| Fertilizer | 3542.704 | 2 | 1771.352 | 475.841 | .000 | .437 |
| Irrigation * Year | .033 | 1 | .033 | .009 | .925 | .000 |
| Irrigation * Plantingdensity | 35.629 | 1 | 35.629 | 9.571 | .002 | .008 |
| Irrigation * Hybrid | 6.196 | 2 | 3.098 | .832 | .435 | .001 |
| Irrigation * Fertilizer | 106.628 | 2 | 53.314 | 14.322 | .000 | .023 |
| Year * Plantingdensity | 19.129 | 1 | 19.129 | 5.139 | .024 | .004 |
| Year * Hybrid | 1.013 | 2 | .506 | .136 | .873 | .000 |
| Year * Fertilizer | 35.367 | 2 | 17.684 | 4.750 | .009 | .008 |
| Plantingdensity * Hybrid | 29.178 | 2 | 14.589 | 3.919 | .020 | .006 |
| Plantingdensity * Fertilizer | 64.228 | 2 | 32.114 | 8.627 | .000 | .014 |
| Hybrid * Fertilizer | 9.529 | 4 | 2.382 | .640 | .634 | .002 |
| Error | 4556.424 | 1224 | 3.723 | | | |
| Total | 145287.103 | 1296 | | | | |
| Corrected Total | 9111.548 | 1295 | | | | |

a. R Squared = .500 (Adjusted R Squared = .471)

## CONCLUSIONS

Hybrids varied in their response to planting density, fertilizer dosages and irrigation. Armagnac (FAO 490) adaptability to higher plant density was superior to Fornad (FAO 420) and Lopiac(FAO 380), under

irrigated and N160 kg $ha^{-1}$ treatments. Fornad (FAO 420) yield was the highest at lower planting density, making it most suitable for situation of reduced soil moisture (drought).
Optimum benefits of irrigation can only be realized by taking into consideration both the soil moisture content, as well as the nutrient status of the soil, including applied fertilizer dosages.

**ACKNOWLEDGEMENTS**
The research was supported by the EFOP-3.6.3-VEKOP-16-2017-00008 project and co-financed by the European Union and the European Social Fund.

**REFERENCES**

1. Abdelmula, A. A.-Sabiel S. A. I. (2007): Genotypic and differential responses of growth and yield of some maize (*Zea mays* L.) genotypes to drought stress. Conference on International Agricultural Research for Development, University Gottingen, Khartoum, Sudan, pp.1-6.
2. Adediran, J.A.-Banjoko, V.A. (1995): Response of maize to N, P, and K fertilizers in the savanna zone of Nigeria. Commun. Soil Sci. Plant Anal. 26: 593-606 p.
3. Berzsenyi, Z. -Arendas, T-Bonis, P.-Micskei, G.-Sugár, E. (2011):Longterm effect of crop production factors on the yield and yield stability of maize (Zea mays L.) in different years. Acta Agronomica Hungarica. 2011. 59: 3, 191-200. p.
4. Boomsma, C. R., Santini, J. B., Tollenaar, M. -Vyn, T.J. (2009): Maize morphophysiological responses to intense crowding and low nitrogen availability: an analysis and review. Agronomy Journal 101, 1426–1452.
5. Debreczeni, B. 1980. Artifical fertilization. ActaAgronomica, 29. 117-225.
6. Fanus, A.-Aregay, F.- Minjuan, Z. (2014). Impact of Irrigation on Fertilizer Use Decision of Farmers in China: A Case Study in Weihe River Basin. Journal of Sustainable Development. 5. 1913-9071. 10.5539/jsd.v5n4p74.
7. Gardner, F.P.-Valle, R.- McCloud, D.E. (1990): Yield characteristics of ancient races of maize compared to a modern hybrid. Agron. J., 82: 864-868 p.
8. Gonzalez, V. H.-Tollenaar, M.-Bowman, A.-Good, B.-Lee, E. A. (2018): Maize yield potential and density tolerance. Crop Science,58, 472–485. https://doi.org/10.2135/cropsci2016.06.0547
9. Győrffy, B. (1976): Evaluation of maize yield in crop production factors. Releases of Agricultural Sciences 35: 239-266.
10. Hammer, G. L.-Dong, Z.-McLean, G.-Doherty, A.-Messina, C.-Schussler, J.-Cooper, M. (2009): Can changes in canopy and/or root system architecture explain historical maize yield trends in the U.S. Corn Belt? Crop Science, 49, 299–312. https://doi.org/10.2135/ cropsci2008.03.0152
11. Haque, M.M.-Hamid, A.- Bhuiyan, N.I. (2001): Nutrient uptake and productivity as affected nitrogen and potassium application levels in maize/sweet potato intercropping system. Korean J. Crop Sci., 46(1): 1-5.
12. Hashemi, A.-Herbert, S.-Putnam, D. (2005): Yield Response of Corn to Crowding Stress. Agronomy Journal - AGRON J. 97. 10.2134/agronj2003.0241.
13. Huzsvai, L.- Széles, A. (2009): Water Stress. In which cases does irrigation reduce the yield of maize.?. Cereal Research Communications Vol. 37, 2009, Suppl. 45-48.
14. Hungarian Central Statistical Office. http://www.ksh.hu/?lang=en accessed May 24th 2020
15. Jamil, M. M. (2004): Utilization of applied fertilizer nitrogen and irrigation water by drip-fertigated squash as determined by nuclear and traditional techniques. Nutrient Cycling in Agroecosystems 68, 1–11 (2004). https://doi.org/10.1023/B:FRES.0000012229.61906.6c
16. Khan, M.B.-Hussain, N.-Iqbal, M. (2001): Effect of water stress on growth and yield components of maize variety YHS 202. J. Res. Sci. 12(1):15-18.
17. Ku, L. X.- Zhao, W. M.-Zhang, J.-Wu, L. C.-Wang, C. L.-Wang, P. A (2010): Quantitative trait loci mapping of leaf angle and leaf orientation value in maize (Zea mays L.). Theor. Appl. Genet. 121, 951–959. doi: 10.1007/s00122-010-1364-z
18. Li, W.-Li, W.-Li, Z. (2004): Irrigation and fertilizer effects on water use and yield of spring wheat in semi-arid regions. Agricultural Water Management, 67 (1), 35-46. http://dx.doi.org/10.1016/j.agwat.2003.12.002
19. Marton L.- Szundy, T.-Hadi, G.-Pintér, J. (2005): Practical results of the selection to improve the adaptability of maize (Published work style), In.: Adaptability and crop safety of maize hybrids, Debrecen, 139-146 p.
20. Monneveux, P.- Zaidi, P.H.-Sanchez, C. (2005): Population density and low nitrogen affects yield. - Associated Traits in Tropical Maize. Crop Science. Vol. 45(2)
21. Murányi, E. (2015): Effect of the plant density on different maize (Zea mays L.) hybrids yields and leaf area index (LAI) values. ActaAgraria Debreceniensis, (64), 51-56.
22. Nagy, J. (2003): Effect of Irrigation on Maize Yield (Zea mays L.). Acta Agraria Debreceniensis. 30-35. 10.34101/actaagrar/11/3441.
23. Nagy, J.(2007): Evaluating the effect of year and fertilisation on the yield of mid ripening (FAO 400-499) maize hybrids. Cereal Research Communations.2007. 35.3. 1497-1507.
24. Nahar K.-Ahmed, S.-Akanda, M.-Mondal, M.- Islam, M. (2010): Genotype-Environment interaction for con yield and maturity in baby corn(Zea mays L.).Bangladesh J. Agril. Res. 35(3) : 489-496, September 2010
25. Pepó, P., (2007): Evaluation of ecological conditions and agrotechnical elements in maize (Zea mays L.) production. ActaAgronomicaOvariensis. 2007. 49: 2(1), 169-175. p.

