ASSOCIAZIONE ITALIANA
DI AGROMETEOROLOGIA
XX CONVEGNO NAZIONALE

UNIVERSITÀ DEGLI STUDI DI MILANO

DiSAA

SOCIETÀ ITALIANA
DI AGRONOMIA
XLVI CONVEGNO NAZIONALE

AIAM SIA MILANO 2017

STRATEGIE INTEGRATE PER AFFRONTARE LE SFIDE CLIMATICHE E AGRONOMICHE NELLA GESTIONE DEI SISTEMI AGROALIMENTARI

INTEGRATED STRATEGIES FOR AGRO-ECOSYSTEM MANAGEMENT TO ADDRESS CLIMATE CHANGE CHALLENGES

MILANO
12 - 14 SETTEMBRE 2017

A CURA DI
FRANCESCA VENTURA
GIOVANNA SEDDAIU
GABRIELE COLA

DIPARTIMENTO DI SCIENZE AGRARIE - UNIVERSITÀ DI BOLOGNA

STRATEGIE INTEGRATE PER AFFRONTARE LE SFIDE CLIMATICHE
E AGRONOMICHE NELLA GESTIONE DEI SISTEMI AGROALIMENTARI

*INTEGRATED STRATEGIES FOR AGRO-ECOSYSTEM MANAGEMENT TO
ADDRESS CLIMATE CHANGE CHALLENGES*

XX CONVEGNO NAZIONALE DELL'ASSOCIAZIONE ITALIANA DI AGROMETEOROLOGIA (AIAM)

XLVI CONVEGNO NAZIONALE DELLA SOCIETÀ ITALIANA DI AGRONOMIA (SIA)

Strategie integrate per affrontare le sfide climatiche e agronomiche nella gestione dei sistemi agroalimentari

Integrated strategies for agro-ecosystem management to address climate change challenges

Milano
12 - 14 settembre 2017

a cura di
Francesca Ventura
Giovanna Seddaiu
Gabriele Cola

Dipartimento di Scienze Agrarie
Università di Bologna

ISBN 9788898010707
DOI 10.6092/unibo/amsacta/5692

Grafica di copertina realizzata da Matteo Grandi

Bologna, 2017

INDICE

SESSION 1 “AGRO-ENVIRONMENTAL INNOVATIONS TO SUPPORT THE AGRICULTURAL POLICIES”
ORALI

POSTER

DOI 10.6092/unibo/amsacta/5692

EFFECT OF HIGH PLANT DENSITY ON YIELD AND MAIZE KERNEL QUALITY

EFFETTO DELL'ALTA DENSITA' SULLA RESA E QUALITA' DELLA GRANELLA DI MAIS

Giulio Testa[1], Massimo Blandino[2*], Amedeo Reyneri[2]

[1] Isagro S.p.A., Via Fauser, 28 Novara 28100 (NO).
[2] Dipartimento di Scienze Agrarie, Forestali e Alimentari, Università degli Studi di Torino, Largo Braccini 2, Grugliasco 10095 (TO).
[*] Massimo.blandino@unito.it

Abstract

Increasing the population density is an agronomical practice that has continuously been studied to increase yield. The present study compared different planting patterns and evaluated grain yield and kernel quality. It consisted on two experiments: the first one evaluated two row widths (traditional 0.75 m; narrow 0.50 m) combined with four planting densities, starting from 7.5 up to 12 plants m^{-2}. The second experiment was focused on 32 production situations (PS) in which standard planting pattern was compared to an innovative one. High planting density increased grain yield from 7.5 to 9.8% only on narrow inter-row. This result was confirmed on 90% of the PS where the narrow inter-row was combined with 10.5 plants m^{-2}. This system puts however the crop on more stressful conditions concerning higher mould development and lower kernel hardness. Therefore, stress control and commodity final destination should be considered before undertaking high plant density.

