NARDI FUNDULEA, ROMANIA ROMANIAN AGRICULTURAL RESEARCH, NO. 41, 2024
www.incda-fundulea.ro; doi.org/10.59665/rar4109 First Online: December, 2023. DII 2067-5720 RAR 2024-33

The Reaction of Some Maize Hybrids to Several Plant Densities, In the Cultivation Conditions of the Central-northwest Part of Romania

Carmen Daniela Vana[1], Andrei Varga[1*], Roxana-Elena Călugăr[1], Loredana Ancuța Ceclan[1,2], Călin Popa[1,2], Laura Șopterean[1*], Nicolae Tritean[1], Florin Russu[1]

[1]Agricultural Research and Development Station, Turda, Cluj County, Romania
[2]University of Agricultural Science and Veterinary Medicine, Cluj-Napoca, Cluj County, Romania
[*]Corresponding authors. E-mail: andrei_varga06@yahoo.com; ticulaura@yahoo.com

ABSTRACT

The density of plants on a certain area is a method used on a large scale to increase yield, but in certain environmental conditions and cultivation areas, it can be a stress for plants. At the Agricultural Research and Development Station Turda (ARDS Turda), seven maize hybrids, the most recent creations, were tested at four plant densities, in order to monitor their reaction in non-irrigated conditions. The plant densities used were 60,000, 70,000, 80,000 and 90,000 plant/ha and the experiment was carried out in three years: 2020, 2021 and 2022. The behaviour of the hybrids was different, but most of them had the best yield at 60,000 plants/ha. However, two hybrids stood out, Turda 335 and Turda 380, which had very good yield at 70,000 plants/ha, as well as a better tolerance to the stress of higher densities, especially due to characteristics such as superior production capacity, erect port or semi-erect leaves, prolific, good tolerance to water stress. Especially in non-irrigated conditions, maize yield is highly influenced by climatic conditions, regardless of density, so the use of high densities must be associated with ensuring optimal cultivation conditions.

Keywords: hybrids, maize, plant density, yield.

INTRODUCTION

The sowing density is one of the most effective technological factors for increasing the production of a genotype (Xue et al., 2017; Partal, 2022) and it must be carefully chosen in order to achieve maximum production without affecting its quality (Ghețe, 2019).

The sowing density is conditioned by the possibilities of ensuring soil moisture, the fertility and fertilization of the soil and the readiness of the hybrids to support high densities, the architecture of the plants and last but not least the FAO group (Vana et al., 2022).

High density tolerance, together with tolerance to other biotic and abiotic stresses as well as improved resource use efficiency, are the determining parameters contributing to improved productivity (Tokatlidis and Koutroubas, 2004).

To increase the yield, a larger number of plants per surface unit can be used, but it must be taken into account that with the increase of the sowing density, the resistance of the plants to falling becomes weaker, the sterility increases and finally the grain production can be lower. Testing maize hybrids under different ecological conditions and studying them for their ability to adapt to variations in ecological conditions is essential (Sarca, 2004).

Maize plant density in the US, one of the world's largest maize producers, has increased from 30,000 plants/ha in the 1930s to about 70,000 plants/ha in 2010. At the same time, average yield increased from 1,287 kg/ha in the 1930s to 9,595 kg/ha in 2010 (Mansfield and Mumm, 2014). In the areas favorable to maize crop, even thicknesses exceeding 100,000 are used. In China, average density increased from 15,000 plants/ha in the 1950s to 60,000 plants/ha in 2010, with average yields increasing from 1,000 kg/ha to 6,000 kg/ha (Li et al., 2016).

Received 3 October 2023; accepted 6 November 2023.

One of the problems caused by too high density is sensitivity to stalk lodging, which can lead to significant yield losses, so obtaining resistant genotypes is one of the main objectives of modern breeding (Xue et al., 2017). Production losses due to stalk lodging can be 5-25% in some years, but can be as high as 100% (Li et al., 2016). Stalk lodging in maize usually occurs by breaking at or below the ear.

To date, many successful approaches have been developed to reduce stem breakage, through conventional or biotechnological methods, reduction of nitrogen doses, addition of potassium and phosphorus, emergence and use of plant growth regulators, breeding to obtain shorter and stronger stem (Berry et al., 2004).