26. Pepó, P.- Karancsi, G.L. (2014): New Results of nutrient utilization and response of maize (Zea mays) hybrids. Columella - Journal of Agricultural and Environmental Sciences. Vol. 1, No. 2 (2014) 87-93 p.
27. Pepó, P.- Sárvári, M. (2013): Different maize(Zea mays L.) agrotechnical models on chernozem and loamy soils. AnaleleUniversittii din Oradea, FasciculaProtectiaMediului Vol. XXI, 2013 156-165 .p.
28. Pepó, P.-Vad, A.-Berenyi, S. (2008): Effects of irrigation on yields of maize (Zea mays L.) in different crop rotations. Cereal Research Communications. 2008. 36: Suppl. 5, 735-738. p.
29. Rogers, D.-Leikam, D.-Mengel, D. (2007): Corn Production Handbook. Kansas State University Agricultural Experiment Station and Cooperative Extension Service. Accessed: December, 10th , 2017: http://www.ksre.ksu.edu/bookstore/pubs/c560.pdf
30. Sangoi, L. (2001): Understanding plant density effects on maize growth and development: an important issue to maximize grain yield Ci. Rur. 31, 159–168 (2001).
31. Sárvári, M. (2005): Impact of nutrient supply, sowing time and plant density on maize yields. ActaAgronomica Hungarica. 53. (1.): 59-70.
32. Sárvári, M.-Pepó, P. (2014) Effect of production factors on maize yield and yield stability, Cereal Research Communications 42(4), pp. 710–720.
33. Széles A.-Ragán, P.-Nagy, J. (2013): The effect of natural water supply and fertilization on maize (Zea mays L.) yield in the case of different crop year. Növénytermelés. 62:Suppl. 119-122 p.
34. Testa G.- Reyneri A.- Blandino M. (2016): Maize grain yield enhancement through high plant density cultivation with different inter-row and intra-row spacings. Europ. J. Agronomy 72: 28–37
35. Tollenaar, M.-McCullough, D.E.-Dwyer, L. M. (1994): Physiological basis of the genetic improvement of field crops. Marcel and Dekker Inc., New York, pp: 183-236.
36. Tollenaar, M.-Wu, J. (1999): Yield Improvement in Temperate Maize is Attributable to Greater Stress Tolerance. Crop Science - CROP SCI. 39. 10.2135/cropsci1999.3961597x.
37. Vári, E. (2013): Factors Determining Yield Safety of Maize. International Journal of Chemical, Environmental & Biological Sciences (IJCEBS) Volume 1, Issue 2 (2013) ISSN 2320 –4087.
38. Veldboom, L.R.-Lee, M. (1996): Genetic mapping of quantitative trait loci in maize in stress and non-stress environments. Crop Sci. 36: 1310-1319.
39. Wang X.- Xing Y. (2017) Effects of Irrigation and Nitrogen on Maize Growth and Yield Components. In: Pirasteh S., Li J. (eds) Global Changes and Natural Disaster Management: Geo-information Technologies. Springer, Cham
40. Wenzel, W.G., (1999): Effect of moisture stress on sorghum yield and its components. South of African Journal of Plant and Soil, 16 (3): 153-157.