Keywords: Maize, planting density, yield, kernel quality
Parole chiave: Mais, densità colturale, resa colturale, qualità granella

Introduction

In the last decade the Italian maize yield index has progressively decreased, thus it is important to focus and develop agronomical tools that can support farmers to get the best advantages in terms of yield, offering a better breakthrough that can remove barriers and increase back again competitiveness. Increasing the population density of maize plants is indeed one of these strategies and it is the crop technique has evolved the most and will continue to evolve over the years (Tollenaar, 1992). After the introduction of the first maize hybrids, farmers started to steadily increase the plant density. In the US Corn Belt of the 1930s, the mean population density was 3 plants m^{-2}, while its average yield was around 2 t ha^{-1}. Nowadays the plant density is around 8 plants m^{-2} with proportional average yield increase (Duvick, 2005 and Li et al., 2015). The main purpose of increasing the number of plant per unit surface is to enhance maize yield in terms of grain or biomass, thus making the crop system more efficient and competitive per area unit. In fact, in case of absence or lenient biotic and abiotic stresses, grain yield is related to the amount of solar radiation intercepted by the crop, and the use of a high-density population, with an earlier canopy closure, can maximize the leaf area index (Cox and Cherney, 2001). Modern hybrids can generally withstand higher population densities, since they can bear a more stressful environment caused by a higher intra-specific competition more easily. However, in order to place the crop in the best growing conditions, planting pattern has to be re-thought with a reduction in the inter-row spacing that brings to a more balanced equidistance. Plants spaced more uniformly in fact compete minimally for the main growing factors, such as light, mineral nutrient uptake and water (Li et al., 2015).
Crop productivity however is not the only final aspect of yield agronomists are considering to sustain and guarantee maize competitiveness. Nowadays kernel quality features are becoming very important parameters for maize traders to suit to its best final destination. The two main quality aspects requested by the market trading maize are: low mycotoxins contamination for a healthy matter and good kernel technological properties, which for the dry-milling industry is related to the kernel endosperm hardness. These two quality features are indeed influenced by the field growing conditions, and it is supposed that high planting can play a key role on that.
The aim of this study was to evaluate the effects of different plant densities and sowing patterns on single plant and whole crop yield potential and on kernel qualitative traits in the concern of the food chain. The final objective was to understand whether high planting density can provide not only an increased yield but also maintain kernel quality for health and technological matters.

Materials and Methods

The study of the effect of different planting densities on the morphological development of plants, ears and kernels was performed over four growing seasons, from 2011 to 2014 (Testa et al., 2016). It involved two different experiments conducted in the agricultural area of North West of Italy in the Piedmont region.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

The experiment number 1 consisted of two field trials conducted in 2013 and 2014 on which the compared treatments were a factorial combination of two inter-row spacings: 0.75 m wide, considered as the standard one for maize crop system (standard inter-row spacing: SIS), and 0.5 m, considered as the narrow one (NIS); four increasing planting densities, starting from the standard one of 7.5 plants m^{-2}, 9, 10.5 and 12 plants m^{-2}. Two hybrids were compared, characterized by a different ear development: with a stable (fix) or variable (flex) number of kernels set depending on the environmental conditions.
The second experiment consisted on the comparison of a standard planting system (StD), characterized by 7.5 plant m^{-2} planted in row 0.75 m apart with an average intra-row spacing of 0.18 m against an innovative high-density system (HiD) featuring 10.5 plant m^{-2} planted on 0.5 m wide rows and an intra-row distance of 0.19 m. The overall comparison of these two systems (StD vs HiD) was conducted considering 32 production situations spread in North West Italy, characterized all by equal fertilization levels among the two plant density regimes, all of them under irrigated conditions.
Ears were collected manually from each plot from a sub-area of 4.5 m^2. Ear weight, grain moisture, test weight, thousand kernels weight, kernel rows, kernel per row and kernel per square meter were assessed. A subsample of 1 kg was then used for further analysis concerning the kernel milling technologic aptitude, evaluated by the course/fine endosperm ratio, the milling energy test (Stenvert test, Blandino et al., 2010) and fumonisins and deoxynivalenol development.
The analysis of variance (ANOVA) was utilized to compare the effect of the planting density of experiment 1 on the recorded parameters. The average relative ratio (RR = HiD / StD) between the two planting systems was calculated for each measured parameter of all the production situations taken into account in the experiment 2.