Some studies indicate that the number of broken plants can be influenced by the periods of nitrogen application, with significant effects on the quality of the basal internodes being observed, so application at sowing is recommended. Tillage can also influence the reaction of genotypes, a crossing with the combiner can positively influence resistance by creating optimal conditions for the development of the root system (Bian et al., 2016). Among the agrotechnical methods for improving resistance, the most used is the use of growth regulators (Xue et al., 2017).

The impact of local weather conditions on the growth and development of the maize crop can be intensified by extreme environmental conditions, mainly regarding the occurrence of thermal and water stress episodes in different physiological stages of the crop (Beruski et al., 2020). Higher tolerance to drought and heat is also a necessity for obtaining satisfactory yield at higher plant densities. Drought associated with too high plant densities can cause the appearance of sterile plants, smaller ear sizes and implicitly significant decreases in yield. Climatic conditions have a great influence on maize growth (Liu et al., 2015; Xu et al., 2017), so determining the optimal plant density is closely related to both the genotype and environmental conditions.

For better resistance to the stress caused by high densities, hybrids with erect or semi-erect leaves are also recommended, which can make better use of the light, a too rich and lax canopy overshadows other plants and negatively influences the photosynthetic capacity (Xue et al., 2016).

MATERIAL AND METHODS

The biological material used in this study is represented by seven maize hybrids, created at ARDS Turda: Turda 248, Turda Star, Turda 332, Turda 344, Turda 335, Turda 380, SUR18/399. From the point of view of the vegetation period, one hybrid is early (Turda 248), and the others are semi-early, and regarding the hybrid type, two are trilinear (Turda Star and Turda 344) while the rest are simple. The hybrids were studied in randomized blocks, in 4 sowing densities: 60,000, 70,000, 80,000 and 90,000 plants/ha. Each density was sown in three repetitions, two 7 m rows/plot, 0.7 m between the rows.

The experiment was carried out in non-irrigated conditions, in the fields of the Agricultural Research and Development Station Turda, on the upper terrace of the Aries river. The dominated soils in the area are vertical-iluvial chernozem, the most important biochemical indices have the following average values: humus content over 3.5%, mobile phosphorus content is 4.5 mg P_2O_5/100 g soil, and mobile potassium content is over 30 mg K_2O/100 g sol and the soil reaction is neutral, between 6.2 and 6.8 pH units (Calugar et al., 2022).

The experiment was carried out in 3 years: 2020, 2021, 2022, the same crop technology being used. In the experimental field, the rotation of soybean, wheat and maize crops is used. The land was plowed in the fall, and in the spring a superficial pass was made with the combinator. For mineral fertilization, 400 kg/ha of complete NPK 27:13.5:0 fertilizer was applied. The crop herbicide was carried out in two phases: pre-emergent and post-emergent. The first herbicide was carried out with 1.5 l/ha using metolachlor 960 g/l as active substance and post-emergence with

2 l/ha using tembotrione (44 g/l) and isoxadiphen-ethyl (22 g/l) as active substances.

The meteorological data used were obtained from Turda Meteorological Station, longitude 23º47`, latitude 46º35`, altitude 427 m.

RESULTS AND DISCUSSION

From the climatic point of view, the years are very different in the area of the experimental area of Turda (central north-west part of Romania, longitude 23º47` E, latitude 46º35` N, 427 m altitude). Average temperatures vary greatly depending on the year, and the distribution of precipitation is very uneven.

In 2020, the average temperatures slightly exceeded the multiannual average, or had values close to the average (Figure 1). In the months of February and March, precipitations were recorded that exceeded the multiannual average by approximately 19 and 10 mm, but during the sowing period, a precipitation deficit was recorded, so the crop sprouted in 18 days. In June, temperatures close to the multi-year average were associated with an excess of precipitation, of approximately 82 mm, thus creating favorable conditions for the maize crop. The normal temperatures and rainfall in July and August helped to achieve optimal pollination and grain formation.

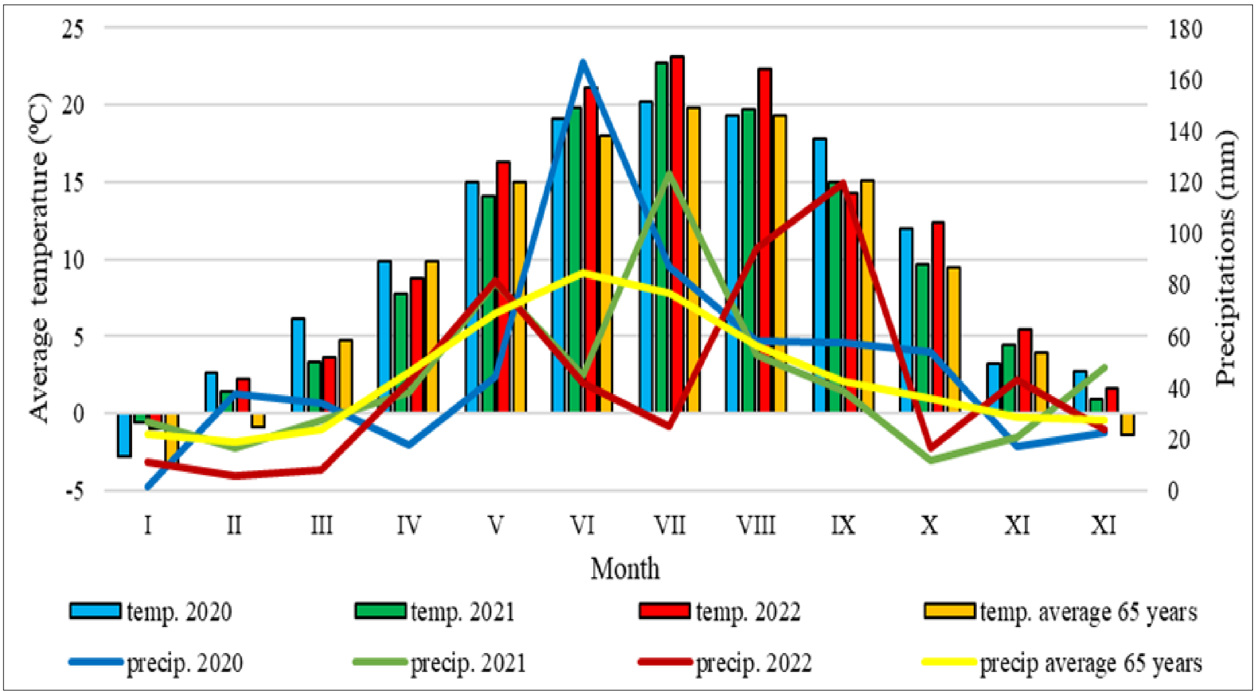

Figure 1. Average temperatures and precipitations sum at Turda, 2020-2022

2021 was a very favorable year for maize cultivation, with values close to the multi-year average, both in terms of temperatures and precipitation. The crop sprouted after only 14 days from sowing. Although in June the amount of precipitation was less than in other years, the excess of precipitation in July favored the optimal achievement of pollination, and together with the normal temperatures and precipitation in August determined the obtaining of a very good yield.

Both at the national level and in the Turda area, the year 2022 was unfavorable for maize crop. In the first months of the year, there was a deficit of precipitation, so that the reserve of water in the soil was very low. The near-normal rainfall recorded in April and May still managed to favor the emergence of the crop, in 16 days after sowing. June and July were disastrous for the maize crop. In June, a deficit of 43 mm was recorded in terms of precipitation, while the average temperature exceeded the multiannual average by 3.1ºC. Another atypical aspect of the area, but which was observed in 2022, was the recording of temperatures over 32 degrees (in 5 days), in one of them the temperatures were even over 35 degrees (Simon, 2022). In July, the excess precipitation was higher, 52 mm less than the multi-year average, while the temperatures exceeded the average by 3.3ºC. This month there were 16 hot days (over 32ºC), and 6 with temperatures over 35ºC, a record in the area (Simon, 2022). The climatic conditions of June and July, as well as the first part of August, when high temperatures were associated with a lack of precipitation, adversely affected the maize crop. The increased rainfall in the last part of August and in September did not influence the yield, but had negative effects by favoring the appearance of some *Fusarium* species.

The experimental year had a major influence on the yield. The average of all hybrids obtained in 2020 was 9,525 kg/ha, and in 2021, a favorable year for maize cultivation, the average yield of all hybrids, in all four densities, was 10,518 kg/ha. The yield was strongly negatively influenced in 2022, the average of all hybrids being only 5,954 kg/ha (LSD 5%=105; LSD 1%=174; LSD 0.1%=326).