Results and Discussion
A significant interaction between the hybrid ear development kind and inter-row spacing was reported on the experiment 1. A diminishing trend of the average number of kernels developed per row was observed for both types of hybrid as a consequence of the increasing planting density, from 7.5 to 12 plants m^{-2}. However, the effect was more consistent and significant on the flex hybrid, characterized by a variable kernel set number which, as expected, was influenced by the growing conditions occurred (fig. 1).

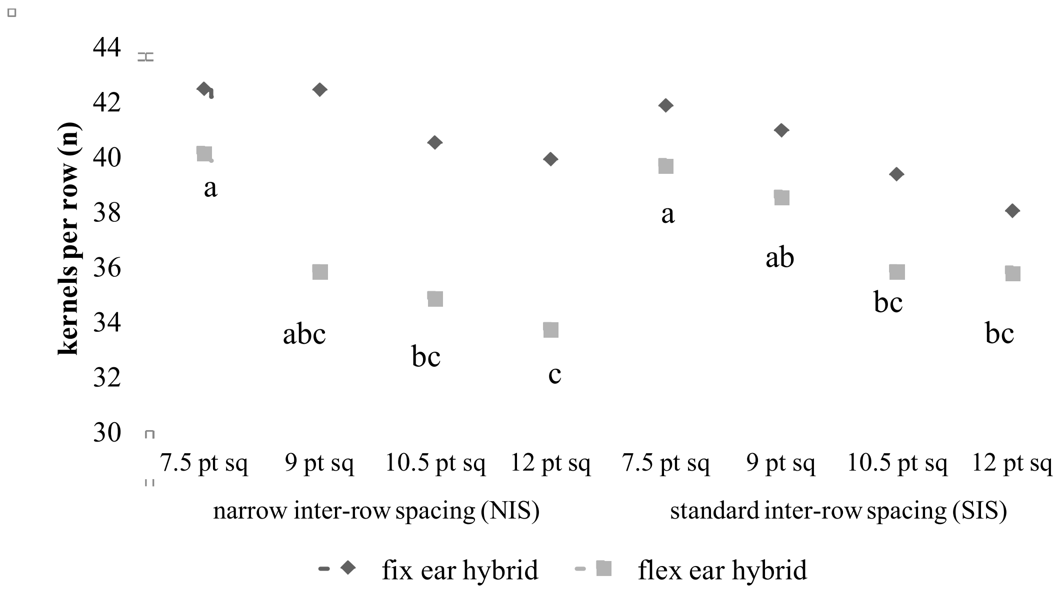

Fig. 1: Effect of inter-row spacing and planting density on the number of kernels per row developed on the fixed and flex ear hybrids. Means followed by different letters are significantly different (P<0.05).
Fig. 1: Effetto della distanza interfila e della densità colturale sul numero di cariossidi per rango sviluppate sull'ibrido a sviluppo "fix" e flex" della spiga. Valori medi seguiti da lettere diverse si differenziano in modo statistico (P<0.05).

Figure 2 shows the effect of different inter-row spacing and planting density on the final grain yield. As it is clearly shown, in the standard inter-row spacing (SIS), the grain yield did not increase by means of the higher planting density. On the other hand, the narrow inter-row system (NIS) showed a significant yield benefit when the plant population was increased from 7.5 to 10.5 plants m^{-2} (+7.4%). The highest yield peak (+9.8%) was obtained on 12 plants m^{-2} sowed on 0.5 m wide rows, however it was not significantly different from the lower density of 10.5 plants m^{-2}.