In terms of the influence of the ”hybrid” factor on yield, the newest registered maize hybrid, Turda 380, stands out, with an average of 9,914 kg/ha in three experimental years, four plant densities. With higher average yields, Turda 335 and SUR18/399 are also noteworthy.

As expected, maize hybrids had the best behavior at densities of 60,000 and 70,000 plants/ha, while high densities constituted a stress that negatively influenced the yield (Table 1). The hybrids Turda 335 and Turda 380 stood out for their very good behavior, regardless of the tested density, the differences between the densities being very small, statistically insignificant. This good tolerance to increased densities is due to traits such as: high production capacity, the erect position of the leaves, the ability to form more ears/plant, the reduced number of sterile plants, the reduced number of broken plants, as well as a good tolerance to water stress.

In general, the differences in yield between the four cultivation densities were not statistically significant, with the exception of the Turda Star hybrid, which was more sensitive to the stress created by using the density of 90,000 plants/ha.

One of the most important traits that determine the yield, the ear weight, was strongly influenced by the density of the plants, so in all hybrids significant positive differences were calculated for 60,000 plants/ha and negative for the density of 90,000 plants/ha. The weight of the ear is negatively influenced by too high densities, especially by the formation of shorter, incompletely covered ears (Figure 2).

Table 1. The effect of plant densities on yield and ear weight of studied maize hybrids, Turda, 2020-2022

Hybrid	Plant density (plants/ha)	Yield (U=14%)		Ear weight	
		kg/ha	± average	g	± average
Turda 248	Average	8,144	-	142	-
	60,000	8,548	+404	165	+23***
	70,000	8,336	+192	148	+6
	80,000	7,883	-261	132	-10
	90,000	7,810	-334	121	-21^{000}
Turda Star	Average	7,060	-	135	-
	60,000	7,758	+698*	157	+22***
	70,000	7,361	+301	139	+4
	80,000	6,969	-91	126	-9
	90,000	6,151	-909^{00}	118	-17^{00}
Turda 332	Average	8,437	-	147	-
	60,000	9,001	+564	160	+13*
	70,000	8,702	+265	150	+3
	80,000	7,942	-495	138	-9
	90,000	8,103	-334	140	-7
Turda 344	Average	8,656	-	145	-
	60,000	9,191	+535	162	+17**
	70,000	9,059	+403	150	+5
	80,000	8,260	-396	136	-9
	90,000	8,115	-541	130	-15^{00}
Turda 335	Average	9,002	-	154	-
	60,000	9,245	+243	169	+15***
	70,000	9,308	+306	155	+1
	80,000	8,874	-128	147	-7
	90,000	8,582	-420	145	-9
Turda 380	Average	9,914	-	155	-
	60,000	9,978	+64	176	+21**
	70,000	10,443	+529	160	+5
	80,000	9,696	-218	151	-4
	90,000	9,540	-374	133	-22^{000}
SUR18/399	Average	9,227	-	160	-
	60,000	9,890	+663*	193	+33***
	70,000	9,347	+120	162	+2
	80,000	8,745	-482	152	-8
	90,000	8,925	-302	134	-26^{000}
		LSD 5%	610		11
		LSD 1%	810		15
		LSD 0.1%	1052		19

Figure 2. The influence of plant densities on ears:
60,000 (first from left) and 80,000 plants/ha (the five ears on the right)

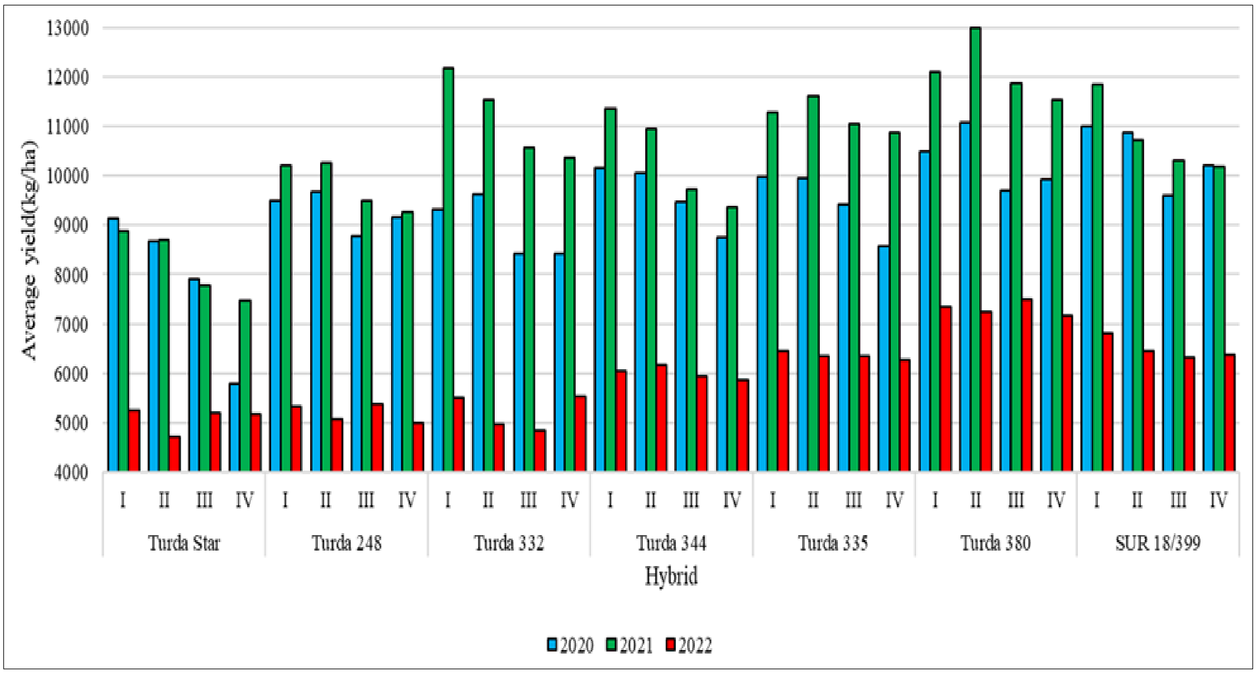

Figure 3. The influence of ”plant density x year x hybrid” interaction on yield - Turda, 2020-2022

The highest yield was obtained in 2021, regardless of the hybrid and density, while in 2022 it was much lower than the other two experimental years, density stress being superimposed on thermal and water stress. The best productions were obtained in 2021 at 60,000 plants/ha by hybrids Turda 332 (12,179 kg/ha), Turda 344 (11,368 kg/ha), Turda 335 (11,293 kg/ha), Turda 380 (12,090 kg/ha) and SUR18/399 (11,847 kg/ha). In the case of Turda 335 and Turda 380 hybrids, the yield obtained at 70,000 plants/ha exceeded those obtained at 60,000 plants/ha, being obtained 11,619 respectively 12,985 kg/ha. The explanation of this reaction can be given by the ability of the two hybrids to form two ears/plant, when the conditions are optimal, a fact encountered in the case of the 60,000 plants/ha density; in the case of the density of 70,000 plants/ha, a single, larger ear was formed.

The two hybrids that performed very well at all densities, Turda 335 and Turda 380 are the latest creations of the Maize Breeding laboratory and are characterized by a series of traits that make them suitable for cultivation at increased densities: high capacity of production and its good stability, the ability to form more ears/plant, the absence or presence of a very small number of sterile plants, high photosynthetic capacity due to the erect or semi-erect leaves, high plant height, high and uniform main ear insertion, extended stay-green at physiological maturity, very good resistance to stem breakage, as well as good tolerance to drought and heat.

CONCLUSIONS

The high plant density can be justified if the production significantly exceeds that obtained in the lower densities, an aspect that can be achieved easily in the case of irrigated crops, where the stress is not overlapped with the water stress. Due to too high densities under non-irrigated conditions, sterile plants may appear, the size of ears is reduced, aborted grains appear, in the end, yield being negatively affected.

Maize breeding for tolerance to high plant densities includes targeting new creations to a specific plant idiotype: uniformity of plant height and main ear insertion height, erect or semi-erect leaf position, reduced panicle size, high prolificacy, such so that it can produce at least one fertile ear, low number of sterile plants, a good pollination capacity, the best possible resistance to plant breaking, good tolerance to drought and heat as well as a very good production capacity. The newest creations of the Maize breeding programm from ARDS Turda, Romania, the hybrids Turda 335 and Turda 380 meet these requirements.