DOI 10.6092/unibo/amsacta/5692

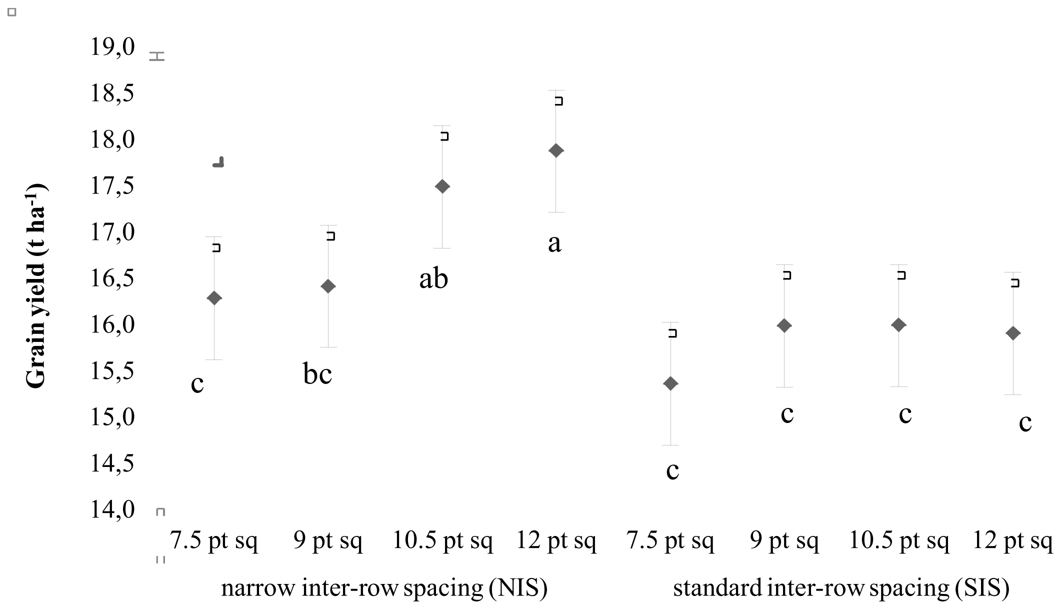

Fig. 2: Effect of inter-row spacing and planting density on grain yield. Mean values followed by different letters are significantly different (P<0.01).
Fig. 2: Effetto della distanza interfila e della densità colturale sulla resa in granella. Valori medi seguiti da lettere diverse si differenziano in modo statistico (P<0.05).

The comparison between the two agronomical systems conducted on the experiment n.2 (table 1), confirms the trend that a better grain yield is achieved when high planting density is applied, in fact the average yield gain was 11.4% and was achieved on 90% of the production situations. Parameters such as the grain moisture, test weight and the number of kernel rows, were not influenced. The high planting system showed to place the crop in a more sensible condition concerning the water consumption, especially from flowering to late ripening. The grain moisture in fact resulted to be lower generally in those production situations where a dry weather occurred prior to harvest. Vice versa, without drought conditions, the high plant population kept the canopy more humid, with more shade and less air flow, thus slowing down the kernel dry down phase. Other aspects related to the single plant yield potential were negatively influenced. For example a lower thousand kernel weight (-6%) was observed in the innovative system as well as the ear weight (-17.6%), since a lower number of kernel was present on each ear (-9%). However, since a higher number of ears were harvested per unit surface, an increase in the total number of kernels was observed (+23%).
Concerning the qualitative kernel trait, both the endosperm course/fine ratio, and grain protein content, were lower, indicating a reduced milling extraction capability on kernels belonging to the innovative system (HiD). In terms of health, the effect is not completely clear, since a higher severity of fungal rots was observed on ears, even though an average lower mycotoxin contamination was observed.