REFERENCES

Berry, P.M., Sterling, M., Spink, J.H., Baker, C.J., Sylvester-Bradley, R., Mooney, S.J., Tams, A.R., Ennos, A.R., 2004. *Understanding and Reducing Lodging in Cereals*. Advances in Agronomy, 84: 217-271. https://doi.org/10.1016/S0065-2113(04)84005-7

Beruski, G.C., Schiebelbein, L.M., Pereira, A.B., 2020. *Maize Yield Components as Affected by Plant Population, Planting Date and Soil Coverings in Brazil*. Agriculture, 10(12): 579. https://doi.org/10.3390/agriculture10120579

Bian, D., Jia, G., Cai, L., Ma, Z., Eneji, A.E., Cui, Y., 2016. *Effects of Tillage Practices on Root Characteristics and Root Lodging Resistance of Maize*. Field Crops Research, 185: 89-96. doi:10.1016/j.fcr.2015.10.008

Calugar, R.E., Muntean, E., Varga, A., Vana, C.D., Has, V.V., Tritean, N., Ceclan, L.A., 2022. *Improving the Carotenoid Content in Maize by Using Isonuclear Lines*. Plants, 11: 1632. https://doi.org/10.3390/ plants11131632

Ghețe, A., 2019. *Cercetări privind perfecționarea tehnologiei de producere de sămânță la porumb*. Teză de doctorat, Universitatea de Științe Agricole și Medicină Veterinară, Cluj-Napoca.

Li, S., Wang, K., Xie, R., Hou, P., Ming, B., Yang, X., Han, D., Wang, Y., 2016. *Implementing higher population and full mechanization technologies to achieve high yield and high efficiency in maize production*. Crops, 32(4): 1-6. doi: 10.16035/j.issn.1001-7283.2016.04.001

Liu, T., Gu, L., Dong, S., Zhang, J., Liu, P., Zhao, B., 2015. *Optimum leaf removal increases canopy apparent photosynthesis, 13C-photosynthate distribution and grain yield of maize crops grown at high density*. Field Crops Research, 170: 32-39. https://doi.org/10.1016/j.fcr.2014.09.015

Mansfield, B.D., and Mumm, R.H., 2014. *Survey of Plant Density Tolerance in U.S. Maize Germplasm*. Crop Science, 54(1): 157-173. https://doi.org/10.2135/cropsci2013.04.0252

Partal, E., 2022. *Sunflower Yield and Quality under the Influence of Sowing Date, Plant Population and the Hybrid*. Rom. Agr. Res., 39: 463-470. https://doi.org/10.59665/rar3944

Sarca, T., 2004. *Ameliorarea porumbului*. In: Cristea M., Căbulea, I., Sarca, T. (eds.), Porumbul - Studiu monografic 1. Ed. Academiei Române, București: 363-462.

Simon, A., 2022. *Caracterizarea climatică a lunilor iunie și iulie din ultimul deceniu pentru zona Turda*. Revista Agricultura Transilvană, 37: 9-14.

Tokatlidis, I.S., and Koutroubas, S.D., 2004. *A Review of Maize Hybrids' Dependence on High Plant Populations and Its Implications for Crop Yield Stability*. Field Crops Research, 88(2-3): 103-114. doi:10.1016/j.fcr.2003.11.013

Vana, C., Haș, V., Copândean, A., Călugăr, R., Varga, A., 2022. *Desimea de semănat, un factor tehnologic important în realizarea producțiilor de porumb*. An. INCDA Fundulea, 89: 169-176.

Xu, W., Liu, C., Wang, K., Xie, R., Ming, B., Wang, Y., Zhang, G., Liu, G., Zhao, R., Fan, P., Li, S., Hou, P., 2017. *Adjusting maize plant density to different climatic conditions across a large* *longitudinal distance in China*. Field Crops Research, 212: 126-134. https://doi.org/10.1016/j.fcr.2017.05.006

Xue, J., Gou, L., Zhao, Y., Yao, M., Yao, H., Tian, J., Zhang, W., 2016. *Effects of Light Intensity Within the Canopy on Maize Lodging*. Field Crops Research, 188: 133-141. https://doi.org/10.1016/j.fcr.2016.01.003

Xue, J., Xie, R., Zhang, W., Wang, K., Hou, P., Ming, B., Gou, L., Li, S., 2017. *Research Progress on Reduced Lodging of High-yield and -Density Maize*. Journal of Integrative Agriculture, 16: 2717-2725. https://doi.org/10.1016/S2095-3119(17)61785-4