Conclusions
This work has proved that, for the cultivation of medium-late maturing hybrids in temperate areas and irrigated conditions, a high planting density of up to 10.5 plants m^{-2} can lead to a significant yield increase. This is true mainly when it is combined with narrow inter-row spacing (SIS), since by guaranteeing a better plant equidistance the single plant yield potential is more preserved. The high-density condition increases plant stresses, and modifies plant morphology and development to the detriment of the single plant yield. However, the lower yield per plant is fully compensated by the higher plant population. However, depending on which final use the harvest is aimed to, whether as livestock feed or human food, growers need to cautiously decide how to setup the crop system. This starts at planting, by choosing the most suitable hybrid that better responds to these requests, then by the correct planting density and planting pattern. If the main aim is yield and stress control allow it, a higher and intensive planting can drive to successful results. On the contrary, if the main objective is kernel quality, for the food chain, a standard planting density allows to obtain better grain in terms of kernel hardness for the milling industry with a lower mycotoxins content.

Tab. 1: Comparison of the innovative planting density (HiD) and the standard density (StD) in different production situations on average grain yield, grain moisture, test weight, thousand kernel weight, ear weight, kernel rows, kernels harvested per square meter, course and fine endosperm ratio, grain protein content, severity of fungal rot development on ears, fumonisins and deoxynivalenol contamination.
Tab. 1: Confronto tra la densità colturale innovativa (HiD) e quella standard (StD) nelle differenti situazioni produttive sulla resa ad ettaro e l'umidità della granella, il peso ettolitrico, dei mille semi e della spiga intera, il numero di ranghi e di cariossidi raccolte per metro quadro. Il rapporto tra endosperma grossolano e fine, il contenuto in proteine nella granella, sviluppo fungino sulla spiga e contaminazione da fumonisine e deossinivalenolo.

Parameter	**Unit**	**Mean HiD**	**Mean StD**	**Mean RR**	**Significance**
grain yield	t ha^{-1}	18.1	16.2	1.117	***
grain moisture	%	25.4	25.0	1.013	NS
test weight	kg hL^{-1}	78.3	78.2	1.001	NS
thousand kernel weight	g	372	394	0.942	***
ear weight	g	260	317	0.824	***
kernel rows	n	16.5	16.3	1.013	NS
kernel per row	n	36.4	40.2	0.904	***
kernels per ear	n	597	653	0.913	***
kernels m^{-2}	n m^{-2}	5775	4690	1.233	***
course / fine endosperm ratio		0.887	0.917	0.962	***
grain protein content	g/100g	9.0	9.2	0.978	**
severity fungal rot	%	5.86	5.13	1.461	**
fumonisins	ppb	2644	2869	1.862	*
deoxynivalenol	ppb	3057	3946	1.785	NS

References

Blandino, M., Mancini, M.C., Peila, A., Rolle, L., Vanara, F., Reyneri, A. 2010. Determination of maize kernel hardness: comparison of different laboratory tests to predict dry-milling performance. J. Sci Food Agric. 90: 1870-1878.

Blandino, M., Reyneri, A., Vanara, F., 2008. Effect of plant density on toxigenic fungal infection and mycotoxin contamination of maize kernels. Field Crops Res. 106: 234–241.

Boomsma CR, Santini JB, Tollenaar M, Vyn TJ. 2009. Maize morphophysiological responses to intense crowding and low nitrogen availability: An analysis and review. *Agron J.* 101(6): 1426-1452.

Cox, W.J., Cherney, J.R., 2001. Row spacing, plant density, and nitrogen effects on corn silage. Agron. J. 93, 597–602.

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

Li, J., Xie, R.Z., Wang, K.R., Ming, B., Guo, Y.Q., Zhang, G.Q., Li, S.K., 2015. Variations in maize dry matter, harvest index, and grain yield with plant density. Agron. J. 107: 829.

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. *F Crop Res.*: 170:32-39.

Sangoi L. 2000. Understanding plant density effect on maize growth and development: an important issue to maximize grain yield. *Ciência Rural*. 31(1): 159-168.

Testa, G., Reyneri A., Blandino, M. 2016. Maize grain yield enhancement through high plant density cultivation with different inter-row and intra-row spacings. European J. of Agronomy 72: 28-37.

Tollenaar, M, 1992. Is low plant plant population a stress in maize? Maydica, 37: 305-311.